

PREDATION RISK TO LOGGERHEAD HATCHLINGS AT A HIGH-DENSITY NESTING BEACH IN SOUTHEAST FLORIDA

Kelly R. Stewart and Jeanette Wyneken

ABSTRACT

It has been suggested that mortality is high for early life history stages of long-lived vertebrates such as sea turtles. However, few studies have quantified mortality rates for these stages. We assessed the risk to loggerhead sea turtle hatchlings at the commencement of their offshore migration from a natural high-density nesting beach (Juno Beach, Florida), and at high-density (managed) open-beach hatchery sites. We followed individual hatchlings by kayak, at night as they left the beach, to document the proportion of turtles that survived their initial 15 min in the water. Of the 217 hatchlings followed, 206 survived for an observed survival rate of 95%. Tarpon were the most common predator observed. This in-water survival rate is much higher than that previously observed in the waters adjacent to a Florida hatchery (72%) and may be due to reduced risk associated with temporal and spatial variation in nest location at the natural beach, but not at the hatchery.

Sea turtles are iteroparous and produce numerous, small offspring in several clutches (Miller, 1997). These characteristics indicate that, over time, evolutionary pressures have selected for a life history strategy in which investment in individual offspring is minimal and survival of young is low (Frazer, 1992). Many authors agree that mortality in early life stages is probably extremely high in turtles (Richardson and Richardson, 1982; Stanczyk, 1982; Frazer, 1986; Heppell et al., 1996). Egg loss and nest predation by mammalian, avian, and crustacean predators are well documented (Witzell and Banner, 1980; Stanczyk, 1982; Gyuris, 1994a). Because sea turtles have high fecundity, some laying 200–600 eggs per nesting season (Hirth, 1980; Van Buskirk and Crowder, 1994; Miller, 1997), perhaps one in 10,000 hatchlings will survive to maturity (Frazer, 1986). Important information can be obtained from the nesting beach regarding the reproductive cycles, fecundity, and variables that determine nest success of sea turtles, however, disproportionately little is known about mortality after hatchlings have entered the water.

Life for hatchling sea turtles is inherently risky. Besides their small body size (around 4 cm carapace length), hatchlings have few defenses against predators. During their offshore migration, they may dive to avoid aerial predators (Frick, 1976; Witherington and Salmon, 1992) or tuck in their flippers and float motionless to avoid detection (Witherington, 2002). Threats to survival include predation at the nest, during the crawl from the nest to the ocean, during the swim through nearshore waters, and during growth on pelagic nursery grounds. Predation risk decreases with size. Other sources of mortality for young turtles include incidental capture in fishing gear, entanglement in marine debris, and ingestion of foreign materials such as tar and plastics (Lutcavage et al., 1997).

Baseline population sizes (e.g., for hatchlings, juveniles, adults), recruitment levels, and mortality/survival rates for loggerhead turtles [*Caretta caretta* (Linnaeus, 1758)] in the U.S. are estimated from limited empirical data (Frazer, 1986; Crouse et al., 1987; National Marine Fisheries Service, 2001; Heppell et al., 2003). Few studies have quantified or partitioned mortality at various life stages. The pelagic stage of loggerheads may last for 6.5–11.5 yrs (Bjorndal et al., 2000), and begins when hatchlings enter the water after having traversed the beach from the nest. To date, no demographic baselines based on empirical data have been established for this early stage. Quantification of mortality

for different life stages is important to our understanding of basic life history characteristics of loggerhead sea turtles, and is critical to managers charged with formulating and implementing recovery plans. Empirical data become the baseline against which to measure future trends.

