Southeastern Naturalist

Volume 9 2010 Number 2

Time, Temperature, and Depth Profiles for a Loggerhead Sea Turtle (*Caretta caretta*) Captured With a Pelagic Longline

Mark A. Grace[1,*], John Watson[1], and Dan Foster[1]

Abstract - During a pelagic longline pilot study conducted by the National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center, Mississippi Laboratories along the US Atlantic Ocean coast (NOAA Ship OREGON II OT-06-02-269), a *Caretta caretta* (Loggerhead Sea Turtle) was captured with longline gear equipped with time-temperature-depth recorders attached in proximity to hooks. Time-temperature-depth data documented changes in hook depth and water temperature, and reflected behavior of the Loggerhead Sea Turtle (rates of descent and ascent, time at depth, time near surface). Sea turtle mortality mitigation recommendations for pelagic longline gear proved effective for this Loggerhead Sea Turtle capture since there were successive ascents to surface, and the viability status was good after landing.

Introduction

Use of pelagic longline gear is common for several commercial fisheries operating along the coastal United States (i.e., tuna and swordfish). Pelagic longline gear is passive, and captures are generally hooked by mouth or on occasion tangled by gear, at times resulting in mortality of incidentally captured fish or sea turtles (Lewison et al. 2004, Witzell 1999, Witzell et al. 2001). Assessing how pelagic longline deployment potentially affects sea turtle mortality is important when developing mitigation measures for sea turtles, which are often the focus of conservation efforts (Watson et al. 2005) due to their threatened or protected status (Plotkin 1995). Even though an emergency bottom longline fishery closure by the National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NOAA/NMFS), does not directly pertain to pelagic longline fisheries (Fisheries of the Caribbean, Gulf of Mexico, and South Atlantic; Reef Fish Fishery of the Gulf of Mexico; Gulf Reef Fish Longline Restriction, Federal Register/Vol. 74, No. 83), the emergency closure reflects the importance of longline gear and sea turtle interactions and subsequent regulations.

During a 2006 NOAA/NMFS Southeast Fisheries Science Center Mississippi Laboratories (MSL) pilot study to determine the feasibility

[1]US Department of Commerce/NOAA/NMFS/SEFSC/Mississippi Laboratories, PO Drawer 1207, Pascagoula, MS 39568-1207. [*]Corresponding author - Mark.A.Grace@noaa.gov.

of using pelagic longline gear to assess the relative abundance and distribution of pelagic sharks and finfish (NOAA Ship OREGON II survey OT-06-02-269; Fig. 1), a *Caretta caretta* (L.) (Loggerhead Sea Turtle) was captured, tagged, and released. Since the pelagic longline gear was equipped with time-depth-temperature recorders (TDRs), the Loggerhead Sea Turtle capture provided a unique opportunity to collect and examine associated TDR data that documented the Loggerhead Sea Turtle behavior by recording changes in depth and time sequences for descent, ascent, at-depth, and at-surface events (there is no previous record of a capture with a TDR-equipped pelagic longline).

Materials and Methods

Pelagic longline gear components were 9.3 km (the distance between the first and last radar reflector hyflyer) of 454-kg-test monofilament

