Examination of Local Movement and Migratory Behavior of Sea Turtles During Spring and Summer Along the Atlantic Coast Off the Southeastern United States

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For

Examination of Local Movement and Migratory Behavior of Sea Turtles During Spring and Summer Along the Atlantic Coast Off the Southeastern United States

by

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Executive Summary

Since Federal FY2003, the SCDNR has conducted satellite-telemetry research with juvenile loggerhead sea turtles collected from the Charleston, SC, shipping entrance channel, in order to better understand seasonal and inter-annual distributional patterns of juvenile loggerheads in the Southeastern U.S. Understanding the movement and migration patterns of juvenile loggerheads, which comprise the majority of sea turtles collected in the water regardless of gear type, may have direct bearing on tag-recapture rates which may be used to estimate population size. Of 24 juvenile loggerheads satellite-tagged in this research since May 2004, all but two have remained on the continental shelf off of South Carolina during the summer and fall. Furthermore, 10 of 12 juvenile loggerheads which have been monitored through the winter have also remained on the continental shelf, though further offshore, primarily off of SC and GA. Given similarity in inter-annual trends in 2004-05 and 2005-06, we anticipate that sufficient data will have been collected to conclude this phase of research in 2007-08.

In April 2006, a new phase of satellite-telemetry research was initiated with adult male loggerheads collected from the Port Canaveral, FL, shipping entrance channel. Satellite-transmitters were attached to nine adult male loggerheads, of which the disposition could not be determined for one turtle only monitored for 10 days. Four adult males appeared to be residents (location data collected for 36 to 221 days), and four adult males (monitored for 96 to 116 days) migrated to SC, MD, and NJ four to six weeks after satellite-tagging. Following migration, localized detections at these distant coastal areas were recorded for the extent of monitoring for three of the males; however, one male was also tracked on a reciprocal southerly movement in September. North-south movements exhibited by adult males traveling to MD and NJ waters are greater than published tracking data on adult male loggerheads elsewhere in the world; however, few such data sets exist for adult male loggerheads.

Documentation of both resident and migratory individuals, which may be independent of reproductive activity, was a key finding for this research. A variety of stages of reproductive activity was successfully documented using laparoscopic examination. Mixed results among other less invasive methods may be improved with greater sample sizes and continued consultation with experts in this field of research. The difficulty in implementing a standardized method for determining plastron softness, as well as a paucity of reference values for comparison, resulted in exclusion of this analysis from consideration for this annual report; however, it will be re-visited during field sampling in April 2007. High serum testosterone levels were not exclusively associated with migratory males and low serum testosterone levels were not exclusively associated with resident males; thus, this metric alone may not be sufficient to evaluate reproductive activity level. Successful capture of gonad imagery via ultrasound warrants future and more intensive application of this technique in order to refine this technique to produce better results. Laparoscopy and testis biopsy provided the most precise information on reproductive condition; however, these procedures were not fool-proof, as one animal which was expected to migrate appeared to be resident. Larger sample sizes and technique modifications in FY2006 may improve the assuredness of these methods.

Introduction

Loggerhead sea turtles (*Caretta caretta*) inhabiting coastal waters along the southeastern United States represent the progeny of multiple rookeries (Bowen et al., 1993; Sears et al., 1995; TEWG, 2000; Maier et al., 2004). Tagging studies of nesting female loggerheads suggest that most return to the same beaches in successive breeding seasons (Bjorndal et al. 1983) and it is widely accepted that most females return to their natal regions to nest. Although considerable effort has been expended to study adult females on nesting beaches, much less is known about the distributional patterns of juveniles and adult males in coastal waters.

Prior to May 2000, in-water studies targeting sea turtles were primarily conducted at shipping entrance channels (Kemmerer et al., 1983; Standora et al., 1993a,b; Dickerson et al., 1995; Keinath et al., 1995) or at opportunistic inshore collection areas such as where pound nets are located (Byles, 1988; Epperly et al., 1995; Morreale and Standora, 1993). The need to conduct, "…long-term, in-water indices of loggerhead abundance in coastal waters" (TEWG, 1998) led to the development of a regional in-water survey of loggerheads during summers 2000-2003 (Maier et al., 2004). Coastal waters 1-15 km offshore between Winyah Bay, SC, to St. Augustine, FL, were sampled in a nearly simultaneously manner using three research vessels annually. High catch rates were reported (Maier et al., 2004); however, very low recapture rates (<2%) were also reported, the cause of which was not readily evident.

Beginning in May 2004, in an effort to better understand the seasonal distributional patterns of juvenile loggerheads collected in coastal waters sampled during the 2000-2003 regional survey, the focus of the in-water survey was modified to intensively target one small trawling area to: (1) examine the effect of intensive trawling on recapture rates and (2) quickly obtain an adequate sample size of turtles to outfit with satellite transmitters. Prior to 2004, satellite telemetry had only been attempted with four juvenile loggerheads (NMFS 1; USACOE; Whalenet) and seven adult male loggerheads (Keinath, 1993; NMFS 2) south of Cape Hatteras; thus, long-term information on habitat utilization of juveniles and adult males in coastal waters was virtually non-existent for this region.

In order to facilitate historical comparisons of catch-per-unit effort (VanDolah and Maier, 1993; Dickerson et al., 1995), the shipping entrance channel of Charleston harbor was selected for this trawl survey. Logistical considerations, including close proximity to a turtle rehabilitation facility at the SC Aquarium in Charleston, also contributed to the decision to restrict trawling to this location. In April 2006, a second trawling area (the Port Canaveral, FL, shipping entrance channel) was added to this study to facilitate collection of adult male loggerheads (during their presumed mating aggregation) to provide new data on their reproductive biology and distributional habits.

This annual report highlights the major findings for research activities primarily carried out during 2006. More detailed analyses will be included in the 2004-2007 Final Report and manuscripts which will be submitted for peer-review in 2007 and 2008.

Methods

Study Areas

Trawling was conducted in two different shipping entrance channels during 2006, with location-specific study objectives (and therefore different sampling protocols).

In April, trawling was conducted for five days between channel markers “1/2” and “9/10” in the shipping entrance channel to Port Canaveral, FL (28°23’N, -80°32’W; Figure 1). Fifteen minute trawls (bottom time) were conducted between subsequent channel markers (1 to 3; 3 to 5; etc.). Due to the principal objective of collecting adult male loggerheads as quickly as possible, opportunistic (rather than randomized) sampling was employed.

In May, trawling was conducted for two weeks in the Charleston, SC, shipping entrance channel (32°42’N, -79°48’W; Figure 2), between channel markers “17/18” and “13/14”. Seven of 12 index stations utilized in 1990-1991 (VanDolah and Maier, 1993) were systematically sampled. Bottom obstructions and gear damage/loss resulted in permanent elimination of five index stations (E1-E3; B2, D2) and considerable shortening (20%) of two others (D1 and D3) with respect to VanDolah and Maier (1993). Trawl bottom time ranged from 9 to 18 minutes.

Sampling was conducted aboard 75’ double-rigged shrimp trawlers (R/V *Georgia Bulldog* in Canaveral; R/V *Lady Lisa* in Charleston) towing at speeds of 2.5-3.0 knots. Standardized NMFS turtle nets (for surveys associated with channel dredging operations) were utilized: paired 60-foot (head-rope), 4-seam, 4-legged, 2-bridal; net body is of 4” bar and 8” stretch mesh; Top’s sides of #36 twisted with the bottom of #84 braided nylon line; 60’ corkline to cod end; cod end consists of 2” bar and 4” stretch mesh.

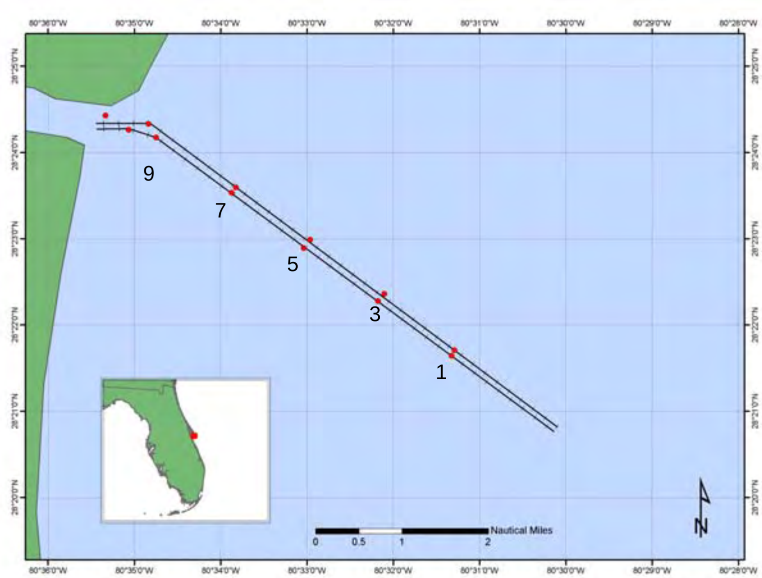

Figure 1. Trawling stations utilized for the collection of adult male loggerhead sea turtles in the Port Canaveral, FL, shipping entrance channel during April 2006.

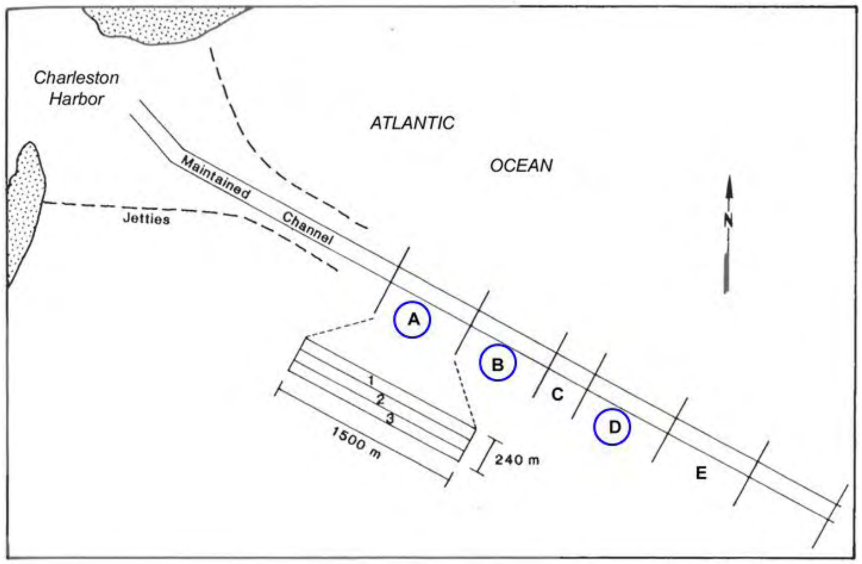

Figure 2. Index trawling blocks (VanDolah and Maier, 1993) in the Charleston, SC, shipping entrance channel sampled in 2004-2006 (blue circles).

Capture and General Processing
Turtles were immediately removed from nets and examined for life-threatening injuries, before being visually/electronically scanned for existing tags. If not previously tagged in this study, a sequential project identification number was assigned to each turtle.

Blood samples were collected for all sea turtles >5kg body weight with a 21ga, 1.5 in. needle from the dorsal cervical sinus of loggerhead turtles as described by Owens and Ruiz (1980). Blood samples consisted of a maximum of 45 ml total volume and did not exceed the total recommended volume (10% of total blood volume) based upon total weight as described by Jacobson (1998), who estimated that total blood volume in reptiles was 5 to 8% of total body weight. Blood samples were used as follows:

- genetics - 5 ml (University of South Carolina & University of Georgia)
- sex determination - 10 ml (University of Charleston)
- CBC/Blood chemistry -- 3 ml (Antech Diagnostics)
- Toxicological screening and immunological bioassay – 20 ml (National Institute of Standards and Technology; Medical University of SC)

A suite of standard (Bolten, 1999) morphometric measurements were collected for all sea turtle species. Six straight-line measurements (cm) were made using tree calipers: minimum (CLmin) and notch-tip (CLnt) carapace length; carapace width (CW); head width (HW); and body depth (BD). Curved measurements of CLmin, CLnt and CW were recorded using a nylon tape measure. Additional curved measurements included plastron width (PW), and two tail length measurements (tip of plastron to tip of tail (PT) and tip of cloaca to tip of tail (CT)). Body weight (kg) was measured using spring scales; turtles were placed in a nylon mesh harness and carefully raised off of the deck.

All sea turtles >5kg received two Inconel flipper tags and one Passive Integrated Transponder (PIT) tag (Biomark, Inc.). Triple tagging minimized the probability of complete tag loss. Inconel flipper tags were provided by the Cooperate Marine Turtle Tagging Program (CMTTP). Per instructions provided by the CMTTP, tags were cleaned to remove oil and residue prior to application. Inconel tag insertion sites, located between the first and second scales on the trailing edge of the front flippers, were swabbed with betadine prior to tag application. PIT tag insertion points, located in the right front shoulder near the base of the flipper, were swabbed with betadine prior to intramuscular injection of the sterile-packed PIT tag.

Prior to releasing turtles, a digital photograph of each turtle in a standard 'pose' (dorsal surface exposed, taken looking from anterior to posterior) was recorded. Additional photographs of unusual markings or injuries were also recorded.

Laparoscopy and ultrasound

Ultrasonography and laparoscopy were specialized sampling methods used only with adult male loggerheads in 2006. Ultrasonography is a noninvasive technique (Owens, 1999) commonly used in human medicine that allows the imaging of gonadal tissue and takes a maximum of 15 minutes per turtle. Laparoscopy is an invasive procedure that requires local anesthetic and highly sterile surgical techniques. Both procedures were performed while turtles were restrained in dorsal recumbency in a specialized restraining chair borrowed from the Florida Fish and Wildlife Commission, and while the research vessel was tied up at the dock, to provide a stable working platform.

For ultrasonography, the probe was placed on the inguinal region cranial to the hind leg. A coupling gel was used to insure transmission of the ultrasonic signal. Images of gonadal tissue were electronically stored for later determination of reproductive activity status (i.e., whether an individual had or was preparing to breed).

Direct viewing of the gonads was done using standard laparoscopy procedures developed for marine turtles and used successfully in the field by sea turtle researchers worldwide (Owens, 1999). Laparoscopy enables direct viewing of the testes (in color vs. black and white imagery); thus, reproductive stage can be determined, providing a necessary validation of ultrasound images.

Turtles were prepped for laparoscopy in typical manner for surgery, including multiple scrubs of surgical site alternating between Chlorohexadine scrub and 70% alcohol. Betadine solution was applied to the site as a final surgical prep solution. The surgical site was completely draped with sterile gowns, typical of any human/animal surgical procedure. A local anesthetic (2% lidocaine) was injected locally to the surgical site prior to making a small incision (~0.5 – 1cm) with a sterile scalpel blade, through which the laparoscope was inserted, allowing view of the testes. Using biopsy forceps, a small piece of testicular tissue (~1x1mm) was removed and preserved for histological examination. (Wibbels et al., 1990). Incisions were sutured with sterile absorbable 3-0 violet monofilament and a small amount of super glue was applied to the incision site. These procedures lasted ~40 min from surgical site preparation to incision closure.

Upon completion of surgery, turtles were carefully transported to circular (~500 gal) tanks on the boat or on shore using a lifting net made of small nylon mesh webbing, after which the tanks were filled with seawater. Turtles were closely monitored to evaluate breathing and diving capability. Once normal buoyancy was confirmed (which in some instances required holding turtles overnight), turtles were lowered into a 21' Privateer (tied along side of the larger research trawler) for satellite tag attachment and/or transport to the ocean (40 min each direction due to no-wake zone requirements) for release.

Satellite telemetry

ST-20 (Telonics, Inc) satellite transmitters were attached directly to the second vertebral scute on the turtle carapace using epoxy (Papi et al., 1997; Polovina et al., 2000; Griffin, 2002). Prior to attachment, barnacles and other organisms were removed with a chisel, the carapace was sanded, washed with betadine and dried with acetone. A roll of 1.0 cm diameter "Sonic Weld" (Ed Greene & Company; Sparta, TN) was placed around the bottom edge of the transmitter to form a well, followed by application of "Fast Foil" epoxy (Power Fasteners Inc.; New Rochelle, NY) to the entire bottom surface of the transmitter within the well using a caulking gun. Turtles were released approximately two hours after initial collection in close proximity (<3 km) to where originally collected.