Many authors speculate that the first few hours or days in the sea are particularly dangerous times for hatchling sea turtles (Carr and Ogren, 1960, Ireland et al., 1978; Frazer, 1986; Salmon and Wyneken, 1987, Wyneken and Salmon, 1992) due to high predator abundance in nearshore waters (Gyuris, 1994a; Wyneken, 2000). Booth and Peters (1972) documented that green turtle [*Chelonia mydas* (Linnaeus, 1758)] hatchlings in Australian waters were taken by crabs, black-tipped sharks, and other species of fish. Gyuris (1994b) suggested that most of the first-year mortality of green turtles at the Great Barrier Reef could be attributed to aquatic predation within the first hour after entering the ocean. Using a variety of techniques, she followed 1740 hatchling green turtles offshore over three seasons finding that predation rates in the water ranged between 0–85%, with a mean predation rate of 31% (69% survival rate). Caldwell (1959), Witham (1974), Fletemeyer (1978), and Vose and Shank (2003) documented predation on loggerhead, green turtle, and leatherback [*Dermochelys coriacea* (Vandelli, 1761)] hatchlings in Florida waters. Aquatic predators took 6.8% (5 of 74) of loggerhead hatchlings during daytime and nighttime swimming trials in turbid waters off the east-central coast of Florida (Witherington and Salmon, 1992). Glenn (1996) reported an 89% survival rate for migrating loggerhead hatchlings (11/100 taken by predators) in clear nearshore waters off southeastern Florida (Palm Beach). Wyneken and Salmon (1997) occasionally found high levels of predation (0–100%) on loggerhead hatchlings in the waters off open-beach hatcheries in southeastern Florida (Hillsboro Beach). That study dealt specifically with the risks associated with artificially high hatchling densities due to hatchery management of nests.

In Florida, coastal development and artificial lighting has degraded nesting habitats in many areas, and may be responsible for the present spatial concentration of turtle nesting beaches (Salmon et al., 2000). As a result, some loggerhead rookeries have very high nest densities (400–600 nests km⁻¹) along the east coast of Florida (Witherington and Meylan, 2001). Spatial concentration of nests elevates risks for nests as well as hatchlings leaving these beaches. At hatcheries, high hatchling densities attract aquatic predators (Wyneken et al., 2000). Predation rates at hatcheries (average mortality was approximately 40%) are an order of magnitude higher than at adjacent low-density sites (4% mortality; Wyneken, 2000).

Here we quantify, at a high-density natural nesting beach, predation rates upon hatchling loggerhead sea turtles during their first few minutes in the water, and compare those to studies done at other sites. We addressed the following four questions. (1) How many hatchlings entering the water survive the initial phase of offshore migration? (2) Do predation rates vary seasonally (July–September)? (3) Do survival rates vary when shallow reef structure is present? (4) How do survival rates compare between high-density natural and hatchery sites in Florida? We observed individual turtles to obtain predation rates, and then calculated an estimate of survival based on productivity measures.

MATERIALS AND METHODS

STUDY SITES AND NEST LOCATIONS.—The study sites were located within Juno Beach and southern Jupiter Island (Palm Beach County, Florida, U.S.; 26°90 N, 80°05 W; Fig. 1) where turtles nest