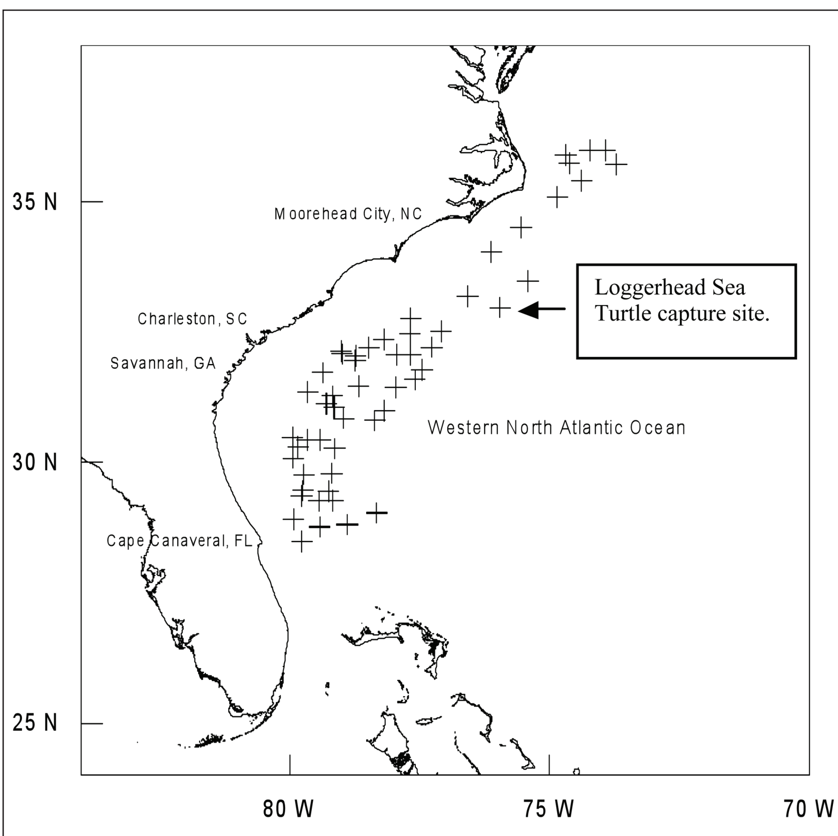

Figure 1. Pelagic longline locations for MSL Pelagic Longline Pilot Study (NOAA Ship OREGON II OT-06-02-269). Location coordinates are degrees latitude north (N), and degrees longitude west (W).

mainline (4 mm diameter), 3 radar reflector hyflyers (strobe light equipped) to mark distal mainline ends and mid-set, bullet floats (50), and 2 gangions attached between bullet floats (100 gangions per set). Gangions (22 m length) were constructed with #18/0 non-offset steel circle hooks with a 0.5 m length of multistrand stainless steel fishing wire (364 kg breaking strength) attached between the hook and a 60-g weighted swivel. The 21.5-m length of gangion monofilament (2 mm diameter, 179 kg test) connected the weighted swivel with the gangion mainline clip. All gangions were equipped with hook timers attached to the gangion mainline clip. Time-temperature-depth recorders (TDRs) were attached to each gangion at the weighted swivel; TDRs logged data at 256 reports per hr, pressure accuracy was ±1% of the depth scale (pressure was used to calculate depth), temperature resolution was 0.2 ºC, and temperature accuracy was ±0.3 °C. Gangions were sequentially numbered with numeric tags attached to hook timers and TDRs; hook timers were used in conjunction with TDRs to provide an independent measure of capture activity. The hook fishing depth beneath the sea surface was a minimum of 40 m, but could be deeper depending on line catenary, activity of hooked catch, or sea conditions. The pelagic longline gear was deployed and retrieved from the NOAA Ship OREGON II (51.8 m length).

Pelagic longline gear configuration followed current NOAA recommendations for mitigating sea turtle captures (NOAA 2001); most importantly, gangion length was at least 110% greater than floatline length so captured turtles could surface to breathe if hooked, and use of a #18 non-offset steel circle hook to minimize hook swallowing. The 18-m floatline length determined mainline depth and was established to allow most deep draft vessels to pass over gear without entanglement. Bait was frozen *Scomber scombrus* L. (Atlantic Mackerel, 400g–600g weight) used whole, cut into halves or thirds depending on bait size; most bait was double hooked.