Satellite telemetry data consisted of (1) geographic position at each surfacing; (2) water temperature at each surfacing; and (3) four descriptive dive cycle metrics for each of four, six-hour collection periods per day: time(s) of last dive; number of dives per collection period; mean dive duration(s) per collection period; and percent of time submerged per collection period. Satellite telemetry data were automatically processed, distributed and received by the Argos system. Daily data e-mails were sent to project personnel; however, data were primarily managed using "STAT" (Satellite Tracking and Analysis Tool; Coyne and Godley, 2005). Data were downloaded from "STAT" monthly to a relational database (MS Access) on a local area network for analyses.

By-catch

Large mesh nets result in low levels of by-catch relative to small mesh nets; however, by-catch were identified to the lowest possible taxon and a count or estimate of abundance noted whenever possible. Sex and appropriate length (cm) measurements were included for all elasmobranches, as well as finfish and invertebrate species of interest. Particular emphasis was placed on by-catch species that represented potential sea turtle prey items, such as blue crabs (*Callinectes sapidus*) and horseshoe crabs (*Limulus polyphemus*). Due to the specialized nature of this research and the desire to return by-catch to the sea as quickly as possible (to increase probability of survival and to provide safer working conditions on the deck), cataloguing of by-catch received lower priority in 2006 than with respect to the regional survey of 2000-2003 (when only standard turtle processing methods were utilized). Thus, although selected by-catch results are presented in this report, data were not always quantified and include estimates of total by-catch collected.

Results

Capture and Recapture, Canaveral

Between 17-21 April 2006, 26 loggerhead sea turtles were collected in 13 trawling events (15 min each) in the Port Canaveral, FL, shipping entrance channel between markers "1/2" to "9/10". Two of 26 loggerheads were juvenile turtles that escaped from the nets and were not brought on board. A third juvenile (partial) loggerhead was collected dead, the likely result of a not-so-recent boat strike (Figure 3). Of 23 remaining loggerheads, eleven (48%) were adult males, two (9%) were adult females, and 10 (43%) were juvenile loggerheads. Catch rates for adult male (3.38/h), adult female (0.62/h) and juvenile (3.08/h) loggerheads at this location were substantially greater than catch rates observed elsewhere (for these size and sex classes) in SCDNR sea turtle trawl surveys between SC and northern FL conducted since 2000 (Maier et al., 2004; Maier et al., 2005; Segars et al., 2006). No tagged loggerheads were collected at Canaveral; however, one turtle (CC2444, "Gaël") appeared to have a tag scar on the right front flipper. None of the loggerheads tagged and released in April 2006 have since been recaptured. One of two adult females collected had ingested a long-line fishing hook; this turtle was immediately transported to the Volusia Marine Science Center, where the hook was removed and the turtle released within three days. Ultrasound revealed that this turtle was full of eggs, but it is unclear if and where nesting occurred following release.

Figure 3. Photographs of partial loggerhead collected in the Port Canaveral shipping entrance channel between markers "3/4" and "5/6" in the morning of 17 April 2006.

Capture and Recapture, Charleston

Forty-six loggerhead collections occurred during 69 trawling events (30.6 paired hours) between 15-19 May and 22-26 May. Of these 46 loggerheads, one was collected freshly dead (Figure 4) and two (CC0394, CC0397) represented short-term (1-4 days at large) recapture events; thus, 43 live, individual loggerheads were collected at a rate of 1.4 loggerheads per hour. Loggerhead catch rates in May 2006 were intermediate with respect to high catch rates in May 2004 (2.2; 49 loggerheads in 22.5 paired trawl hours) and low catch rates in May 2005 (1.0; 33 loggerheads in 34.0 paired trawl hours).

Figure 4. Photographs of a freshly killed loggerhead collected in the Charleston, SC, shipping entrance channel at station "D1" in the afternoon of 25 May 2006. Heavy commercial shipping traffic was noted prior to collection of this loggerhead.

One long-term loggerhead recapture event (CC0310, Figure 5) occurred in May 2006. This turtle was originally tagged and released following collection at "D3" on 17 June 2004. Incidentally, this turtle was again recaptured at "D3" on 23 May 2006. During 706 days at large, this turtle only grew 1.9cm SCLmin (from 75.3cm to 77.2cm).

Of 205 previously un-tagged loggerheads collected in the Charleston, SC, shipping entrance channel since May 2004, five have been recaptured within two months at large and two have been recaptured between nine and 24 months at large. Only one of these 205 loggerheads has been reported as stranded (after a year at large). Two loggerheads tagged during 2000-2003 have also been recaptured in the Charleston, SC, shipping entrance channel during this study (Maier et al., 2004; Segars et al., 2006).

Figure 5. Before (17 June 2004) and after (23 May 2006) photographs of loggerhead CC0310, which was captured twice at station "D3" (~two years apart) in the Charleston, SC, shipping entrance channel.

Inter-annual variability in May water temperature during sampling, Charleston
Inter-annual differences in surface water temperatures at the time of sampling in May have been noted since 2004, despite attempts to schedule sampling in a consistent manner (i.e., the 2nd and 3rd weeks of the month). Mean water temperature on nine sampling days in May 2004 was substantially warmer (i.e., no overlap in 95% C.I.) than six sampling days in May 2005 and seven sampling days in May 2006 (Figure 6). Within years, none of the sampling days in May 2004 were noticeably different from each other. Conversely, in May 2005 and 2006, water temperatures during the first cruise (*n*=5 days) were considerably cooler than the warmest (mean temperature) day observed during the second cruise for the respective year.

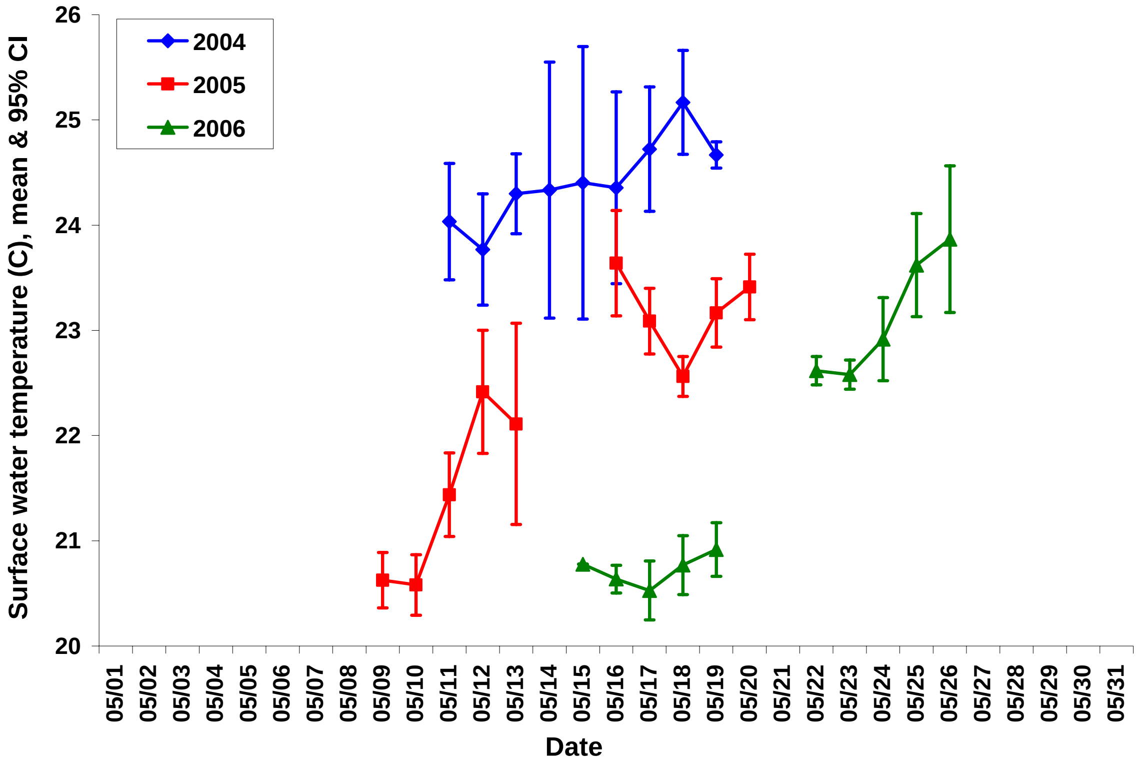

Figure 6. Mean (and 95% C.I.) daily surface water temperatures in May 2004-2006.

Catch variability, Canaveral
Trawling was conducted in four blocks between channel marker pairs "1/2" (offshore) and "9/10" (inshore). Only one trawling event occurred between buoys "7/8" and "9/10"; one juvenile loggerhead and no adult male loggerheads were collected there. Trawling effort, overall loggerhead catch, and male loggerhead catch was comparable for trawls conducted in the block between buoys "5/6" and "7/8" (four trawls with seven loggerheads, including two adult males) and the block between buoys "1/2" and "3/4" (three trawls with six loggerheads, including two adult males). Greatest overall loggerhead collection (11 live turtles in five trawls) and greatest collection of adult male loggerheads (seven of 12) occurred in the block between buoys "3/4" and "5/6". Both juvenile loggerhead escapees and the juvenile mortality were also collected in this block.

Catch variability, Charleston

Loggerhead catches in May were consistently different among stations between 2004 and 2006 (Table 1). Greater than 50% (and as much as 68%) of all loggerheads collected in May were collected in the "D" block in all three years. Catch rates on the southern side (green navigational buoy, number "3" stations) of the entrance channel were consistently greater; May catch rates at B3 were 1.5 to 3 times greater than at B1 (except for 2004), and at D3, May catch rates were 3 to nearly 7 times greater than at D1. May catch rate variability within the same station was also similar among years (Table 1). Notably, most A-block stations resulted in zero turtle catches. Zero turtle catches at B1, B3, and D1 were more common in 2005 and 2006 than in 2004; shorter trawl durations in 2005-2006 may partially account for greater frequency of zero catches at D1, but not for B1 or B3.

Table 1. Variability in May catch rates in the Charleston, SC, shipping entrance channel among principal index stations and years (2004-2006).

		Trawl Duration (min)		Loggerheads caught per trawling event								
Year	**Stn**	**Mean**	**SE**	***0***	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***
2004	A1	15.4	0.2	3	2	0	0	0	0	0	0	0
2005	A1	15.8	0.8	8	2	0	0	0	0	0	0	0
2006	A1	15.9	0.4	7	0	2	0	0	0	0	0	0
2004	A2	13.8	1.5	4	1	0	0	0	0	0	0	0
2005	A2	15.7	0.6	9	1	0	0	0	0	0	0	0
2006	A2	14.6	0.8	11	0	0	0	0	0	0	0	0
2004	A3	13.4	1.6	3	1	1	0	0	0	0	0	0
2005	A3	14.7	0.6	9	1	0	0	0	0	0	0	0
2006	A3	14.4	0.8	9	0	0	0	0	0	0	0	0
2004	B1	14.5	0.8	2	3	1	0	0	0	0	0	0
2005	B1	15.4	0.7	7	3	0	0	0	0	0	0	0
2006	B1	14.7	0.5	6	2	1	0	0	0	0	0	0
2004	B3	14.8	0.2	2	1	0	2	0	0	0	0	0
2005	B3	15.7	0.6	4	4	1	1	0	0	0	0	0
2006	B3	14.5	0.5	7	3	0	1	0	0	0	0	0
2004	D1	15.8	0.4	2	1	1	0	1	0	0	0	0
2005	D1	10.4	0.6	7	2	1	0	0	0	0	0	0
2006	D1	10.1	0.3	7	2	1	0	0	0	0	0	0
2004	D3	15.0	0.4	0	1	0	0	1	2	0	0	1
2005	D3	11.4	0.8	1	5	3	0	0	1	0	0	0
2006	D3	9.3	0.4	1	2	4	0	0	1	2	0	0

Size and Sex Distributions, Canaveral

Of 23 live loggerheads processed, nine (39%) were female (seven juveniles, two adults) and 14 (61%) were male (three juveniles, 11 adults). Minimum straight-line carapace length (SCLmin) ranged from 53.7 to 73.6cm for juvenile females and 57.2 to 62.8cm for juvenile males. Two adult females measured (SCLmin) 93.6cm and 103.0cm. Seven adult males were smaller (by two to 9.6cm, SCLmin) than the smallest adult female; however, the largest adult male (102cm SCLmin) was comparable to the largest female.

Size and Sex Distributions, Charleston

Of 43 live individual loggerheads processed, sex determination using blood testosterone was possible for all but one. Thirty-four (81%) loggerheads were female (29 juveniles, five adults) and eight loggerheads were male (seven juveniles, one adult). Range in minimum straight-line carapace lengths for loggerheads field identified as juveniles (using carapace and tail length) was comparable for females (54.9 to 80.5cm SCLmin) and males (57.6 to 77.2cm SCLmin); however, actual maturity status was not known. Five loggerheads field identified as adult females (confirmed by blood testosterone) ranged in size from 87.4 to 93.0cm SCLmin. Only one loggerhead field identified as an adult male loggerhead (confirmed by blood testosterone) was collected; this turtle was estimated at 101.0cm SCLmin (110.0cm CCLmin) with a total tail length of 51.0cm.

Of 127 individual loggerheads collected in May 2004, 2005, and 2006, sex determination using blood testosterone was possible for 124 of them. Overall female to male sex ratio in May 2004 was 2.7 to 1 (n=48); however, sex ratios were noticeably skewed towards more females in May 2005 (4.7 to 1; n=34) and May 2006 (4.3 to 1; n=42). Size and sex distributions for loggerheads caught in May were highly variable among years (Figure 7).

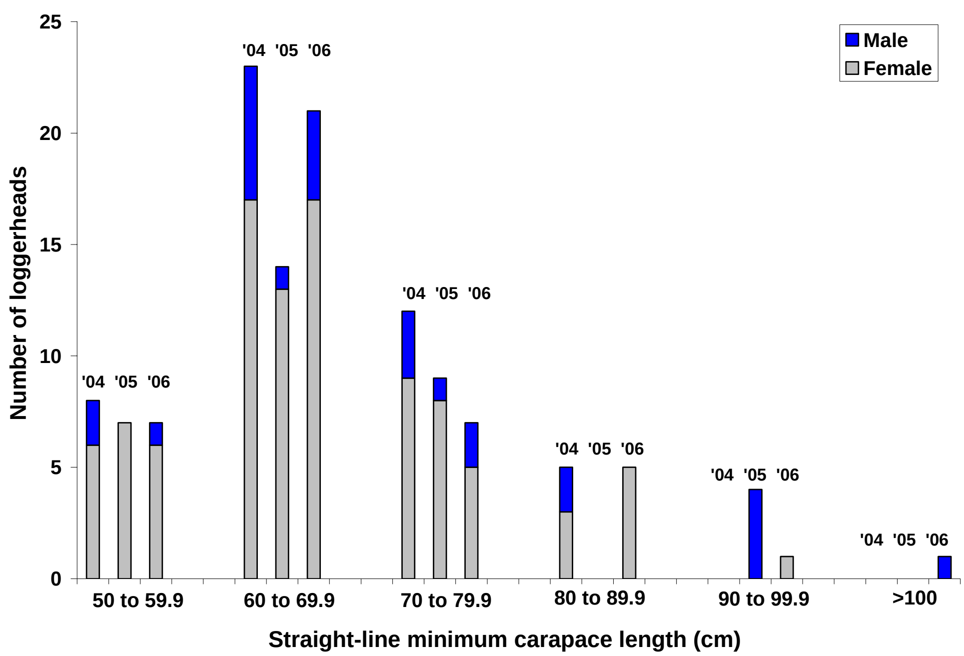

Figure 7. Size and sex distribution of loggerheads collected in the Charleston, SC, shipping entrance channel during May 2004, 2005, and 2006.

Loggerhead Health, Canaveral
In addition to collection of a previously dead turtle, seven of 23 loggerheads (30%) were observed to have recently acquired or healed wounds on the plastron, carapace, and/or flippers which likely resulted from boat prop injuries and/or interactions with predators. Incidence of wounds was disproportionately greater among male loggerheads (4 of 11) with respect to juvenile loggerheads (2 of 10); however, sample sizes were very small. The adult female loggerhead which was captured with an ingested long-line hook and leader was also missing a portion of her right front flipper.

Total protein values for adult loggerheads (5.4 to 8.2) were greater than total protein values for all but one juvenile loggerhead (4.0 to 5.4); however, a definitive relationship between turtle size and total protein was not observed. Blood glucose values overlapped for both juvenile (56 to 104) and adult (42 to 116) loggerheads. With the exception of one juvenile loggerhead (CC2440; pcv = 12), pack cell volumes (pcv) also overlapped between juvenile (26 to 51) and adult (27 to 40) loggerheads. Although pcv was low and this turtle appeared moderately emaciated, blood glucose (63) and total protein (4.0) were within the normal range of 'healthy' (Maier et al., 2004). Diagnostic blood profile data for eleven adult male loggerheads are presented in Table 2.