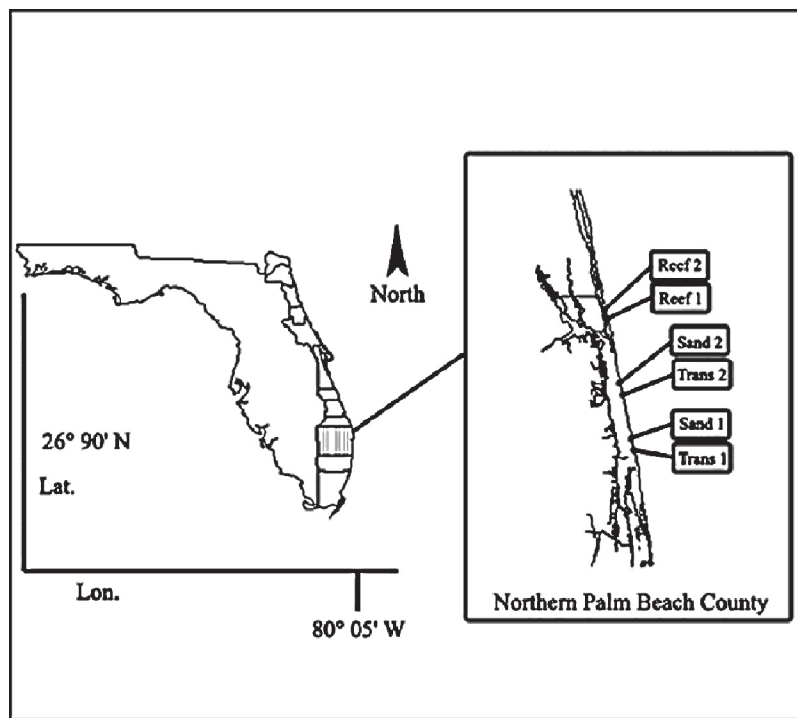


Figure 1. Location of the study sites in Palm Beach County, Florida, U.S. Six sampling sites are indicated by labels at right of the shoreline map of Palm Beach County. Three site-types were qualitatively identified; sand, reef, and transitional categories were based on bottom substrate.

in large numbers ($400\text{--}600$ nests km^{-1} yr^{-1}). Hatchlings at these sites emerge from natural nests and swim offshore over sand, rock reef, or transitional bottom substrates toward deep water.

We conducted the initial qualitative assessment of 15 km of nearshore and offshore waters using a fixed-wing aircraft to categorize bottom habitat. Substrate categories along the shore were: (1) sand – no rock or hard-bottom, (2) transitional – sand with limited rocky outcroppings, rock not extensive, and (3) reef – rock dominated, sand rarely visible. We then assessed fish abundance and species compositions by snorkeling (Dolloff et al., 1996) both by day and night for each of the three site types. We systematically surveyed each of the site types for 30 min, from shore out to a depth of 6 m at 6 m intervals parallel and perpendicular to shore. Once the initial assessment of the area was completed, six sites (two of each bottom type) were chosen (Fig. 1), and random sampling (assessing predation risk by direct observation and predation capture) of these sites was conducted over the course of the season.

During the nesting season (May–July) on morning surveys, 43 natural loggerhead (*C. caretta*) nests at Juno Beach were randomly selected and marked with stakes. We monitored nests daily to document any perturbations (over-wash or predation) and to determine when turtles were ready to emerge from nests. Turtles used in experiments were collected from these marked nests on the night they were due to emerge. They were collected in the afternoon, placed in a lightproof Styrofoam® cooler, and held at ambient temperatures ($24\text{--}28^{\circ}\text{C}$) until their release that night. At the conclusion of the season, hatchling production for the site was determined using excavation data from 626 marked nests.

SURVIVORSHIP, MORTALITY, AND PREDATOR IDENTIFICATION.—Several techniques were used to document hatchling survival and mortality rates and to identify predators in the water at the sites. These included: (1) following hatchlings offshore to quantify mortality, (2) capture of predatory fish during the season, and (3) visual identification of predators, (when possible) as hatchlings were taken.

ASSESSING MORTALITY RATES AND RISK.—Individual turtles were followed by kayak for 15 min, according to a randomly scheduled order of the six sites between July 5 and September 27, 2000. We used the 15 min sampling time because previous studies (Glenn, 1996; Wyneken and Salmon, 1997) showed that hatchlings were able to cross the first reef and get into relatively deep water (> 6 m) within that time. Hatchlings were followed as they swam over reef (n = 74), transitional (sand with rock outcroppings; n = 74), and sand (n = 69) sites. We followed 5–14 hatchlings per site per night depending on weather conditions.

Hatchlings were followed individually as they migrated offshore. Each hatchling pulled a streamlined balsa wood float (Witherington and Salmon, 1992) attached to its body by 150 cm of smooth, lightweight cotton thread. The float was painted flat black and had a cavity in its top surface which contained a green, cold-chemical glow stick (2.4 cm in length); the glow was visible only above the water. The float did not attract fish predators when towed offshore on a 10 m cotton thread without a hatchling (n = 31) and the float was never attacked when hatchlings were taken. Towing the float did not keep hatchlings closer to the surface than they normally swim. The weight of the float was negligible (1.9 g in air); however, it did slow the hatchlings by ~20% (Witherington and Salmon, 1992). Swim speeds were still within normal published values of 18.3–22.9 m min⁻¹ (Salmon and Wyneken, 1987).