Pelagic longline soak time was 3 hr, determined from the time the last radar reflector hyflyer was deployed at the end of the gear set, until the first radar reflector hyflyer was retrieved at the beginning of the gear haulback. In order to collect gear set, gear haulback, and catch data in real time, weather-resistant laptop computers were hard wired via deck network ports to the ship's scientific computer system (SCS), and were operated with software designed for the fisheries science computer system (FSCS) to record gear events, catch, and biological data. Utilizing the ship's SCS data allowed Greenwich Mean Time (GMT) time/date stamps and the corresponding position (latitude/longitude) to be associated with set and haulback events (e.g., radar reflector hyflyer, buoy, and gangion deployments and retrieval, and hook status). TDRs were downloaded if their associated gangion had a capture, the hook timer had been activated, or once weekly to clear memory. TDR files were named with vessel code, cruise number, station number, and hook number to facilitate association of TDR information to SCS and FSCS events.

Results

During the pelagic longline pilot study (54 longline sets completed over 42 sea days), a Loggerhead Sea Turtle was captured (Table 1) and brought aboard with a turtle dip net, then measured, photographed, tagged, and released after the hook was removed. Even though the weight of the turtle was 25 kg, it did not pull the gangion with enough force to activate the hook timer (4 kg–6 kg force needed). The Loggerhead Sea Turtle was the only capture for the associated longline set (no elasmobranchs or teleosts captured), and its viability status at release was good (as determined by active responses to handling and alert behavior). TDR recorded seawater temperatures that ranged from 22.1–23.3 °C (mean = 22.9 °C , SD = 0.1143). The Loggerhead Sea Turtle was on hook (mouth hooked) for 223 min (including 21 min to haul to the ship) as determined by a pronounced depth change at hooking reflected by the TDR data (Fig. 2); the total time of the hook deployment was 263 min (determined by the ship's SCS/FSCS data collection system). At approximately 25 min after hook deployment, there were a series of small depth spikes below the stabilized hook fishing depth (41 m), and that may have been the first gear encounter by the Loggerhead Sea Turtle (Fig. 2). After 40 min, the TDR depth change was pronounced and the Loggerhead Sea Turtle ascended to sea surface (time of ascent was 2106 GMT or local time 1506 Eastern Standard Time). Seventy-two percent of the hooked time was spent within 10 m of sea surface, and 28% of the hooked time was spent below 10.0 m depth. Using TDR depth data to determine surfacing events (depth less than the 0.5 m length of the steel leader between the hook and TDR), it appears the Loggerhead Sea Turtle surfaced at least 22 times while on hook; some TDR depth reports from <0.5 m could be from the TDR aligned along the top of the carapace (sometimes creating a negative value) or from lift created by forward swimming at sea surface. The most TDR reports from <0.5 m (10) followed the first ascent after hooking (Fig. 2).

Table 1. Biological and associated data for a loggerhead sea turtle captured during the 2006 MSL Pelagic Longline Pilot Study (NOAA Ship OREGON II OT-06-02-269).

Latitude/longitude	GMT date	Hook depth	Bottom depth	Surface temperature	Temperature at hook depth
32 58.21ºN/75 57.16ºW	14/02/2006	41 m	2379 m	22.20 °C	22.72 °C

Carapace length	Carapace width	Weight (kg)	Flipper tags	Pit tag
660.0 mm	660.0 mm	25.0 kg	RRM157 (right rear) RRM158 (left rear)	43305E6506

For the purposes of defining descent/ascent events, a descent/ascent event was designated when the descent from sea surface exceeded 10.0 m; according to Boyle's Law (Joiner 2001), air volume is compressed by 50% or two atmospheres absolute (2 ata) at 10.1 m depth. Including the initial ascent to surface after hooking, there were 8 descent/ascent events (Table 2). Descents to maximum dive depths were direct and without stops at intermediate depths, and final ascents to sea surface had few or no stops at intermediate depths. Behavior (as interpreted by depth changes) between descents and ascents were characterized by periods of uniform depth and by depth changes spanning a range of several meters (Fig. 3). Except for the fourth descent/ascent event that reached a maximum depth of 10.4 m, the descent rate exceeded the ascent rate and was often more than doubled (descent/ascent events 2, 3, 6 and 7; Table 2). Time between descent/ascent events (time at surface) ranged from 8 min 9 sec (between descent/ascent number 1 and 2) to 37 min 30 sec (between descent/ascent number 3 and 4). Descent/ascent event 7 was the deepest descent event at 38.4 m and the longest duration descent/ascent event at 11 min. 41 sec.