Table 2. Clinical values and descriptive statistics for adult male loggerhead blood parameters analyzed by Antech Diagnostic Laboratories; data organized as migrants (green), residents (orange), and turtles with little or no residence data collected (yellow).

Blood Chemistry	CC2442	CC2445	CC2450	CC2456	CC2444	CC2452	CC2453	CC2443	CC2446	CC2457	CC2462	Mean	Stdev	S.E.
Albumin	1	1.4	1	1.5	0.8	1.3	1.1	1.6	0.9	1.4	1	1.2	0.3	0.1
AST	162	186	198	360	108	111	267	228	169	124	170	189	74	22
BUN	16	27	29	44	39	28	50	34	26	20	37	32	10	3
Calcium	6.8	7.9	6.7	8.5	6.6	7.3	5.5	8	6	8.1	6.8	7.1	0.9	0.3
Chloride	110	119	111	105	120	111	118	116	117	109	119	114	5	2
CPK	2990	1438	926	3596	1152	1092	1748	5112	1679	1229	984	1995	1342	405
Globulin	3.4	4	4	4.8	3.7	4.5	5.7	3.6	5	4.2	4.4	4.3	0.7	0.2
Glucose	68	108	93	94	81	133	75	79	47	88	83	86	22	7
Phosphorus	9.8	9.6	8.7	8.1	7	8.1	10.9	8.5	7.9	8.9	8.3	8.7	1.1	0.3
Potassium	4.6	4.2	4.1	3.3	4.4	4.5	4.2	4.4	3.5	3.8	4.5	4.1	0.4	0.1
Sodium	164	166	155	140	164	153	159	167	164	142	168	158	10	3
Total Protein	4.4	5.4	5	6.3	4.5	5.8	6.8	5.2	5.9	5.6	5.4	5.5	0.7	0.2
Uric Acid	0.4	0.7	0.5	1.2	0.5	0.3	0.6	0.7	0.5	1.5	0.3	0.7	0.4	0.1

Complete Blood Count	CC2442	CC2445	CC2450	CC2456	CC2444	CC2452	CC2453	CC2443	CC2446	CC2457	CC2462	Mean	Stdev	S.E.
WBC	8	10	7	12	5	6	12	8	7	9	10	9	2	1
Basophils	0	0	0	1	1	0	0	2	2	1	0	1	1	0
Eosinophils	6	5	0	0	5	0	3	0	0	0	10	3	3	1
Heterophils	57	61	62	63	46	49	75	56	49	70	36	57	11	3
Lymphocytes	37	34	36	34	48	49	20	42	46	27	50	38	10	3
Monocytes	0	0	2	2	0	2	2	0	3	2	0	1	1	0
Az Monocytes	0	0	0	0	3	0	0	0	0	0	4	1	1	0
Absolute Basophils	0	0	0	120	50	0	0	160	140	90	0	51	65	19
Absolute Eosinophils	480	500	0	0	250	0	360	0	0	0	1000	235	326	98
Absolute Heterophils	4560	6100	4340	7560	2300	2940	9000	4480	3430	6300	3600	4965	2057	620
Absolute Lymphocytes	2960	3400	2520	4080	2400	2940	2400	3360	3220	2430	5000	3155	807	243
Absolute Monocytes	0	0	140	240	0	120	240	0	210	180	0	103	105	32
Absolute Az Monocytes	0	0	0	0	150	0	0	0	0	0	400	50	124	38
Pack Cell Volume	22	37	29	38	39	36	34	36	37	31	36	34	5	2

Loggerhead Health, Charleston

In addition to collection of a previously dead turtle, 10 of 43 loggerheads (23%) were observed to have recently acquired or healed wounds on the plastron, carapace, and/or flippers which likely resulted from boat prop injuries and/or interactions with predators. Extensive injuries for two turtles (CC0389, CC0420), were consistent with damage (multiple and deep gouges, large portions of carapace and/or scutes missing) reported for other turtles at this sampling location since 2004 (Maier et al., 2005; Segars et al., 2006). Two additional turtles (CC0394, CC0425) had healed neck lesions; CC0394 was monitored for one month post-release via satellite (ID#64554, p. 29 of this report).

Blood parameters evaluated at sea (total protein, glucose, pcv) were within normal ranges (Maier et al., 2004) and with the exception of one adult female with a high (9.2) total protein value, were not noticeably different between juvenile and adult loggerheads. Antech Diagnostic laboratories data suggest differences (i.e., no overlap in 95% C.I.) in numerous blood parameters (Table 3) between ‘healthy’ loggerheads collected in the Charleston, SC, shipping entrance channel versus surrounding coastal waters between St. Helena Sound, SC, and Winyah Bay, SC, the ‘northern’ boat area during 2000-2003 (Maier et al., 2004) and the general vicinity occupied during summer/fall by satellite-tagged loggerheads collected from the Charleston shipping entrance channel. With respect to blood chemistry, all parameters except for sodium, chloride, phosphorus and CPK were lower for loggerheads collected in the shipping channel. White blood cells, absolute heterophils, and absolute lymphocytes were also lower for loggerheads collected in the shipping channel; however, eosinophils (% and absolute) were higher.

Table 3. Summary statistics for blood profile data for loggerheads collected in the Charleston, SC, shipping entrance channel (2004-2006) vs. coastal waters (2000-2003).

	Charleston Shipping Channel					St. Helena Sound to Winyah Bay				
Blood Chemistry	**N**	**Mean**	**Std Dev**	**Std Err**	**95% CI**	**N**	**Mean**	**Std Dev**	**Std Err**	**95% CI**
Albumin	36	1.0	0.2	0.0	0.1	28	1.2	0.2	0.0	0.1
AST	36	169	50	8	17	28	226	70	13	27
BUN	36	61	19	3	6	28	93	22	4	8
Calcium	36	7.1	0.9	0.1	0.3	28	8.6	1.2	0.2	0.5
Chloride	36	117	5	1	2	28	117	6	1	2
CPK	36	1192	895	149	303	28	1082	657	124	254
Globulin	36	2.5	0.8	0.1	0.3	28	3.7	0.7	0.1	0.3
Glucose	36	89	20	3	7	28	120	25	5	10
Phosphorus	36	7.4	1.2	0.2	0.4	28	7.7	1.0	0.2	0.4
Potassium	36	4.5	0.5	0.1	0.2	28	5.0	0.8	0.2	0.3
Sodium	36	158	4	1	1	28	159	3	0	1
Total Protein	36	3.5	0.8	0.1	0.3	28	4.9	0.8	0.1	0.3
Uric Acid	36	0.9	0.3	0.1	0.1	28	1.8	0.8	0.2	0.3
Complete Blood Count	**N**	**Mean**	**Std Dev**	**Std Err**	**95% CI**	**N**	**Mean**	**Std Dev**	**Std Err**	**95% CI**
WBC	36	8	2	0	1	28	12	5	1	2
Basophils	36	1	1	0	0	28	0	1	0	0
Eosinophils	36	4	4	1	1	28	1	2	0	1
Heterophils	36	32	20	3	7	28	35	14	3	5
Lymphocytes	36	61	21	3	7	28	62	16	3	6
Monocytes	36	2	3	1	1	28	2	2	0	1
Az Monocytes	34	1	1	0	0					0
Absolute Basophils	36	50	82	14	28	28	16	41	8	16
Absolute Eosinophils	36	270	292	49	99	28	91	184	35	71
Absolute Heterophils	36	2621	2016	336	682	28	3968	2383	450	922
Absolute Lymphocytes	36	5009	2250	375	760	28	7416	4117	778	1594
Absolute Monocytes	36	183	280	47	95	28	260	217	41	84
Absolute Az Monocytes	34	63	146	25	51					
Pack Cell Volume	35	33	4	1	1	26	37	9	2	4

Sea Turtle Samples for Collaborators

Genetic analyses using mitochondrial DNA (mDNA) for 190 of 207 loggerheads collected from Charleston, SC, during 2004-2006 and 20 of 23 loggerheads collected from Port Canaveral, FL, during 2006 have been completed by the laboratory of Dr. Joe Quattro (University of South Carolina). In Charleston, haploytypes “A” and “B” comprised 88% of non-satellite-tagged and 96% of satellite-tagged loggerheads; however, in Canaveral, these two haplotypes comprised 100% of samples from adult males (*n*=5 each), with one sample outstanding. Nuclear DNA (nDNA) samples were provided to Mr. Brian Shamblin (University of Georgia), a graduate student under Mr. Mark Dodd (Georgia Department of Natural Resources, but results remain unavailable.

Blood and plasma were collected for Ms. Kimberly Reich (University of Florida) to conduct stable isotope analyses for evaluation of trophic foraging levels. Samples were provided for all loggerheads collected at both collection locations in 2006. In contrast to adult females collected from nearby beaches, adult male loggerheads appear to exhibit modal, rather than bi-modal (benthic and pelagic), foraging behaviors; however, it is unclear at this time whether this mode represents benthic (suggested by frequent collection of adult males with ‘worn’ jaws and the single occurrence of scallop shell fragments deposited by an adult male loggerhead held overnight) or pelagic foraging. Furthermore, because comparisons between adult males and females using the same tissue (i.e., skin) is not possible at this time, all results presented here should be considered preliminary. Larger sample size and collection of skin biopsies in 2007 should enable more definitive interpretation of adult male loggerhead data.

Barnacle samples were collected for Dr. John Zardus from The Citadel. One hundred sixty-six barnacles were sampled from six juvenile and ten adult male loggerhead sea turtles during 2006. Three obligate commensal turtle barnacle species were noted: *Chelonibia testudinaria, C. caretta*, and *Platylepas hexastylos*. Two barnacle species that are opportunistic settlers were also found: *Balanus trigonus* and *Lepas anatifera*. *B. trigonus* is typical of coastal habitats and was relatively common whereas *L. anatifera* is typical of the pelagic, open-sea environment. *C. testudinaria* was present on every loggerhead sampled, and specimens are being analyzed genetically to assess patterns of divergence and connectivity relative to turtle populations. Other barnacle species were less common; temporal/spatial analysis of their occurrence is pending.

Reproductive Status of Adult Male Loggerheads, Canaveral

The reproductive status of 11 adult male loggerhead sea turtles was evaluated using a suite of methods including ultrasound, plasma testosterone levels, laparoscopy and testicular biopsy. The purpose of this phase of the research project was two-fold. The first objective was to assess the level of reproductive activity prior to satellite-tagging, in order to better understand the distributional patterns of adult male loggerheads collected at this location, which are known to occur year-round with increased abundance in the spring (Henwood, 1987), when a small component do not appear to be reproductively-active (Wibbels et al., 1987). And second, to evaluate different methods (which vary in their degree of invasiveness and skill level required) for accurate assessment of the reproductive condition of adult male loggerhead sea turtles.

Ultrasound analysis showed a large, often round-shaped, homogeneous mass, which we identified as being testis (Figure 8) for seven of eleven male loggerheads evaluated. In some individuals a distinct epididymal mass was also seen, however this structure was not consistently observed. Ultrasound was easy to implement and results were immediately available, which minimized stress for the animal. However, when we were not able to visualize the epididymides by ultrasound, we could not be certain that this was simply the result of low reproductive activity or technical difficulty with the method. Thus, the lack of "tissue validation" limited the utility of this technique.

Testosterone radioimmunoassay (RIA) was a slightly more invasive technique, as a 10ml blood sample was collected. Because subsequent laboratory analysis of this blood sample was required, results were not immediately available. This analysis revealed two distinct groups: one with low testosterone levels (<10 ng/mL, n=4) and one with very high testosterone levels (>150 ng/mL, n=7). Multiple explanations for low-testosterone males exist, as these turtles could have been non-reproductively-active or post-reproductively-active; however, all males with high testosterone levels were thought to be reproductively-active. Thus, testosterone data alone does not provide a complete analysis of reproductive condition of adult male loggerheads.

Laparoscopic analysis proved to be a more powerful tool than ultrasound to evaluate reproductive status. Despite being a considerably more invasive technique, the testis was directly observed in all cases, and epididymides were visualized in 10 out of 11 males. The epididymides appeared as white convoluted tubules, full of sperm, and the testis appeared turgid in 9 cases (Figure 9). In two cases, the testis looked regressed and the epididymides were atrophic (Figure 10), so these turtles were classified as being inactive using this technique. These two turtles also had low testosterone levels (Table 4).

Biopsy samples were very useful and, through tissue histology, demonstrated the reproductive stage in the greatest detail by evaluating the presence/absence of sperm cells, and their abundance in the seminiferous tubules (Figure 11). Tubule size was also estimated from the histological images by taking two cross section diameters on as many tubules as possible. Four reproductive stages (no spermatogenesis, spermatogenesis: minimal, mild, moderate to orderly) were described, and two of the eleven turtles (also with low testosterone) fell into the "no spermatogenesis" group.

In conclusion, we found that some adult males did not show any signs of reproductive activity, which suggests that they may have a multi-annual reproductive cycle, just as females do. Thus far laparoscopy and testis biopsy are the most powerful tools for assessing reproductive condition of adult male loggerheads. Testosterone measurement showed that high levels were always associated with reproductive activity, but low levels could be wrongly interpreted, as some turtles were predicted to be post-reproductive. The ultrasound technique did not have the best resolution to assess the reproductive activity of these turtles, although it is a very promising technique which deserves further evaluation.

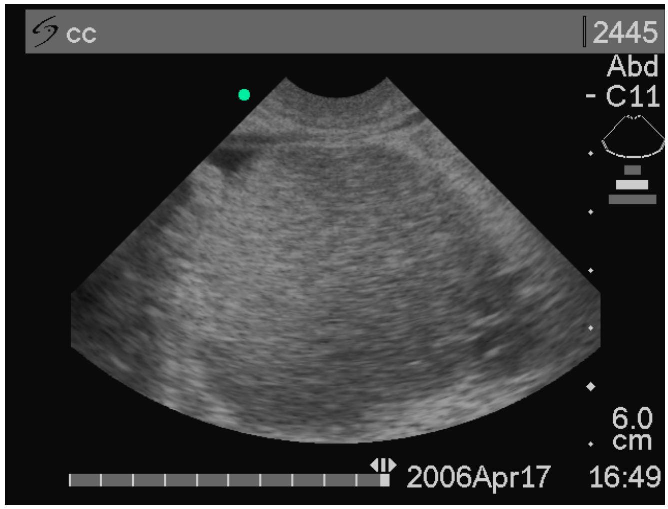

Figure 8. Ultrasound image of testis from an adult male loggerhead sea turtle.

A B

Figure 9. Laparoscopic image of epididymides (A) and testis (B) from a reproductively-*active* adult male loggerhead sea turtle.

A B

Figure 10. Laparoscopic image of epididymides (A) and testis (B) from a reproductively-*inactive* adult male loggerhead sea turtle.

Table 4. Comparison of reproductive activity assessment of eleven adult male loggerheads using four distinct techniques which varied in degree of invasiveness.

Turtle ID	Testosterone	Ultrasound	Laparoscopy	Testis biopsy	Disposition*	Sat Tag ID
CC2442	Inactive	Active	Active	Active - Mild	Migrate to SC	64543
CC2443	Active	Active	Active	Active – Mild	Unknown	64541
CC2444	Inactive	Active	Moderately active	Active – Minimal	Resident	64542
CC2445	Active	Active	Active	Active - moderate to orderly	Migrate to MD	64544
CC2446	Inactive	Not seen	Not active	Not active	Resident?	64546
CC2450	Active	Not seen	Active	Active - minimal	Migrate to NJ	64548
CC2452	Active	Active	Active	Active - moderate to orderly	Resident	64540
CC2453	Inactive	Not seen	Not active	Not active	Resident	64545
CC2456	Active	Active	Active	Active - moderate to orderly	Migrate to NJ	64547
CC2457	Active	Not seen	Active	Active – mild	Unknown	No Sat Tag
CC2462	Active	Active	Active	Active - moderate to orderly	Unknown	No Sat Tag

** see "Satellite-telemetry, Adult Males*

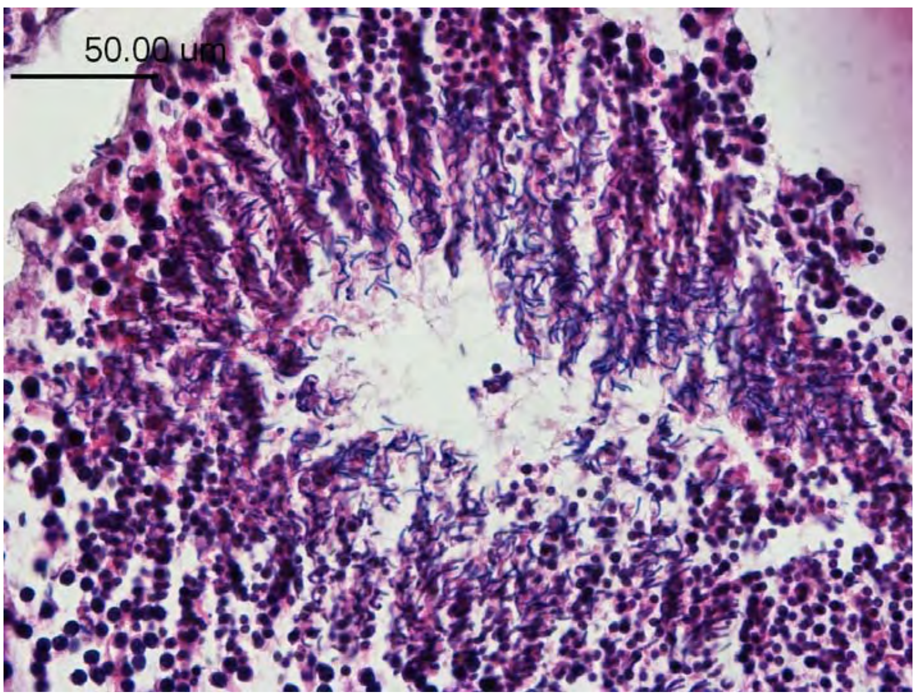

Figure 11. Histological image of a testis in stage 3 (numerous sperm cells) from a reproductively-active adult male loggerhead.