Each hatchling, once fitted, was allowed to crawl down the beach, enter the water, and begin swimming. Each was followed at a distance of 5–20 m to minimize drawing the attention of predators to the kayak or float. At the end of observations (15 min), the hatchling was recaptured and released. When a hatchling was taken by a predator, we recorded the time it had been swimming, water depth (in m), bottom topography at the predation site, and its final position and heading (using a hand-held GPS - Garmin® Models 12 and 38). On some occasions, we could identify the predator species (e.g., if it jumped out of the water during hatchling capture, or if the hatchling was taken close to the kayak so we could see the predator clearly). In these cases, we usually recovered the float and tether, with the line cut and the hatchling gone.

CAPTURE (HOOK AND LINE) METHODS FOR IDENTIFYING PREDATORS.—At each of the sites, we spent six nights angling for predators. Angling was done over a 5-mo. period (June through October). Two fishing lines were used each night. Angling (surfcasting) began at 2000 ± 1 hr and continued for 3 hrs. Baits used were frozen/thawed or live scaled sardines, (*Harengula jaguana* Poey, 1865), squid (*Loligo* spp.), cut fish (*Mugil cephalus* Linnaeus, 1758), penaid shrimp, and mole crabs, *Emerita talpoida* (Say, 1817). When a fish was caught, the time of capture was recorded. The line was quickly returned to the water and fishing resumed.

The length of time each line was in the water (~3 hrs) was converted into a measure of fishing effort. Predatory fish were defined as those having mouth morphologies (teeth and/or a gape) sufficient to take a hatchling, or species known to consume hatchlings (Stancyk, 1982; Wyneken, 2000). Non-predatory fish were immediately released into the water; predatory fish were anesthetized by immersion in ice water, and killed by decapitation. Later that evening, their stomach contents were examined and recorded.

STATISTICAL ANALYSIS.—We used power analysis and sample size estimates to determine that 96 turtles followed offshore were needed to accurately assess survival at the six sites (Box et al., 1978). Chi-square tests (Steel and Torrie, 1980) were used to compare predation rates by site and by season. We also compared predation rates at a hatchery (based upon Wyneken et al., 2000) with those at natural beach (this study) sites. Rayleigh tests (Zar, 1986) were used to determine if swimming hatchlings at each site were normally oriented.

RESULTS

PREDATION RATES AND PREDATORS.—We followed 217 loggerhead hatchlings as they migrated from nearshore waters to deeper waters (average 4.5 m) offshore. Hatchlings swam on an average heading of 77.8° (ENE; range 72–84°, P < 0.001) offshore. When close to the hatchlings, we did not observe any behavior (tuck, dive, etc.) that suggested

Table 1. Predation events for 11 hatchlings, listed by site type, date, predator (if known), final heading, and water depth.

Number of turtles	Site type	Date	Predator	Heading	Water depth (m)	Dist. from kayak (m)
1	Sand	7/11	Tarpon	73°	7	6
1	Sand	7/13	Tarpon	60°	4	10
1	Sand	7/13	Shark	73°	4	5
1	Reef	8/1	Tarpon	105°	5	7
1	Reef	8/11	Unknown	85°	2.5	5
1	Reef	8/31	Unknown	84°	6	10
1	Transitional	9/15	Tarpon	76°	4	15
1	Transitional	9/15	Unknown	80°	4	12
1	Reef	9/23	Unknown	70°	5	5
1	Reef	9/23	Unknown	88°	5	7
1	Reef	9/23	Unknown	61°	5	25

that the hatchlings detected predators before capture (Witherington and Salmon, 1992; Wyneken and Salmon, 1997). Swimming slowed only when the hatchlings surfaced to breathe.

Aquatic predators took 11 hatchlings during trials. Predatory attacks came without warning, and when taken, the hatchling and the float apparatus submerged immediately. The glowing float was sometimes observed underwater, moving faster than any hatchling could swim. Often the float and thread bobbed to the surface shortly after the attack and were recovered, without the hatchling. Tarpon (*Megalops atlanticus* Valenciennes in Cuvier and Valenciennes, 1847) took four hatchlings, a carcharhinid shark took one, and unidentified predators took six (Table 1). On three of the four predation events attributed to tarpon, the predators were observed leaping out of the water after catching the hatchling. All predatory fish ($n = 43$) caught while angling or seen while conducting underwater observations at each site are listed in Table 2. The most commonly caught species were gray snapper, *Lutjanus griseus* (Linnaeus, 1758), ladyfish, *Elops saurus* (Linnaeus, 1766), blue runner, *Caranx crysos* (Mitchill, 1815), bluefish, *Pomatomus saltatrix* (Linnaeus, 1766), and catfish, *Arius felis* (Linnaeus, 1766). Of the predatory fish caught, only one individual (*A. felis*) had eaten any loggerhead hatchlings (four).