Loggerhead Sea Turtles achieve neutral buoyancy with lung air and can remain at a constant depth without swimming (Minamikawa et. al. 1997, 2000), therefore, sequential TDR report groups from uniform depths may be an indication of neutral buoyancy below 14 m depth (30 TDR report groups; Fig. 3) since lung volume positively affects buoyancy within a 14-m range of sea surface (Minamikawa et. al. 1997, 2000). During ascents from maximum dive depths, 63% of sequential TDR report groups were from depths >20 m (3 ata), and 87% were from depths >14 m. The deepest and the longest duration ascent event (ascent event 7; Fig. 3) also had the most sequential

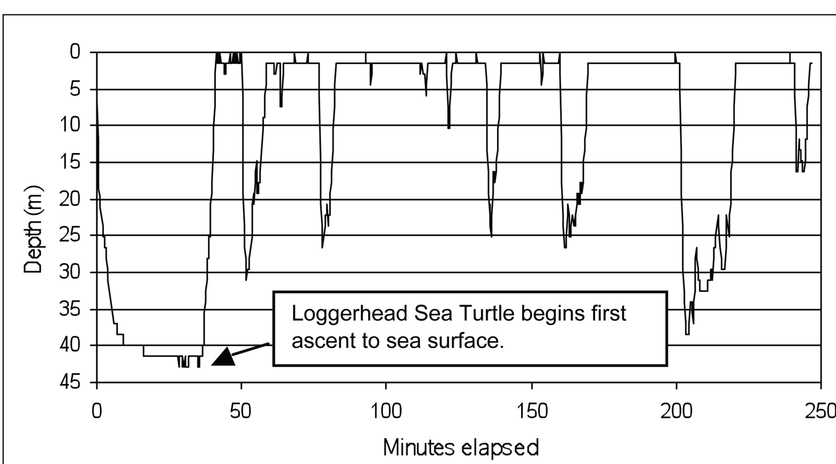

Figure 2. TDR depth and minutes elapsed for a Loggerhead Sea Turtle capture from MSL Pelagic Longline Pilot Study (NOAA Ship OREGON II OT-06-02-269). Minutes elapsed does not include the final 21 min haul to the vessel.

TDR report groups at a uniform depth (11 report groups ranged from depths >23 m); free-swimming Loggerhead Sea Turtles reportedly show a positive correlation between residence depth and dive duration (Minamikawa et. al. 1997, 2000). Descent/ascent 7 also had the maximum time at a fixed depth or at a uniform swimming depth at 32.5 m for 2 min 11 sec. Sea water

Table 2. TDR descent/ascent events for a Loggerhead Sea Turtle capture from MSL Pelagic Longline Pilot Study (NOAA Ship OREGON II OT-06-02-269). Events are descent/ascent (D = descent >10 m below surface, A = ascent to surface), and time between descents (TBD = minutes at surface between descent/ascent events). Event 1A is the initial ascent after hooking at 41.0 m depth.

Event	Elapsed time (min.sec)	Max.depth (m)	Descent or ascent rate (m/sec)	Max. depth temp. (°C)	TBD (min.sec)
1A	4.55	41.0	0.139	23.08	8.90
2D	1.30	31.0	0.344	22.90	
2A	6.48		0.075		18.20
3D	1.52	26.6	0.223	22.72	
3A	3.59		0.105		37.30
4D	1.39	10.4	0.105	22.90	
4A	1.10		0.149		12.00
5D	1.59	25.1	0.210	22.90	
5A	3.16		0.128		20.00
6D	2.06	26.6	0.211	22.72	
6A	9.05		0.049		32.00
7D	2.01	38.4	0.317	22.72	
7A	9.40		0.055		20.00
8D	1.25	16.3	0.188	22.90	
8A	2.21		0.113		