By-Catch, Canaveral

Detailed by-catch assessment was not conducted for trawling events in the Canaveral shipping entrance channel for several reasons, primarily to increase available trawling time and to provide a safe working space on the back deck. As such, by-catch was tossed overboard immediately upon retrieval, which also increased the probability of survival. Notable by-catch species include consistently large catches (~15 per station) of smooth butterfly rays (*Gymnura micrura*) and collection of a very large (~2m) goliath grouper (*Epinephelus itajara*) in the port net (while dragging from inshore to offshore) of the only trawling event conducted between channel marker pairs “9/10” and “7/8”.

By-Catch, Charleston

By-catch assessment was conducted with an emphasis of accounting for elasmobranch species, blue crabs (*Callinectes sapidus*), and horseshoe crabs (*Limulus polyphemus*). For 55 of 138 net collections (40% of total), individual counts were made prior to dumping net contents over the side of the vessel. As such, although attempts were made to be accurate, data for these collections represent estimates rather than true counts. For all other net collections, actual counts were recorded.

At least seven elasmobranch species were observed in May 2006. Only six sharks were collected: two Atlantic sharpnose, *Rhizoprionodon terranovae*; two bonnetheads, *Sphyrna tiburo*; and one scalloped hammerhead, *S. lewini*. With the exception of one trawl in which ~25 Dasyatid stingrays were present, actual counts (1.71 animals per collection for 17 collections) were similar to estimated counts (1.88 animals per collection for 17 collections). Eight smooth butterfly rays (*Gymnura micrura*), six clearnose skates (*Raja eglentaria*), and five guitarfish (*Rhinobatos lentiginosus*) were also collected.

An estimated 551 blue crabs were collected, of which 306 were actually counted in 41 collections (7.5 crabs per collection) and 245 were estimated to be present in 29 collections (8.4 crabs per collection). Given similarity in actual versus estimated counts per collection for blue crabs, data were pooled to reveal an average of 7.9 crabs per collection. As such, blue crab abundances in the Charleston, SC, shipping entrance channel in May 2006 were nearly four times greater than relative abundances for blue crabs observed for this location in May 2004 or 2005 (Table 5). In all three years, approximately 90% of these crabs were “sponge” crabs.

Table 5. Blue crab (*Callinectes sapidus*) and horseshoe crab (*Limulus polyphemus*) collections in the Charleston, SC, shipping entrance channel in May 2004-2006. Data pooled among actual and estimated counts for each species.

	Blue crabs				Horseshoe crabs		
Year	N Collections	N Crabs	Crabs / Collection		N Collections	N Crabs	Crabs / Collection
2004	41	99	2.4		36	148	4.1
2005	45	88	2.0		41	84	2.0
2006	70	551	7.9		43	333	7.7

An estimated 333 horseshoe crabs were collected, of which 72 were actually counted in 19 collections (4.0 crabs per collection) and 261 were estimated to be present in 25 collections (10.4 crabs per collection). After removal of collections from four trawling events in which more than 30 horseshoe crabs were estimated to be present, 60 horseshoe crabs were estimated to be present in 19 collections (3.2 crabs per collection). Given similarity in actual versus estimated counts for horseshoe crabs for collections suggested to have 13 or fewer horseshoe crabs, data were pooled to reveal an average of 3.6 crabs per collection (13 or fewer crabs estimated), or 7.7 crabs per collection for all data. Based on actual counts, horseshoe crab relative abundances in the Charleston, SC, shipping entrance channel in May were similar in 2004-2006 (Table 5).

At least 22 finfish species totaling more than 600 individuals were collected in May 2006. Finfish catch was dominated (77%) by Sciaenids, notably spot (*Leiostomus xanthurus*; *n*=166) and banded drum (*Larimus faciatus*; *n*=224). Butterfish (*Peprilus triacanthus*) accounted for 13% of recorded finfish catch. Other species of interest include collection of a king mackerel (*Scomberomorus cavalla*) and collection of a dead and very decayed Atlantic sturgeon (*Acipenser oxyrhynchus*).

Non-crustacean benthic invertebrate catches were dominated by sea porks (*Aplidium pellucidum*), which accounted for 70% (169 of 242) recorded specimens. Collection of specimens indicative of live-bottom habitats such as sponges (*n*=13) or sea whips (*n*=6) was minimal, suggesting little damage to these valuable fish and invertebrate habitats.

Crustacean collections were minimal as well; however, low catches of these creatures may have stemmed from dumping net contents overboard without scrutinizing the catch. Crab collections were especially low, with only 10 stone crabs (*Menippe mercenaria*), eight spider crabs (*Libinia* sp.), and one lesser blue crab (*Callinectes similis*) observed. Other crustaceans recorded included eight white shrimp (*Penaeus setiferus*), one pink shrimp (*Penaeus duorarum*), and one unidentified mantis shrimp (*Squilla* sp.).

Cannonball jellyfishes (*n*=3,939; estimated) accounted for 99% of jellyfish species recorded during May 2006. Cannonball jellyfishes were present in 70% (n=97 of 138) of collections. Because most collections in which more than 50 cannonball jellyfish were recorded as present represented estimated counts, comparison of cannonball jellyfish abundance between May 2004, 2005, and 2006 is not advisable. However, it is worth noting that the relative occurrence of cannonball jellyfish in trawl collections in the Charleston, SC, shipping entrance was markedly different in May 2006 than in either May 2004 (24%; *n*=23 of 96 collections) or May 2005 (11%; *n*=15 of 140 collections). Fewer than 50 other jellyfish (all unidentified species of Order Cubomedusae) were recorded. Incidentally, a loggerhead (CC0426) collected in the channel regurgitated numerous partially digested jellyfish (tentatively identified as sea nettles, *Chrysaora quinquecirrha*); thus, either our gear was inadequate for sampling these jellyfish species or this particular turtle fed elsewhere prior to being caught.

Satellite Telemetry, Overview

Fifteen loggerheads in two groups were tagged and released with satellite transmitters in 2006. Nine adult male loggerheads (86.6 to 102.0 cm SCLmin; mean = 90.3 cm) were released in April at Cape Canaveral, FL. Six juvenile loggerheads (59.6 to 70.2 cm SCLmin; mean = 66.3 cm) were released at Charleston, SC, in May.

Despite using thicker tubing to protect transmitter antennas in 2006, mean data collection periods were considerably less (though not statistically) in 2006 than in either 2004 or 2005 (Figure 12). Six of nine (67%) transmitters attached to adult male loggerheads ceased regular detection within four months post-release and a similar proportion (*n*=4 of 6; 67%) of transmitters attached to juvenile loggerheads ceased regular detection within 2 months. Representatives at Telonics, Inc. indicate that the poor data collection in 2006 may have resulted from increased drag (associated with thicker antennas) which prevented antennas from achieving a sufficiently upright position for signal transmission.

Poor signal transmission due to antenna drag rather than complete antenna damage may explain variable numbers of daily detection events for several loggerheads during summer 2006. Furthermore, isolated detection events for four juvenile and one adult male loggerhead, which were initially dismissed as 'ghost' transmissions, may also be related to antenna drag, especially considering that one of these juvenile loggerheads (ID58944) was detected as much as 17 times in 380 days following regular detection. Standard ST-20 antenna tubing used in 2004 and 2005 will be utilized in 2007 to eliminate the possibility of antenna drag due to thicker tubing.

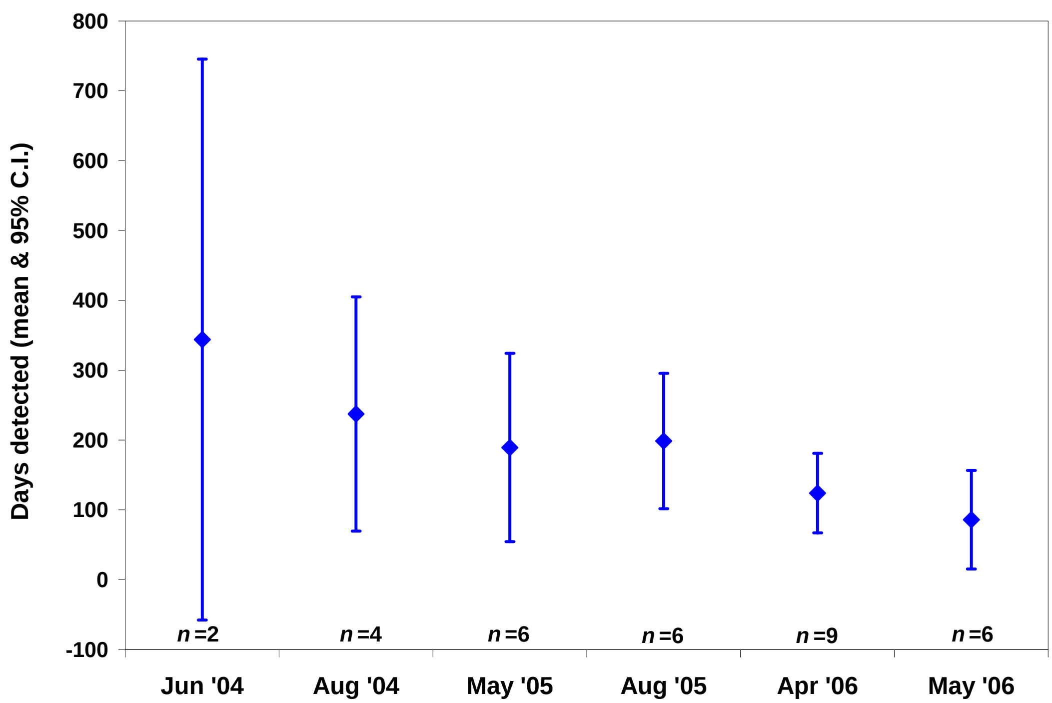

Figure 12. Data collection periods per loggerhead release groupings, 2004-2006. All release groupings are for juvenile loggerheads, except for April 2006 (adult males).

Satellite Telemetry, Adult male loggerheads

Data collection periods for six of nine adult male loggerheads only lasted up to four months, with one of these transmitters (ID64541) only collecting data for one week. Four adult male loggerheads only remained in the vicinity of Cape Canaveral until the middle or end of May, at which time they ventured north to SC, MD, and NJ. Three adult male loggerheads were detected in the vicinity of Cape Canaveral through early July (*n*=1) and as late as November (*n*=2). A fourth adult male (ID64546) may have remained in the vicinity of Cape Canaveral through June (when detections ceased); however, location data were not available after May.

ID64541 ("Big Daddy"), a 103.1 cm CCLmin adult male loggerhead, was caught during a 15-min trawl between buoys "5/6" and "3/4" in the Port Canaveral shipping entrance channel in the morning of 17 April 2006. Following laparoscopy and observation to ensure proper buoyancy, this turtle was satellite-tagged and released just north (0.5km) of the Canaveral jetties at around 8pm on the same day. The first "good" location for this animal was received at 5pm on 20 April (Figure 13). Only four "good" detections were received for this animal, all but one of which was in the vicinity of the shipping entrance channel. All "good" detections for this turtle occurred between 6pm (EDT) on 20 April and 4pm on 22 April; however, this turtle was last detected in the afternoon on 24 April.

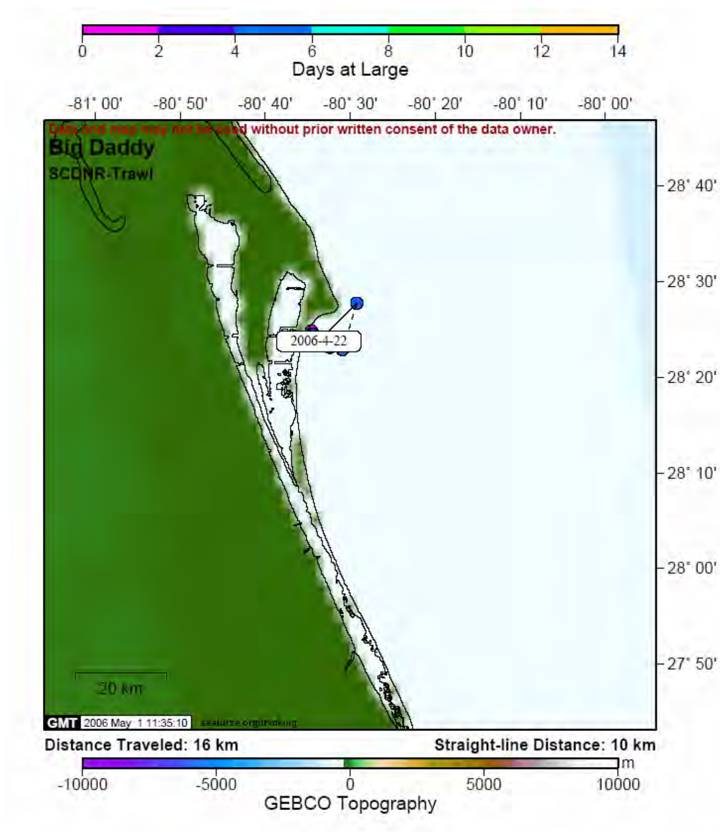

Figure 13. Short-term distributional pattern of a satellite tagged loggerhead (ID64541) from 17-24 April 2006.

ID64546 ("Marty"), an 88.9 cm SCLmin adult male loggerhead, was caught during a 15-min trawl between buoys "5/6" and "3/4" in the Port Canaveral shipping entrance channel in the morning of 18 April 2006. Following laparoscopy and observation to ensure proper buoyancy, this turtle was satellite-tagged and released just north (0.5km) of the Canaveral jetties at around 2pm (EDT) the following day. Unlike ID64541, the first "good" location for this turtle was received just 26 hrs following release; however, similar to ID64541, only four "good" detections were received for this turtle following release (Figure 14). All four "good" detections for ID64546 were received between 4pm on 20 April and noon on 24 April (at which point this animal appeared to be in the Indian River Lagoon, 5km NW of Sebastian Inlet). Between 24 April and 23 May, 23 additional locations (all location classes A, B, 0, and Z) suggested this turtle remained in the same vicinity as the last "good" location. Approximately one sensor-only detection was recorded daily through 8 June, after which only two sporadic detections (25 June and 13 November; both sensor-only) were ever recorded for this loggerhead.