SITE TYPE, SEASON, AND SURVIVAL.—There were no significant differences in predation rates among sites. Survival was 97.3% (72/74) at transitional sites, 95.7% (66/69) at sand sites, and 91.9% (68/74) at reef sites (χ^2 tests; $P = 0.31$). Therefore, data were pooled to calculate a survival rate of 95% (power = 0.96). There were also no significant differences in predation rates among months; however, trends of increased predation as the season progressed were suggested (χ^2 tests; $P = 0.058$). Survival in September was somewhat lower (87.5%) than during the preceding 2 mo (July and August; 96.1 and 97% respectively).

PRODUCTIVITY.—The average emergence success for hatchlings at Juno Beach was 86.5 hatchlings per nest, based on excavations from 626 nests. The total number of loggerhead nests recorded for the season was 7200 (Juno Beach and south Jupiter Island). Therefore, we estimated that 622,800 hatchlings emerged from nests on those beaches. We assume that all emerged hatchlings including those that we used for study reached the ocean, and that 591,660 (95%) were recruited to ocean waters after 15 min of swimming.

DISCUSSION

Our estimate of mortality in nearshore waters, while only covering a brief time interval, is valuable for use in population models and for developing recovery plans for marine turtle species in Atlantic waters. Sea turtles must overcome many obstacles to survive to adulthood (Richardson and Richardson, 1982; Stancyk, 1982; Heppell et al., 1996) and stage-specific mortality is poorly documented. Few studies have quantified mortality associated with the earliest stages of a sea turtle's life (Frick, 1976; Witherington and Salmon, 1992; Gyuris, 1994b). One objective of this study was to assess hatchling predation rates at a natural beach during the turtles' first few minutes in the water (commencement of offshore migration). This survival estimate provides a baseline for future comparison with other natural beach sites, as well as where hatcheries are maintained.

Presumably, the first hour of a hatchling's life is the most treacherous. The time interval chosen to follow the hatchlings in this study (15 min) is based on empirical estimates of the time needed for hatchlings to cross the nearshore reef line (a source of concentrated predators) and to get into deep water. We expect survival to increase after this time due to a decreased concentration of predatory fish and invertebrates, and increased safety while in the epipelagic habitat (hatchlings are spatially dispersed and are cryptic when in sargassum). Wyneken et al. (2000) and Glenn (1996) found that nearshore predation on swimming hatchlings after 15 min (up to 1 hr) was negligible.

As with previous studies that involved observations of individual swimming hatchlings (Frick, 1976; Ireland et al., 1976; Gyuris, 1994b), our presence on the water appeared to have little or no effect on either hatchling or fish behavior. Hatchlings were followed ($n = 217$) at 5–25 m by kayak and were captured both when they were close to the kayaks and when the boats were at maximum distance.

There was no significant difference in hatchling survival among sites; a mean survival rate (95%) was used for the entire study area. Although not significant, hatchling survival tended to be lower at the reef sites when compared to the sandy and transitional sites. Based upon other studies of predation (Witherington and Salmon, 1992; Gyuris, 1994b), we expected to see a higher level of predation at reef sites, since site complexity and structure provide habitat for more species of fish (Table 2). Hatchling survival (95% - 206/217) at Juno Beach (this study) was significantly greater than hatchling survival (72% - 96/125) at the hatchery site ($\chi^2 = 35.9$, $df = 1$; $P < 0.001$; Wyneken and Salmon, 1997).