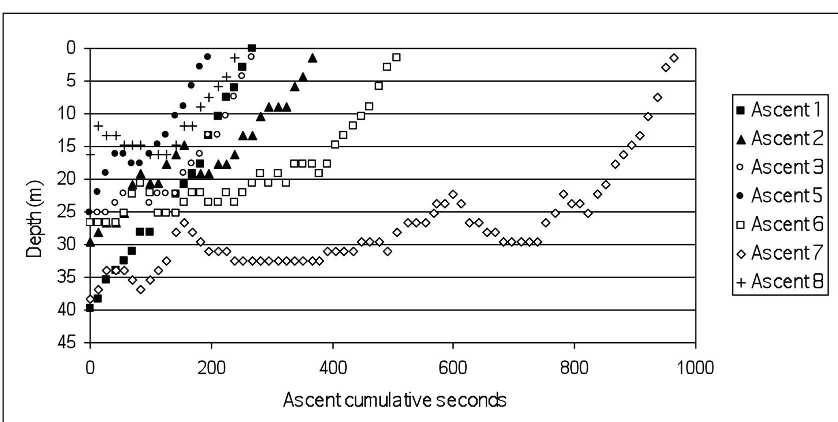

Figure 3. Ascent events for a Loggerhead Sea Turtle captured during the 2006 MSL Pelagic Longline Pilot Study (NOAA Ship OREGON II OT-06-02-26).

temperature potentially affects the neutral buoyancy depth for Loggerhead Sea Turtles since ambient temperature affects air volume (Charles's Law; Joiner 2001); however, since the sea surface to maximum dive depth water temperatures only varied by 1.27 °C (22.08–23.35 °C), the effects of water temperature over the relatively short duration descent/ascent events was probably minimal.

Anecdotal observations by NOAA divers testing turtle excluder devices (D. Foster NOAA/NMFS Mississippi Laboratories, Pascagoula, MS, pers. observ.), suggest that Loggerhead Sea Turtles released well below sea surface often complete a direct and relatively uniform final ascent to sea surface with minimum physical effort. Minamikawa et. al. (2000) reported a final ascent phase with a final ascent rate greater than the gradual ascent that begins after the maximum dive depth. Final ascent behavior was reflected in the TDR data for 7 of the 8 ascent events (descent/ascent events 1, 2, 3, 5, 6, 7, and 8; Fig. 3); due to the 14-sec report period and shallow maximum depth coupled with a relatively immediate ascent from maximum dive depth, descent/ascent event 4 did not have enough data points to be useful in a final ascent comparison. The inflection point marking the start of the final ascent was designated when there was a consistent depth decrease terminating at sea surface (none of the sequential final ascent TDR report periods had a depth increase between reports though a few had equal depths). The inflection point for final ascents was between 25 m–16 m from sea surface (Fig. 3), and R^2 values for the trend line ranged from 0.97–0.99 (y ranged from $-0.0994x + 39.259$ to $-0.1636x + 162.45$), as opposed to a R^2 range of 0.27–0.79 (y ranged from $0.0212x + 13.433$ to $-0.0215x + 26.462$) for the portion of ascents in depths >25.0 m (initial ascent, excluding descent/ascent 1 that occurred just after hooking; Table 3). During final ascents, the increase in R^2 indicates a more uniform and less variable ascent rate, and the increase in y indicates a steeper ascent depth gradient.

Table 3. Ascent trend line R^2 and slope (y) values for a Loggerhead Sea Turtle captured during the 2006 MSL Pelagic Longline Pilot Study (NOAA Ship OREGON II OT-06-02-269); D/A = descent/ascent event.