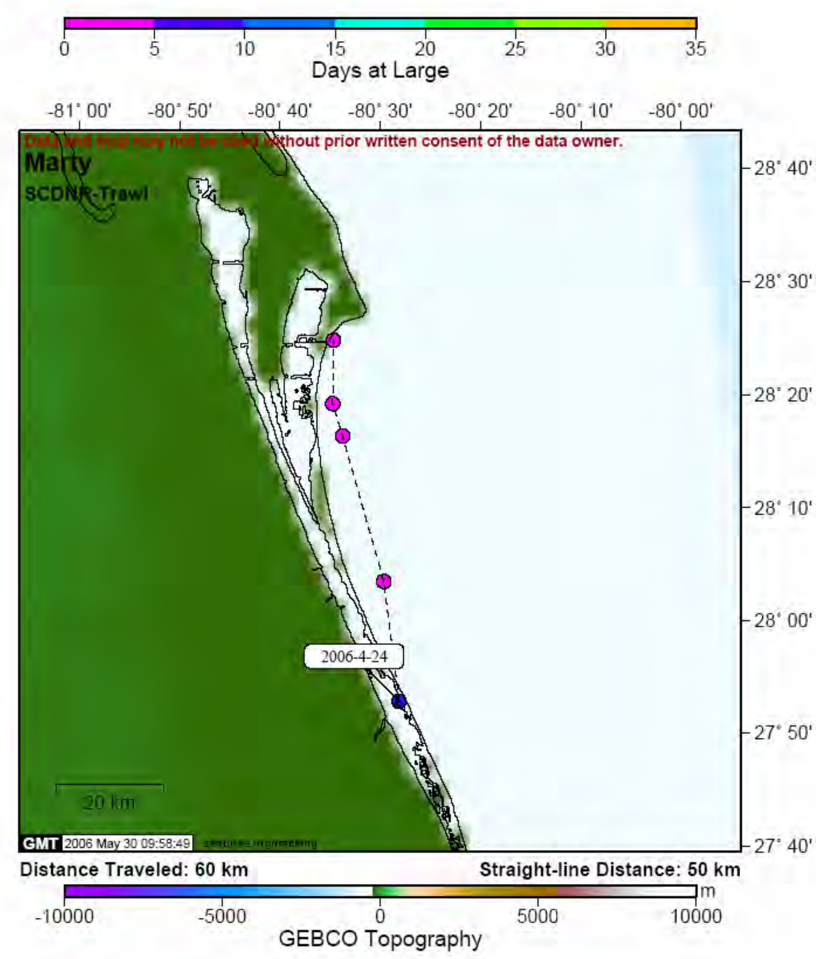

Figure 14. Short-term distributional patterns for adult male loggerhead ID64546, which moved from Cape Canaveral, FL, to the Indian River Lagoon in the vicinity of Sebastian Inlet, FL, within 5 days of release.

ID64543 (“Rostal”), an 89.5 cm SCLmin adult male loggerhead, was caught during a 15-min trawl between buoys “5/6” and “3/4” in the Port Canaveral shipping entrance channel in the morning of 17 April 2006; at the time of collection, a mating pair of loggerheads was observed at the surface, just outside of the channel. Following laparoscopy and observation to ensure proper buoyancy, this turtle was satellite-tagged and released just north (0.5km) of the Canaveral jetties at around 6pm (EDT) on the same day. Although 90 detections were received for this loggerhead during the first 13 days post-release, the first “good” location was not received until 9pm on 30 April. Not surprisingly, “good” locations only accounted for 2% (*n*=11 of 533) of total detections for this loggerhead. Furthermore, 62% (n=8 of 13) of “good” detections for this loggerhead occurred between 17-25 May while en route to Hilton Head Island, SC (Figure 15). The next “good” detection occurred on 4 June, and indicated the animal was inside Port Royal Sound. Additional location data through 21 July suggest residence in this vicinity. A sensor-only (no location) for detection for this animal occurred on 19 December.

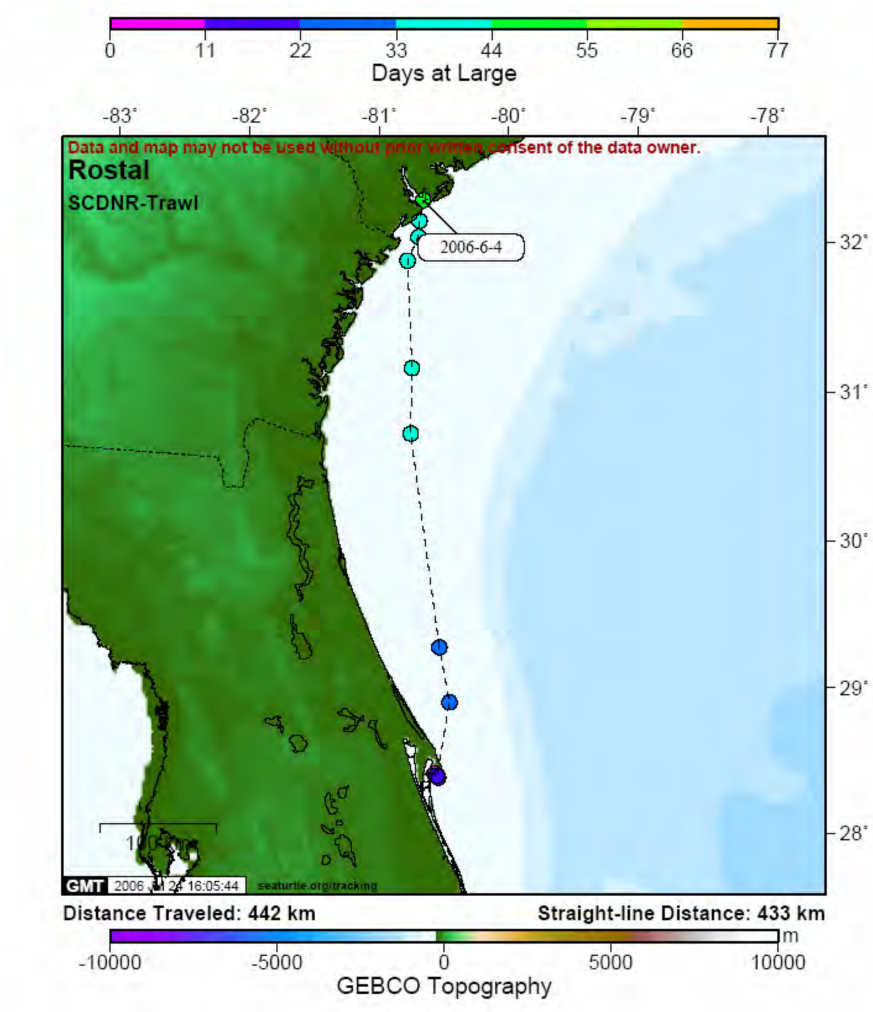

Figure 15. Short-term distribution of adult male loggerhead ID64543. This loggerhead migrated (17-25 May) from Cape Canaveral, FL, to Hilton Head Island, SC, and ultimately into Port Royal Sound, where it likely remained through 21 July.

ID64544 ("Tomo"), a 98.3 cm SCLmin adult male loggerhead, was caught during a 15-min trawl between buoys "5/6" and "3/4" in the Port Canaveral shipping entrance channel in the morning of 17 April 2006; at the time of collection, a mating pair of loggerheads was observed at the surface, just outside of the channel. Following laparoscopy and observation to ensure proper buoyancy, this turtle was satellite-tagged and released just north (0.5km) of the Canaveral jetties at around 10am (EDT) the next day (18 April). This loggerhead was detected at least once every day for the next 123 days. The first "good" detection occurred three days post-release (21 April) and placed this turtle about 25km due south of Cape Canaveral; however, between 25 April and 8 May, four "good" locations were tightly clustered in an area closely approximating collection location. Between 9 and 29 May, this turtle appeared to be in the vicinity of Cape Canaveral; however, no "good" detections were recorded. Between 30 May and 22 June, 11 "good" detections (of 225 total detections) were recorded during migration from Cape Canaveral, FL, to the vicinity of Chincoteague Island, VA (Figure 16). Between 23 June and 19 August, this turtle appeared to remain in the same general area, and a similar proportion of "good" detection events (*n*=33 of 725 total detections) were also recorded.

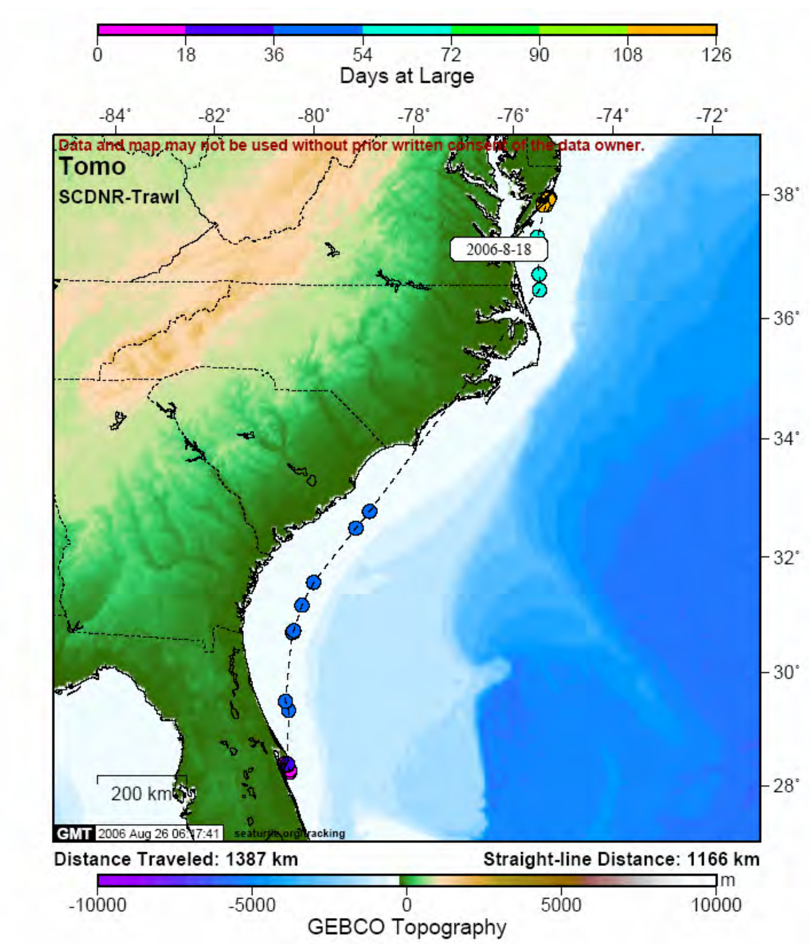

Figure 16. Short-term distribution of adult male loggerhead ID64544. This loggerhead migrated (30 May to 22 June) from Cape Canaveral, FL, to Chincoteague, VA, where it likely remained through 19 August.

ID64547 ("Bruce"), a >97.4 cm SCLmin adult male loggerhead, was caught during a 15-min trawl between buoys "7/8" and "5/6" in the Port Canaveral shipping entrance channel in the morning of 20 April 2006. Following laparoscopy and observation to ensure proper buoyancy, this turtle was satellite-tagged and released just north (0.5km) of the Canaveral jetties at around 5pm (EDT) on the same day. The first "good" location following release for this turtle occurred mid-day on 24 April. During 24-25 April, three "good" locations place this turtle within 6km of shore off of Cocoa Beach, FL. Two "good" locations on 29 April and 5 May place this turtle in the vicinity of the Canaveral shipping channel; however, by 13 May (the next "good" location) movement away from the Cape began. Between 14 May and 15 June, this turtle migrated between Cape Canaveral, FL, and the middle continental shelf off the coast of New Jersey, roughly offshore of Atlantic City, NJ (Figure 17). Nineteen of 30 (63%) "good" locations for this turtle occurred during migration. Between 16 June and 16 August (last detection), this turtle was rarely detected more than three times per day (and often not at all), except for two brief periods of increased detections during 24-28 July and during 14-15 August.

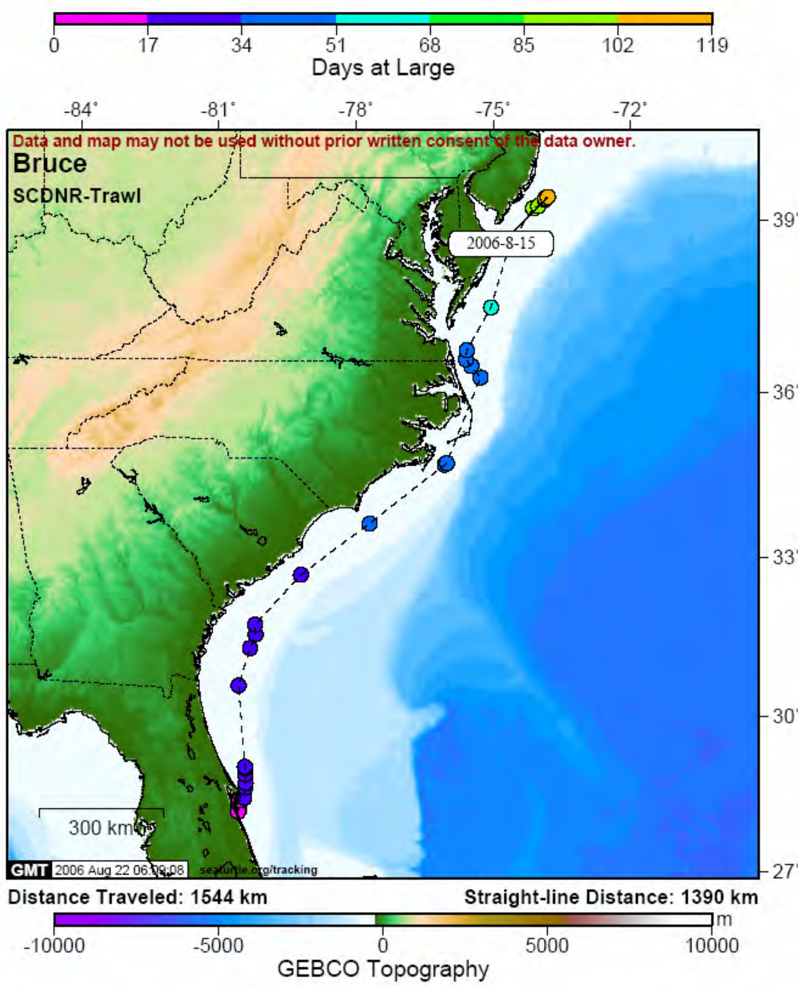

Figure 17. Short-term distribution of adult male loggerhead ID64547. This loggerhead migrated (14 May to 15 June) from Cape Canaveral, FL, to offshore of the southern coast of New Jersey, where it likely remained through 16 August.

ID64548 ("Norton"), a 91.6 cm SCLmin adult male loggerhead, was caught during a 15-min trawl between buoys "1/2" and "3/4" in the Port Canaveral shipping entrance channel in the afternoon of 18 April 2006. Following laparoscopy and observation to ensure proper buoyancy, this turtle was satellite-tagged and released just north (0.5km) of the Canaveral jetties at around 10am (EDT) the next day (19 April). While held overnight, this turtle regurgitated or excreted fragments of calico scallop (*Argopecten gibbus*). The first "good" location for this turtle following release occurred in the evening of 26 April. Between 26 April and 5 May, "good" locations placed this turtle north of the collection area, but south and inshore of the Cape. During 8-15 May, "good" locations documented an arc-shaped movement towards the shoreline off of Cocoa Beach. During 20-21 May, "good" locations documented directed movement away from waters occupied for the previous month. Between 22 May and 13 June, this turtle migrated (Figure 18) from Cape Canaveral, FL, to offshore off the southern NC coast. Migration utilizing the middle continental shelf was well-documented (40 "good" locations in 23 days); however, this turtle was briefly detected within 5km of the Charleston, SC, shipping entrance channel during 6-8 June. Between 14 and 28 June no "good" locations were detected; however, two "good" locations on 29-30 June indicated that this turtle was off the New Jersey coast, where it remained through August. No "good" locations were detected again until 11 September, at which time it appeared to be off of Cape Hatteras, NC, where it was last detected on 30 September.

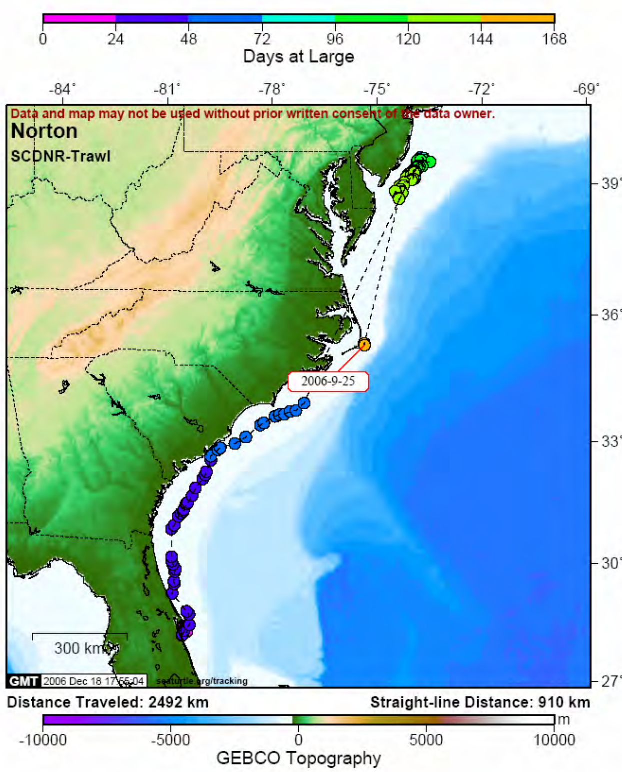

Figure 18. Six-month distribution of adult male loggerhead ID64548. This loggerhead migrated (22 May to 29 June) from Cape Canaveral, FL, to offshore of the coast of New Jersey. This turtle remained off coast of NJ through August, returned south, and spent the month of September off of Cape Hatteras, NC.

ID64540 ("Davy Bill"), an 86.6 cm SCLmin adult male loggerhead, was caught during a 15-min trawl between buoys "5/6" and "3/4" in the Port Canaveral shipping entrance channel in the morning of 19 April 2006. Following laparoscopy and observation to ensure proper buoyancy, this turtle was satellite-tagged and released just north (0.5km) of the Canaveral jetties at around 4pm (EDT) on the same day. The first "good" location for this turtle following release occurred around noon the very next day (20 April). This turtle remained resident in the vicinity of Cape Canaveral (Figure 19) into the first week of July (last "good" location on 2 July, last overall detection on 6 July). Within two days following release (19-21 April), this turtle traveled approximately 20km offshore, before heading south approximately 30km. For the next four days (22-25 April), this turtle made a directed approach to the vicinity of where it was collected, before resuming a reciprocal course offshore two days later (27 April). This turtle remained in this general vicinity through 2 July. During 79 days of data collection, "good" locations and total detections were disproportionately recorded in the last half of April. Nine of 21 (43%) of "good" locations occurred between 20-27 April, and 135 total detections (11.3 per day) were recorded through the end of April. Conversely, mean daily detections decreased from 4.0 to 2.5 to 0.5 in May, June, and the first week of July, respectively.

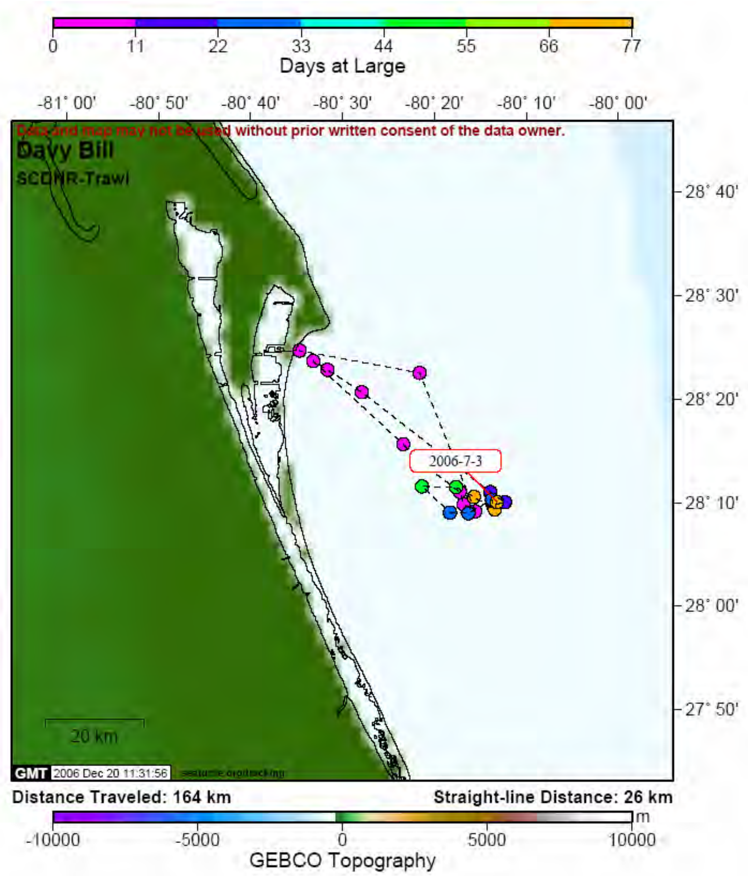

Figure 19. Short-term (2.5 months) distribution of adult male loggerhead ID64540. This loggerhead remained near Cape Canaveral, FL, between 19 April and 2 July, and occupied a localized area 40km to the southeast of the channel during this period.

ID64542 ("Gaël"), an 87.2 cm SCLmin adult male loggerhead, was caught during a 15-min trawl between buoys "5/6" and "3/4" in the Port Canaveral shipping entrance channel in the morning of 17 April 2006. Due to a multi-turtle catch, this turtle was held overnight before conducting laparoscopy. Following laparoscopy and observation to ensure proper buoyancy, this turtle was satellite-tagged and released just north (0.5km) of the Canaveral jetties at around 5pm (EDT) on 18 April. The first "good" location for this turtle following release occurred around noon the very next day (19 April). This turtle remained resident in the vicinity of Cape Canaveral (Figure 20) for the duration of monitoring, with the last "good" location occurring on 23 November. Four "good" locations during 19-26 April place this turtle within 10km of the shoreline between Cape Canaveral and Cocoa Beach, FL; however, by noon (EDT) on 28 April, this turtle had moved approximately 50km offshore. Between 28 April and 23 November, this turtle was repeatedly detected (260 "good" locations). Overall detections per day averaged 8.7 in June and 9.1 in August, which was slightly greater than in May, July, and October (range = 5.8 to 6.9). Mean daily detections decreased to 4.5 per day in October and 3.4 per day in November, which may indicate transmitter fouling.

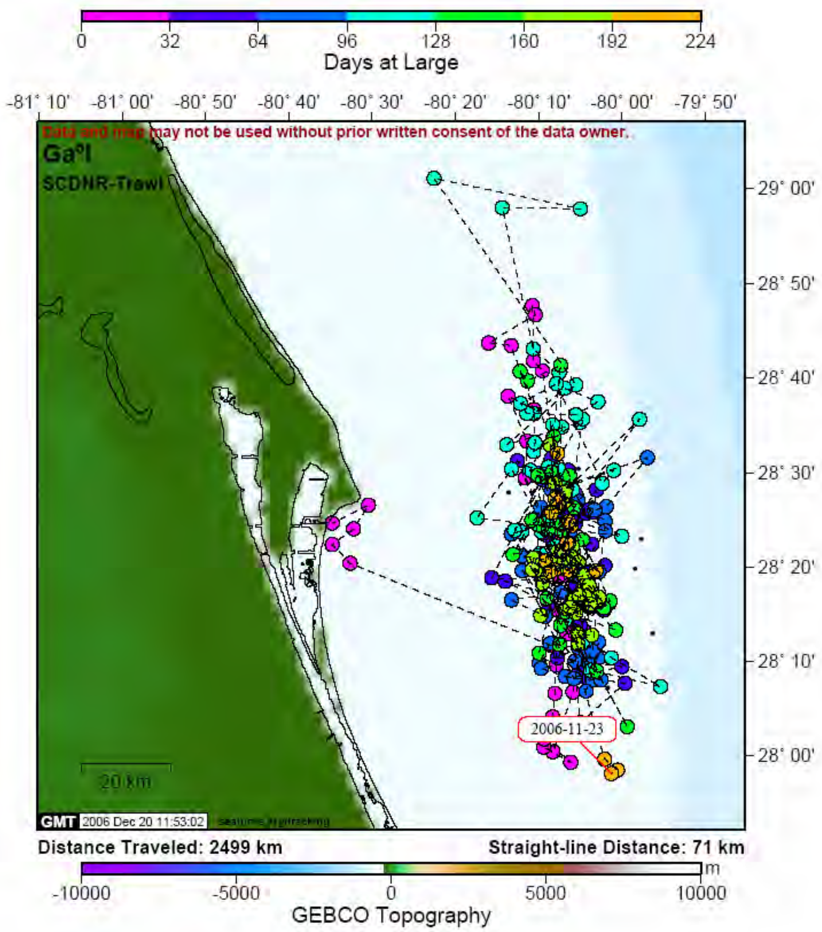

Figure 20. Six-month distribution of adult male loggerhead ID64542. This loggerhead remained near Cape Canaveral, FL, between 19 April and 23 November, and occupied a large area (115km north to south) situated approximately 50km from shore.

ID64545 ("Jaws"), a 90.7 cm SCLmin adult male loggerhead, was caught during a 15-min trawl between buoys "5/6" and "3/4" in the Port Canaveral shipping entrance channel in the morning of 19 April 2006. Following laparoscopy and observation to ensure proper buoyancy, this turtle was satellite-tagged and released just north (0.5km) of the Canaveral jetties at around 6pm (EDT) on the same day. This turtle remained resident in the vicinity of Cape Canaveral (Figure 21) for the duration of monitoring; however, "good" locations were only available through October. The first "good" location for this turtle following release occurred around the time of release; however, the next "good" location did not occur until 17 days later (7 May). Six "good" locations between 7 May and 12 June suggested a localized distribution east of where collected in an area 10-20km offshore. Between 24 June and 26 July, 19 "good" locations documented an shift in distribution further offshore (20-60km) and within an area about four times as great with respect to latitudinal range. Between August and October, this turtle's distribution shifted south, such that "good" locations south of 28°20'N were observed twice as frequently (82%; *n*=46 of 56) as during May through July (38%; *n*=10 of 26). Monthly detections decreased dramatically in November (*n*=26) and December (*n*=8; all sensor-only), suggesting transmission problems, possibly due to sensor fouling.

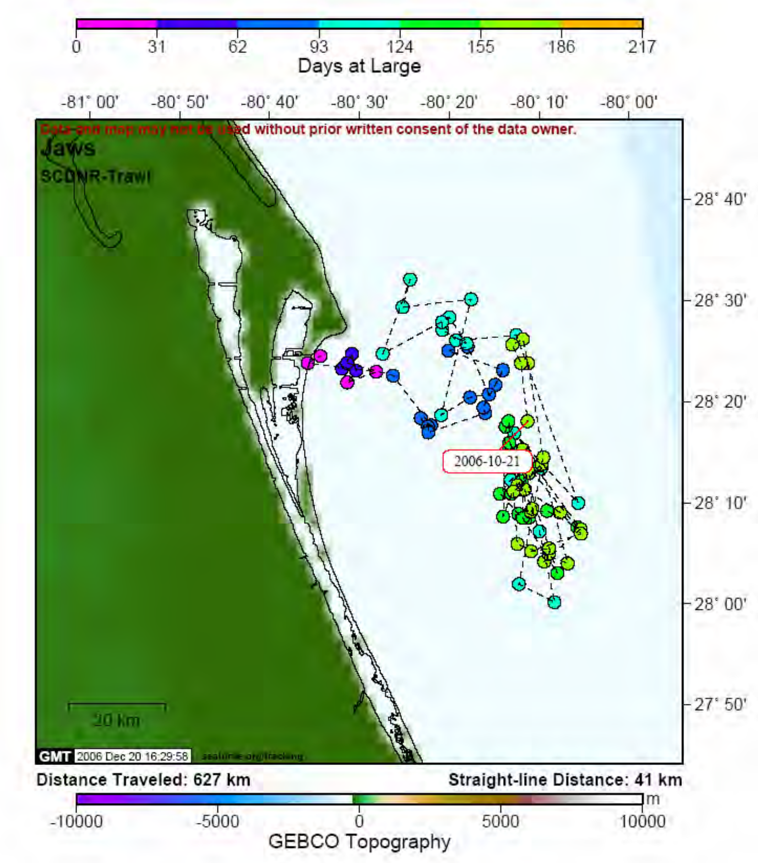

Figure 21. Six-month distribution of adult male loggerhead ID64545. This loggerhead remained near Cape Canaveral, FL, between 19 April and at least 21 October, and occupied a large area (80km north to south) predominantly 40-60km from shore.

Satellite Telemetry, Juvenile loggerheads

Data collection periods for four of six juvenile loggerheads only lasted between one and two months. All four of these loggerheads remained within the vicinity of Charleston, SC, for the duration of monitoring. A fifth juvenile loggerhead (ID64552) moved to the offshore waters of Frying Pan Shoals, NC, within a few weeks of tag and release, and was detected there until early October. The sixth juvenile loggerhead (ID64550) initially traveled north to Cape Romain, SC; however, this turtle soon reversed course and headed south, spending the summer and fall in the near-shore waters off of Matanzas Inlet, FL.

ID64554 ("DuBose"), a 64.8cm SCLmin female loggerhead, was caught at station "B1" in the Charleston, SC, shipping entrance channel on the morning of 18 May 2006. Twenty-seven "good" locations during 31 detection days post-release placed this turtle in a fairly localized area 20-30km offshore between the Isle of Palms and Bull Island (Figure 22). The last "good" location (15 June) indicated movement to within 10km of shore. Total daily detections were variable, but showed similar declines at two week intervals; thus, suggesting transmission problems which may have been fouling-related.

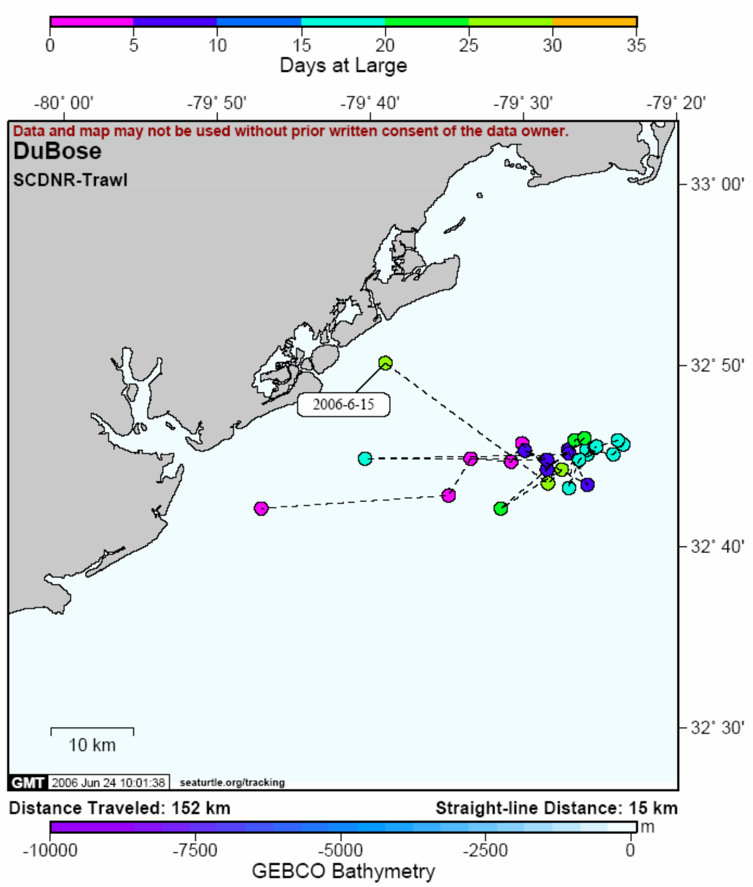

Figure 22. One-month distribution of juvenile loggerhead ID64554. This loggerhead generally remained 20-30km offshore, between the Isle of Palms and Bull Island, SC.

ID64553 ("JB"), a 59.6cm SCLmin female loggerhead, was caught at station "D3" in the Charleston, SC, shipping entrance channel during the middle of the day on 17 May 2006. The first "good" location following release did not occur until seven days later (24 May); however, this location and three others (two to 23 days later) placed this turtle in very close proximity to where it was collected and released (Figure 23). On 27 June, eleven days after last detected near the shipping entrance channel for one month, this turtle was detected about 80km northeast of the channel, in an area approximately 40km due east of Cape Romain, SC. Despite few "good" locations, total daily detections were often numerous (16 per day). Daily detections were variable, and fluctuated between high and low values with almost weekly periodicity; thus, problems with signal transmission as a result of chronic fouling are difficult to assess for this turtle.