D/A	Initial ascent R^2	Initial ascent y	Final ascent R^2	Final ascent y
1	0.9858	$-0.1269x + 39.660$	0.9892	$-0.1806x + 48.755$
2	0.7933	$-0.0700x + 28.186$	0.9725	$-0.0994x + 39.259$
3	0.5940	$-0.0324x + 25.427$	0.9808	$-0.1555x + 44.295$
5	0.7539	$-0.1174x + 23.563$	0.9870	$-0.1510x + 31.331$
6	0.7265	$-0.0215x + 26.462$	0.9910	$-0.1363x + 70.845$
7	0.5865	$-0.0119x + 34.884$	0.9828	$-0.1636x + 162.45$
8	0.2648	$0.0212x + 13.443$	0.9867	$-0.1258x + 16.371$

Discussion

Considering a minimum of 25 min to a maximum of 40 min transpired before the Loggerhead Sea Turtle took the baited hook at the fishing depth (41 m), it is possible that the Loggerhead Sea Turtle did not follow the baited hook from sea surface during set operations, but may have encountered the pelagic longline gear while swimming or at neutral buoyancy depth. Since the hook timer did not activate, it can be inferred that the Loggerhead Sea Turtle did not struggle against the pelagic longline gear with enough force to initialize the hook timer (the vessel slowed once the sea turtle was sighted at surface). If the Loggerhead Sea Turtle was pulled toward the vessel during the gear haul, the hydrodynamics of the plastron and carapace did not provide enough resistance to activate the hook timer (wave height was estimated at 1 m).

The effects of being hooked by longline on the behavior of the Loggerhead Sea Turtle were difficult to determine since capture with a TDR-equipped gangion was a rare event and TDR-derived data were confined by the 14-sec report periods. If the longline-captured Loggerhead Sea Turtle experienced a forced diving situation due to altered behavior from being mouth hooked, there are a number of associated physiological effects that can include rapid consumption of oxygen stores, anaerobic glycolysis activation, and heart rate decline (Lutcavage and Lutz 1997). However, for relatively unstressed free-swimming Loggerhead Sea Turtles not hooked on longlines, physiological stress from submersion is minimized (due to a number of unique physiological responses and adaptations; Lutcavage and Lutz 1997), maximum submergence times range from 60–240 min for pelagic stage juveniles (339–576 mm straight carapace length; Dellinger and Freitas 2000), and mean submergence times for Loggerhead Sea Turtles 400–600 mm straight carapace length range from 17–76 min (Nelson 1996); the maximum submergence time for the MSL Loggerhead Sea Turtle capture was 11 min. 41 sec (descent/ascent event 7, Tab. 2). Dellinger and Freitas (2000) also reported a primary peak in submergence times just below sea surface and a secondary peak at 10 m–25 m depth; except for the relatively short descent/ascent events 4 and 8 (Tab. 2), most of the time on hook for the MSL Loggerhead Sea Turtle capture was just below sea surface (Fig. 2), and the secondary submergence time peak was in depths >15 m (Fig. 2). TDR data (Houghton et. al. 2001) from free-swimming Loggerhead Sea Turtles during internesting intervals (TDRs attached to the carapace then retrieved during nesting) documented descent rates were generally greater than ascent rates. Satellite-transmitted data from Loggerhead Sea Turtles also recorded descent rates greater than ascent rates (Nelson 1996). Houghton et. al. (2001) and Minamikawa et. al. (1997, 2000) described several types of dive profiles that were similar to those observed from the MSL capture.

Thus, it appears that NOAA/NMFS sea turtle mortality mitigation recommendations were effective for the Loggerhead Sea Turtle capture since TDR data documented successive ascents/descents to and from surface, and viability status was good after landing.