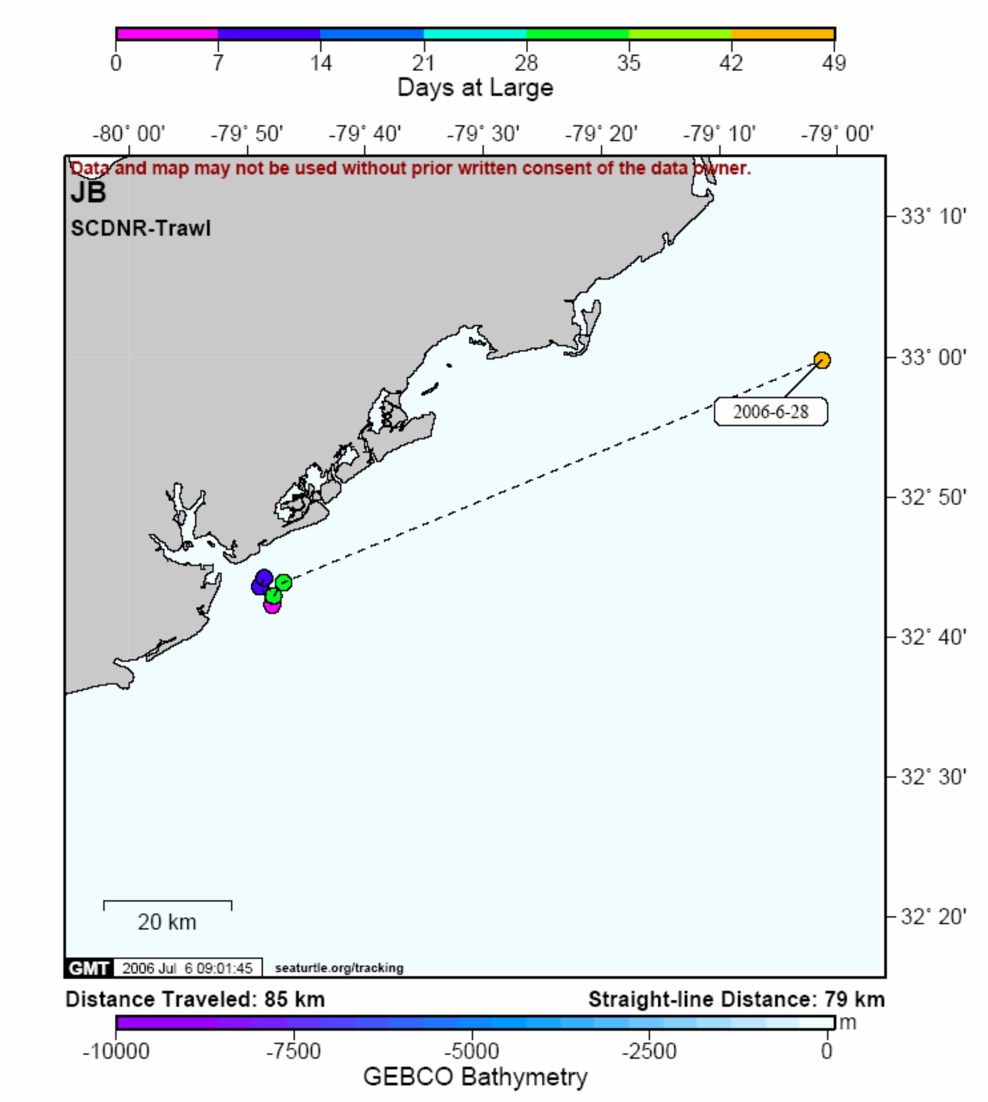

Figure 23. Six-week distribution of juvenile loggerhead ID64554. This loggerhead appeared to remain in the vicinity of the shipping entrance channel for one month, prior to re-locating ~ 40km offshore of Cape Romain, SC.

ID64551 (“Brian”), a 70.2cm SCLmin female loggerhead, was caught at station “D3” in the Charleston, SC, shipping entrance channel during the middle of the day on 18 May 2006. The first “good” location for this turtle occurred 20 days following release (7 June), and placed this turtle outside of the shipping entrance channel and about 10km offshore of the Isle of Palms (Figure 24). The next “good” location occurred eight days later (15 June) and placed this turtle almost 50km due east of the previous “good” location. Fifteen days later (30 June), two “good” locations recorded 39 minutes apart in the vicinity of the shipping entrance channel. Strangely, these were the last two detections for this turtle. One possible explanation for the sudden disappearance of this turtle from detection is transmitter damage due to increased time spent at the surface (two “good” locations 39 minutes apart), where loggerheads are vulnerable to shark attacks (Heithaus et al., 2002) and boat strikes. Biological fouling of the salt-water switch may also be to blame, as total daily detections declined steadily during the last eight days.

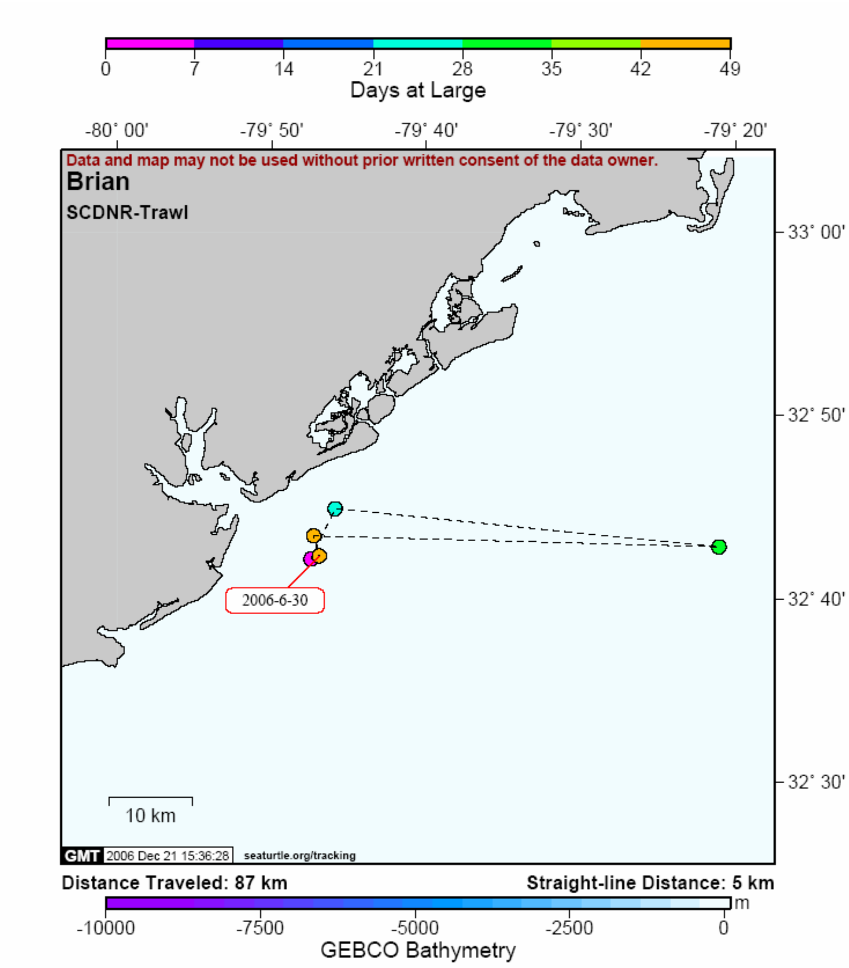

Figure 24. Six-week distribution of juvenile loggerhead ID64551. Only four “good” locations for this turtle were collected in 44 days of monitoring, but suggest that this turtle moved laterally between near-shore and offshore environments adjacent to the Isle of Palms, SC. Immediately prior to permanently losing contact with this turtle, two “good” locations placed it in the vicinity of the shipping entrance channel.

ID64549 ("Bill"), the only male juvenile loggerhead satellite tagged in 2006, was collected at station "D3" in the Charleston, SC, shipping entrance channel during the afternoon of 16 May 2006. This turtle was missing between 2 and 7 cm of its posterior carapace, based straight-line minimum carapace lengths (67.9 to 72.4cm) for nine juvenile loggerheads previously collected with the same straight-line carapace width (58.2cm). The first "good" location occurred four days following release (20 May) and placed this turtle 15km offshore from where released (Figure 25). Between 20 May and 3 June, this turtle traveled in an arc-shaped course to the near-shore waters off of the Isle of Palms. One day after completing this two-week circuit, this turtle made a directed movement to a patchy live-bottom area off of Morris Island, where it was regularly detected (5 "good" locations in 13 days) through 17 June. On 28 June, a "good" location indicated movement 40km to the northeast (Bulls Bay, SC); however, by 4 July, this turtle had resumed a return course for Morris Island. Six "good" locations placed this turtle off of Morris Island between 10-12 July, and other detections suggest it remained in the same general area through at least 15 July. With the exception of the last week before transmission ceased, the range of inter-daily variation was noticeably less after 20 June; however, this shift may represent a behavioral change rather than transmitter fouling.

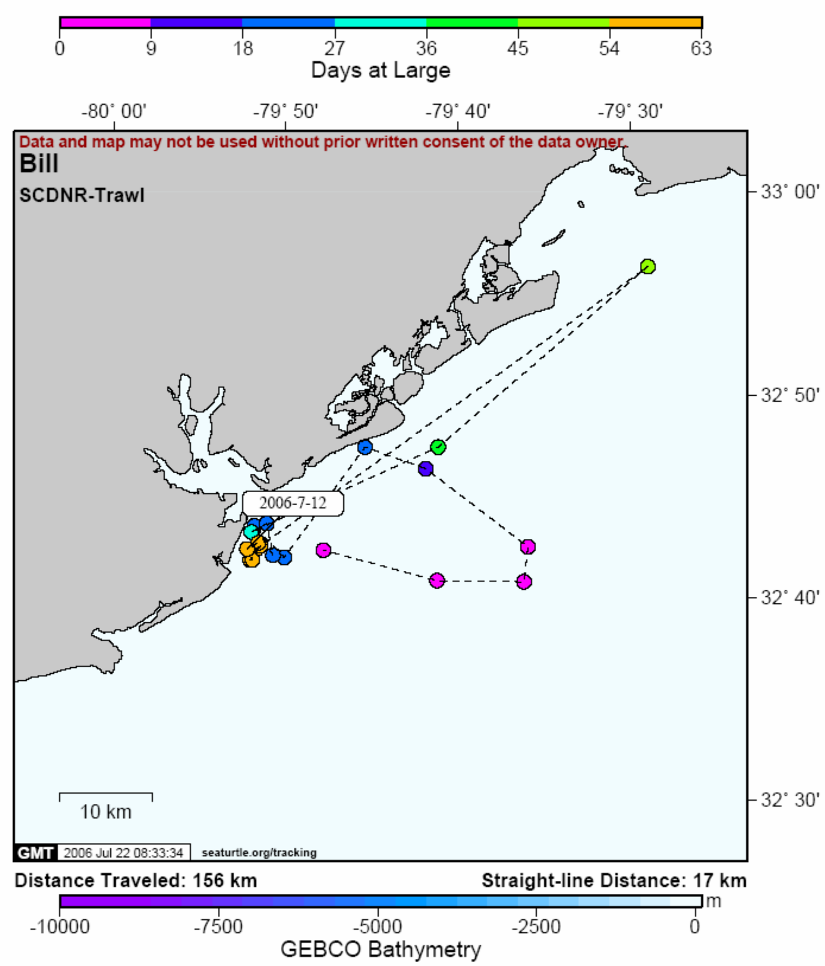

Figure 25. Two-month distribution of a juvenile male loggerhead, ID64549. This turtle alternated between large-scale (>40km) movements and periods of localization.

ID64552 (“Randy”), a 69.3cm (SCLmin) female loggerhead, was collected at station “D1” in the Charleston, SC, shipping entrance channel during the late afternoon of 24 May 2006. Immediately following declination of the head for the purpose of drawing blood samples, this turtle regurgitated approximately one gallon’s worth of partially digested jellyfish pieces, presumed to be the sea nettle, *Chrysaora quinquecirrha*. Two “good” detections occurred 1-3 days following release, and documented directed movement into the Charleston Harbor (Figure 26). Detections with location classes other than those considered “good” suggested that this turtle remained within the Charleston Harbor for over two weeks, exiting in the early morning hours of 11 June. By 15 June this turtle was located on the middle continental shelf, and by 17 June had moved nearly 80km offshore. Ten days later (27 June), this turtle was detected more than 100km due east of Cape Romain, SC, en route for Frying Pan Shoals, NC. Loggerhead 64552 appeared to remain in the general vicinity of Frying Pan Shoals, NC, through the first week in October; however, the last “good” location was recorded on 30 September. Total daily detections were greatest during periods of large-scale movements. Although regularly fluctuating between high and low detection days, with the exception 6-20 August, this pattern of fluctuation remained relatively stable throughout data collection.

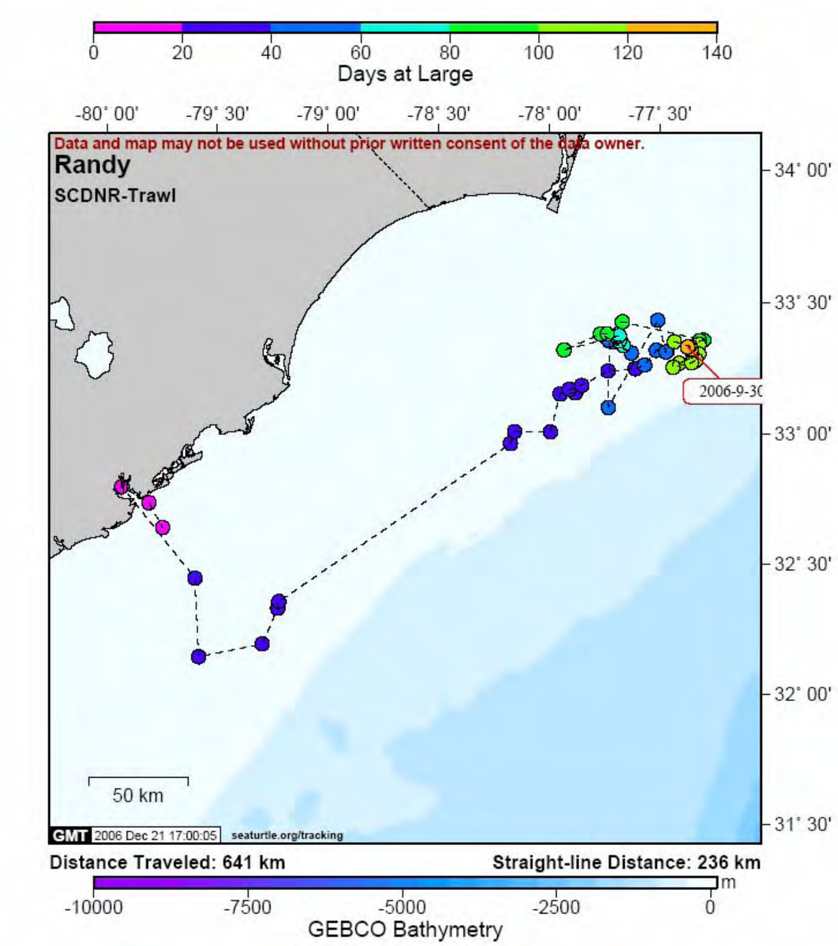

Figure 26. Four-month distribution of juvenile loggerhead, ID64552. Following release, this turtle spent more than two weeks inside the Charleston Harbor before moving offshore and traveling northeast to near the shelf-edge near Frying Pan Shoals, NC.

ID64550 ("David"), a 67.4cm (SCLmin) female loggerhead, was collected at station "D3" in the Charleston, SC, shipping entrance channel in the morning on 25 May 2006; incidentally, this turtle was featured in a local newspaper cover story (Appendix 1). Immediately following release, this turtle traveled near shore to the northeast, where it was detected in the vicinity of either Bulls Bay, SC, or Cape Romain, SC, for several weeks. A directed southerly movement began on 14 June (Figure 27); by 26 June this turtle was offshore of Cumberland Island, GA, and by 8 July, this turtle reached an area offshore of Matanzas Inlet, FL, where it remained through October. By 6 November, this turtle began traveling near shore and to the southeast, reaching Jupiter, FL, by 18 December. For the next two weeks it remained in South Florida waters, but by 2 January, had become entrained in the Gulf Stream. After traveling to the northeast in this current, this turtle returned to the continental shelf, very near shore off of Cape Hatteras, NC, by 18 January. Shortly thereafter, a slow reciprocal track to the southwest was initiated. By early Feb this turtle was off of Frying Pan Shoals, NC, but had returned to northern FL waters by mid-March, where it continues to reside as of 19 June 2007.

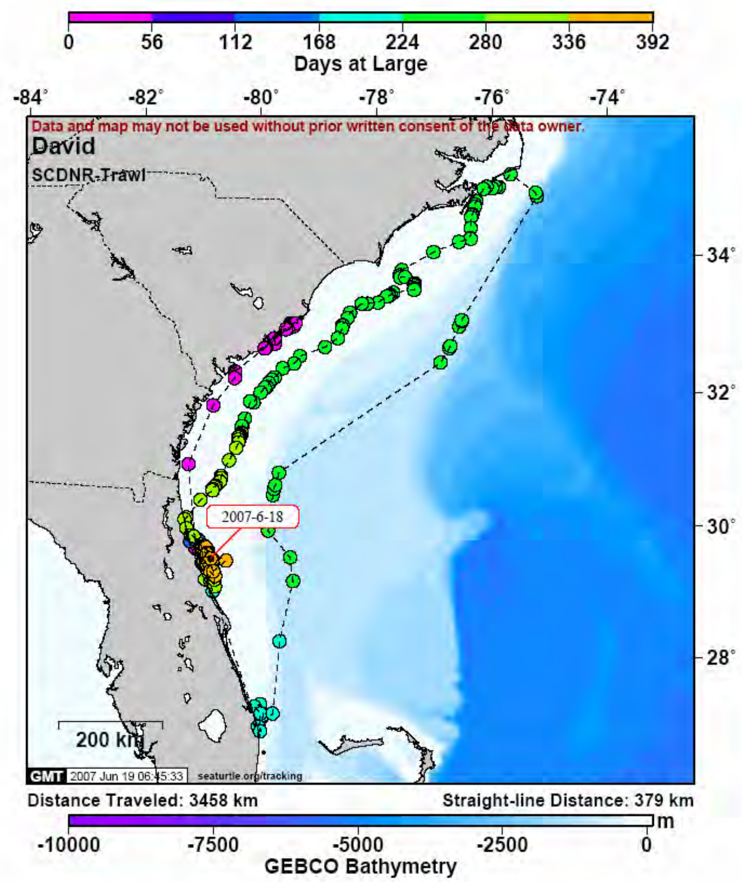

Figure 27. Thirteen-month distribution of juvenile loggerhead, ID64550. Following a brief existence 100km north of the capture site, this turtle traveled more than 700km southwest to Matanzas Inlet, FL, where it remained through October. After traveling further south in the fall, this turtle became entrained in the Gulf Stream and rode this current until reaching the NC coast. Winter was spent on the middle continental shelf returning to northern FL waters, where residence was again established in April 2007.

Discussion

Charleston

Loggerhead catch rates during May continued to be highly variable among and within sampling stations, including highly productive stations such as "D3" and "B3"; thus, illustrating the importance of determining catch-per-unit-effort rates based on rigorous sampling. Exceptionally high catch rates observed in May 2004 continue to be un-surpassed at this location in our sampling efforts, despite a perceived increase in the relative abundance of blue crabs, an important prey item. Similarly, exceptionally warm water temperatures associated with May 2004 sampling have also not been observed at this location during May in two subsequent years. In this context, it would appear that warm water temperature is an important factor for increasing loggerhead catch rates at this location; however, there are likely other factors beyond the scope of this study which also influence catch rates. To better address the effects of time of day and tide stage on loggerhead catch rates at this location, the most highly productive stations will be repeatedly (rather than systematically) sampled during cruises in May and August 2007.

Low recapture rates (*n*=7 of 205; 3.4%) in the current research study are consistent with high catch rates, but also suggest low site-utilization within the confines of the channel. Indeed, low site-utilization is corroborated by satellite telemetry data sets for 24 juvenile loggerheads monitored to date, even those only monitored for up to one month. Following capture and release, satellite-tagged loggerheads are almost never observed to remain within the channel boundaries, although this location may be periodically re-visited during the summer and fall. Despite low utilization patterns during the warmer months of the year, five of six satellite-tagged loggerheads monitored through the winter off the coast of South Carolina have made directed returns to this location during April, suggesting seasonal importance of this location. It is during these spring re-migration events that loggerheads are likely the most vulnerable to fatal interactions with cargo shipping traffic in this channel; of which we saw evidence of in May 2006.

Mean size of loggerheads collected (*n*=203 measured) from the Charleston, SC, shipping entrance channel continued to be slightly (but significantly) skewed towards smaller individuals than collected from surrounding waters aboard the R/V *Lady Lisa* (*n*=223 measured) during the 2000-2003 regional trawl survey (SCDNR, 1). However, mean size of loggerheads collected from this channel during 2004-2006 was significantly greater than mean size of loggerheads collected during the fishery-dependent portion of the 2000-2003 survey, even though a large proportion of fishery-dependent turtles were collected from the Charleston, SC, shipping entrance channel (SCDNR, 1). Given inter-annual affinities of satellite-tagged loggerheads to this location, it is not out of the realm of possibility to surmise that many other (non-tagged) loggerheads also return to this location annually; thus, such growth over time could be expected for those year-classes. However, if the loggerheads utilizing this location are predominantly fidelic individuals, with minimal recruitment (or survival of recruits) from other areas, the management concerns of possible regional-level recruitment failure raised by Maier et al. (2004) warrant further consideration, particularly in light of declining nesting on Florida index beaches (CCC, 2006).

Canaveral

The significance of the Port Canaveral shipping entrance channel to the life cycle of loggerhead sea turtles along the U.S. Eastern Seaboard has been recognized for at least thirty years, quite remarkable considering that this man-made channel has only been in existence since the mid 1950's. The potential of this channel as a regular over-wintering habitat for loggerhead sea turtles received attention after juvenile loggerheads were collected there in the winter of 1978 (Carr et al., 1980). Subsequent trawling studies have documented year-round collection of loggerheads in this channel, with seasonal shifts in the size and sex ratios of loggerheads collected (Henwood, 1987; Dickerson et al., 1995). The almost assuredness of catch has prompted other researchers to target loggerheads at this location to assess a variety of population parameters including health (Lutz and Dunbar-Cooper, 1987; Wibbels et al., 1987; Bolten et al., 1992; Crain et al., 1995) and physiology (Wibbles et al., 1987); relative abundance (Butler et al., 1987; Schmid, 1995); vessel inter-actions (Dickerson et al., 1991; Ehrhart, 1987); and local distribution patterns (Kemmerer et al., 1983; Nelson et al., 1987; Standora et al., 1993a,b).

Although only 13 trawling events were completed in April 2006, a definitive 'hot spot' for both total loggerheads and adult male loggerheads was noted between buoy pairs "3/4" and "5/6". This finding is consistent with year-round trawling efforts conducted by Dickerson et al. (1995), who observed greatest CPUE (in excess of 2.5 turtles per hour) in their station "3", which roughly corresponds to the area between these buoy pairs. Similar to Dickerson et al. (1995), trawling in April 2006 was also conducted in the middle of the channel. High densities of loggerheads near buoys "5" and "6" is also reported by Bolten and Bjorndal (1990).

In contrast to patterns noted for juvenile loggerheads from the Charleston, SC, shipping entrance channel, many "good" locations for adult male loggerheads appeared to be in the confines of the channel where they were collected, particularly through the end of April. Additional "good" satellite locations during these two weeks included the near-shore waters off of Cocoa Beach, and as far south as the southern end of the Archie Carr National Wildlife Refuge. These observations provide more information on habitat utilization patterns for adult males collected from the Canaveral channel than were previously available from a month-long monitoring study of radio-tagged animals within 10km of shore, in which only three adult males were included and data only collected on two of them for up to 2 days (Kemmerer et al., 1983). From the available literature it is uncertain whether or not additional data were collected during a subsequent study involving one of the same authors the following spring (Nelson et al., 1987). Short-term (20-48 h post-release) but intensive acoustic tracking of adult male loggerheads collected in the Port Canaveral channel in spring 1993 documented initial movement away from the channel followed by a return to within a 3.5km radius (Ryder et al., 1994).

Within a two-week period, four adult males documented to migrate away from Canaveral had departed this area, with all four having emigrated by the end of May. Three of these adult males traveled to the Mid-Atlantic, ultimately establishing residence off of the coasts of Delaware and New Jersey after taking nearly a month to reach these destinations, which are known to be important post-nesting foraging grounds for adult female loggerheads satellite-tagged on beaches in the Southeastern U.S. (GADNR, unpublished; SCDNR, 2). The fourth adult male traveled more rapidly to the coastal waters near the SC/GA border, and eventually into Port Royal Sound, SC, where mating loggerhead pairs have been documented in late May/early June (VonHarten, personal communication). Data collection for three of these migratory males ceased during July and August; however, the fourth adult male was monitored until the end of September, at which time it had moved from New Jersey to coastal waters off of Cape Hatteras, NC.

Although complete annual distribution data were not collected for migratory males in the current study, data collected to date document greater north-south migration distances than previously reported for adult male loggerheads elsewhere. Prior to the current study, known north-south movements by adult male loggerheads occurred on scales of less than four degrees of latitude (~450km). Two rehabilitated adult male loggerheads satellite-tagged in the fall near the VA/NC border over-wintered off the coast of southern NC prior to re-emigration to the Chesapeake Bay the following spring (Keinath, 1993). Adult male loggerheads satellite-tagged in Florida Bay have been documented to migrate as far north as central Florida during the mating season; however, most of nearly 20 adult male loggerheads satellite-tagged at that location to date have remained much more localized (Schroeder, personal communication). Off the coast of Japan, two adult male loggerheads (<80cm straight-line carapace length) have also been satellite-tagged following incidental capture in coastal set nets. Although track lengths varied (35 days vs. 115 days), both turtles utilized the Kushimoto Current, which transported them offshore and generally between latitudes 29°N and 33°N (Sakamoto et al., 1997; Hatase et al., 2002). For the longer track, the turtle traveled more than 2,100 km during Jan-May before returning to coastal waters for the mating season (Sakamoto et al., 1997).

Two adult males satellite-tagged in the current study remained resident on the middle to outer continental shelf off of Canaveral, through October, while two additional males remained resident in the general area through at least June. Although the occurrence of adult male loggerheads in the Port Canaveral shipping channel during spring has predominantly been associated with mating activities, previous researchers have suspected, based on tag-recapture (Henwood, 1987) and low serum testosterone levels (Wibbles et al., 1987), that resident males also comprise some portion of the spring aggregation. Extended residence of two adult males in the current study in deeper waters of the continental shelf is similar to residence patterns noted for a large (101cm curved carapace length) but presumably non-reproductively active male loggerhead which received considerable study (including radio and satellite tag attachment) at the Flower Banks National Marine Sanctuary between 1995 and 1999 (STBC, 1999).

Assessment of methods to determine the level of reproductive activity of migratory and resident male loggerheads revealed mixed results. High testosterone levels and laparoscopic examination suggested reproductive activity for three of four migratory males; however, the fourth migratory male (which didn’t migrate as far) had low testosterone levels despite a laparoscopic examination which suggested reproductive activity. Of four resident males, laparoscopy and low testosterone levels suggested non-activity for three individuals; however, a fourth male monitored until early July was observed to have high testosterone levels and laparoscopy suggested reproductive-activity. Incidentally, this individual (CC2452) was recaptured in the Port Canaveral shipping entrance channel on 29 April 2007, during sampling efforts for year two of this study, further supporting the probability of long-term residence at this location.

Given the disparity in testosterone levels among resident and migratory males, as well as differential habitat utilization among these two groups (geographically as well as distance from shore and water depth), it is possible that differential foraging patterns (for example, fasting vs. active foraging or benthic vs. pelagic foraging) may affect testosterone levels. In order to better understand the temporal variability of serum testosterone-levels on short time intervals and potential relationships between foraging and serum testosterone levels, the following modifications will be made to the study design in 2007. First, time series analysis of testosterone levels from the same individual will be collected by collecting a blood sample immediately when the turtle is landed (existing procedure) as well as following laparoscopy and prior to satellite-tagging, which can be as much as 24 hours later for individuals held overnight. Second, sample size of adult males satellite-tagged will be increased from nine to 20 individuals, five of which will be outfitted with depth-sensitive transmitters to confirm that loggerheads are foraging on the bottom regardless of geographic location. Third, tissue biopsy samples will facilitate more complete examination of stable isotope ratios from a greater number of individuals than in 2006.

Acknowledgements
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Appendix 1: ***Post and Courier*** **news article from Friday May 26, 2006.**

In-water loggerhead study shows more juvenile turtles

BY CHRIS DIXON
The Post and Courier

A mission off the coast has given researchers optimism about the future of loggerhead sea turtles. But a day's work studying the animals off Charleston Harbor also offered a graphic illustration of the threats these animals face on a daily basis.

State Department of Natural Resources scientists have been conducting a two-week in-water sea turtle study aboard a converted shrimp boat called the Lady Lisa in a program funded by the National Marine Fisheries Service. On Thursday, the Lady Lisa's haul was a trio of loggerhead sea turtles — two living and one very recently deceased.

According to research team leader Al Segars, the study is showing significantly higher numbers of turtles

A sea turtle named David sits atop a tire before his release into the ocean off Charleston. On his back sits a satellite transponder that will enable researchers to track his movements.

cent to the Charleston shipping channel — an area that was last studied from 1991 to 1992.

That study began shortly after area shrimpers were mandated to begin us-

On the Web

Track the movements of David and other satellite-tagged turtles at www.seaturtle.org.

on their nets to prevent the creatures from drowning if they were unintentionally netted.

"We're seeing a lot more juvenile turtles," Segars said.

DNR biologist Mike Arendt said that during the 1991 study, researchers caught 53 or 54 loggerheads between central Florida and Georgetown. Today, they are catching that many in two weeks.

"When we started the program in 2000, people said, 'You go out looking for turtles in the open ocean and you're not going to catch squat,' " he said. "But we caught over 300."

FROM 1B

Loggerhead study shows more juvenile turtles

TURTLES From Page 1B

According to Segars, an at-sea study has enormous benefits compared with observing females as they heave their massive bodies up on the beach to lay their eggs.

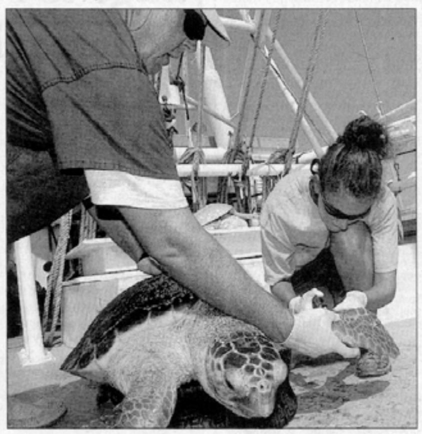
"All the management decisions in the past have been determined by studies of nesting females," he said. "Nobody sees the males. Once they hatch, we don't know what's going on with them because they never return to the beach."

In addition to being able to catch, tag and release males at sea, researchers have been tracking the creatures with remarkably compact satellite transmitters that are fastened to shells with a harmless epoxy. When the animals surface, the transmitter indicates location, length of dives, number of dives and water temperature. One animal tagged last May has been tracked off Dewees Island lately.

Brought on deck with the Lady Lisa's old shrimp rigging, a pair of near 100-pound turtles were measured for length, weighed and had blood samples and barnacles on their backs taken for testing. The barnacles go to a Citadel scientist who can tell what part of the world they came from through genetic tests.

The researchers decided to name one of their turtles David and fitted him with a satellite transponder. After having his skin poked with needles and a spot on his shell scraped clean of barnacles, a hissing David was clearly not amused. But placed atop an old tire that was once caught in the Lady Lisa's nets, he was helpless to escape.

Among the findings from five consecutive years of in-water studies has been the discovery that loggerheads can thrive in a far colder ocean than the mid-60 degree waters they were thought to find uncomfortable. They have been found in offshore waters as cold as the mid-50s.



CHRIS DIXON/STAFF

Department of Natural Resources research team leader Al Segars helps DNR biologist Julia Byrd attach an identification tag to the flipper of a loggerhead turtle they dubbed David.

It was also thought that turtles regularly migrated all over the Atlantic. But satellite data has shown that while some do indeed roam far and wide, many prefer to stay within a few hundred miles of the coast where they hatched. In one case, transponders have shown turtles several hundred miles apart making beelines for Charleston waters as temperatures rise.

Around Charleston, it has also been widely assumed that turtles typically feast on blue and horseshoe crabs, but according to Arendt, a large turtle on Wednesday "threw up about two gallons of jellyfish," when it was propped upside down for a blood sample.

In addition to measuring levels of toxins such as mercury, pesticides and PCBs, blood tests reveal the sex of juvenile turtles. The sex of embryonic turtles is determined by the temperature of the sand in which their eggs are buried. Segars and Arendt said that an inordinate number of females could arise from a warming climate or even beach renourishment, which often places darker, more heat-absorbing sand on the beach.

As the Lady Lisa made her last haul, the crew was initially excited to see a turtle shell in the net. But excitement soon turned to shock when it became evident that the 100-pound, decade-old animal had been sliced completely in half — apparently by the propeller of an enormous container ship that had passed a few minutes earlier. Though the turtle was dead, its rear flippers still moved as its body was lowered onto the deck. Several on board said they had occasionally seen animals that had been cut in two by ships, but they had never seen both halves together, or one so recently killed.

"It actually amazes me that this doesn't happen more often than it does," Segars said. "If we're to point fingers, we have to point them at ourselves since we buy the products that come in on container ships, or hit turtles with our own small boats. When wildlife and humans interact, it's the wildlife that often ends up losing."

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