Acknowledgments

Chuck Schroeder, a contract employee with IAP/NMFS MSL, was the primary software designer responsible for the SCS/FSCS (SELLIT) program for documenting longline events. Survey planning and participation by MSL Shark Unit members William Driggers and Lisa Jones was critical to the project's success. Patrick Rice of the University of Miami provided guidance for TDR operations and for interpreting and displaying TDR-derived data. Sheryan Epperly of NMFS, Miami provided advice for literature searches, and LaGena Fontroy (MSL) assisted with literature searches. Survey logistics and catch-handling assistance of crew and command of the NOAA Ship RV OREGON II was greatly appreciated.

Literature Cited

Dellinger, T., and C. Freitas. 2000. Movements and diving behavior of pelagic stage Loggerhead Sea Turtles in the North Atlantic: Preliminary results obtained through satellite telemetry. Pp. 155–157, *In* H.J. Kalb and T. Wibbels (Eds.). Proceedings of the 19th Annual Symposium on Sea Turtle Biology and Conservation. US Department of Commerce, NOAA Technical Memo NMFS-SEFSC-443. Available online at http://www.nmfs.noaa.gov/pr/pdfs/species/turtles symposium 1999.pdf. Accessed April 2010.

Houghton, J.D.R., A.C. Broderick, B.J. Godley, J.D. Metcalfe, and G.C. Hays. 2001. Diving behavior during the internesting interval for Loggerhead Sea Turtles *Caretta caretta* nesting in Cyprus. Marine Ecology Progress Series 277:63–70.

Joiner, J.T. (Ed.). 2001. NOAA Diving Manual. Fourth Edition. 2:11. Best Publishing Company, Flagstaff, AZ.

Lewison, R.L., S.A. Freeman, and L.B. Crowder. 2004. Quantifying the effects of fisheries on threatened species: The impact of pelagic longlines on Loggerhead and Leatherback Sea Turtles. Ecology Letters 7:221–231.

Lutcavage, M.E., and P.L. Lutz. 1997. Diving physiology. Pp. 277–296, *In* P.L. Lutz and J.A. Musick (Eds.). The Biology of Sea Turtles. CRC Press, Boca Raton, FL.

Minamikawa, S., Y. Naito, and I. Uchida. 1997. Buoyancy control in diving behavior of the Loggerhead Turtle, *Caretta caretta*. Journal of Ethology 15:109–118.

Minamikawa, S., Y. Naito, K. Sato, Y. Matsuzawa, T. Bando, and W. Sakamoto. 2000. Maintenance of neutral buoyancy by depth selection in the Loggerhead Turtle *Caretta caretta*. Journal of Experimental Biology 203:2967–2975.

Nelson, D.A. 1996. Subadult Loggerhead Sea Turtle (*Caretta caretta*) behavior in St. Marys entrance channel, Georgia, USA. Ph.D. Dissertation. School of Marine Science, College of William and Mary, Williamsburg, VA. 132 pp.

National Oceanographic and Atmospheric Administration (NOAA). 2001. Endangered Species Act Section 7 Consultation. Biological Opinion. National Marine Fisheries Service, Silver Spring, MD. P. 113:8.2.2.2

Plotkin, P.T. (Editor). 1995. National Marine Fisheries Service and US Fish and Wildlife Service Status Reviews for Sea Turtles Listed under the Endangered Species Act of 1973. NMFS, Silver Spring, MD.

Watson, J.W., S.P. Epperly, A.K. Shah, and D.G. Foster. 2005. Fishing methods to reduce sea turtle mortality associated with pelagic longline. Canadian Journal of Fisheries Aquatic Science 62:965–981.

Witzell, W.N. 1999. Distribution and relative abundance of sea turtles caught incidentally by US longline fleet in the western North Atlantic Ocean, 1992–1995. Fisheries Bulletin 97:200–211.

Witzell, W.N., S.P. Epperly, and L.A. Csuzdi. 2001. Description of the Atlantic Ocean and Mediterranean Sea pelagic longline fisheries. NOAA Technical Memorandum NMFS-SEFSC-455:108–119. Available online at http://www.sefsc.noaa.gov/PDFdocs/species/TM 455 NMFS.pdf. Accessed April 2010.