Although hatchlings enter the water nightly, they are not spatially predictable so resident fish may utilize them opportunistically and may not actively target hatchlings or respond to them in the same way they would to a school of baitfish. Predatory reef fish, which tend to be ambush predators, especially at twilight (Helfman, 1993), can also become confused when several prey items appear at once in a tight group (Goodenough et al., 2001) because they are not able to choose which target to attack. Non-resident or wide-ranging cruising species, such as bluefish (*P. saltatrix*), rely on visual cues to locate schools of prey, and may be able to take advantage of high prey densities (Collette, 1999). At a natural high-density nesting beach, resident aquatic predators, such as tarpon (*M. atlanticus*; Lieske and Myers, 1994) may encounter more loggerhead hatchlings than at less densely nested sites, but loggerhead hatchlings may not be as temporally predictable as other potential prey (e.g., other fish species, invertebrates).

Table 2. All predatory fish species seen (U = underwater observations, A = angling) during our study. Sizes of fish are estimated. Bottom substrate for the sites is indicated by: R = reef, S = sand, and T = transitional.

Scientific Name	Common Name	Site Type	Observed	Size (cm)
<i>Sphyræna barracuda</i>	Barracuda	RT	U	30–150
<i>Caranx crysos</i>	Blue runner	TS	A	30
<i>Pomatomus saltatrix</i>	Bluefish	S	A	25
<i>Centropomus undecimalis</i>	Common snook	TR	U/A	100
<i>Caranx hippos</i>	Crevalle jack	R	A	35
<i>Mycteroperca microlepis</i>	Gag grouper	R	U	30
<i>Lutjanus griseus</i>	Gray snapper	RTS	U/A	26–35
<i>Arius felis</i>	Hardhead catfish	TS	A	32–40
<i>Elops saurus</i>	Ladyfish	TS	A	40–65
<i>Lutjanus synagris</i>	Lane snapper	TR	U	30
<i>Ginglymostoma cirratum</i>	Nurse shark	TR	U/A	45–100
<i>Haemulon parrai</i>	Sailor's choice	TR	U/A	42
<i>Lutjanus apodus</i>	Schoolmaster	R	U	30
<i>Carcharhinus brevipinna</i>	Spinner shark	S	A	105
<i>Elops atlanticus</i>	Tarpon	R	U	200
<i>Caranx bartholomaei</i>	Yellow jack	R	U	45
<i>Ocyurus chrysurus</i>	Yellowtail snapper	R	U	35

Our angling survey results suggest that loggerhead hatchlings are not a key prey item for shallow water predatory fish at Juno Beach. Of the 24 predatory fish caught during our study, only one individual catfish had recently consumed four hatchlings. In this study, only 11 of 217 turtles were taken by fish, yet large predatory fish were seen in the water at the study site. It appears that predatory fish do not specialize on loggerhead hatchlings per se and instead may take them opportunistically. However, catch-per-unit-effort in angling was low, even for the reef sites. Thus it was not an effective assay for predation risk for this particular study because of the low total captures and high variability in the number of captures for each site.

At Juno Beach, loggerhead nest numbers are consistently high (~500 nests km⁻¹ yr⁻¹). Loggerheads nest 2–7 times per season (Hirth, 1980; Van Buskirk and Crowder, 1994), roughly every 2.5 yrs in Florida (Turtle Expert Working Group [TEWG], 2000). Successive clutches by the same female are laid at least a few km apart depending on the locale (Miller, 1997). This behavior allows turtles to distribute reproductive effort over time and space, and helps to ensure that in a highly dynamic and temporally unstable environment such as a beach, chances are minimal that all clutches could be lost (Miller, 1997). High nest density on a natural beach, combined with spatial and temporal variation of nesting, may have contributed to the observation that there was no significant difference in survival rates for hatchlings at the three site types. However, this is in contrast to the higher predation rates observed near hatcheries, where hatchlings leave the beach at unnaturally high densities from the same 100 m stretch each night (Wyneken et al., 2000). Hatcheries in Florida (and worldwide) may have nest densities that are an order of magnitude higher than even the most densely nested natural beaches. The same strategies for escaping aquatic predators that are successful for hatchlings at a natural beach may fail to help them survive at hatcheries. For hatchlings in the waters adjacent to hatcheries, the advantage of being part of a group may be reduced, because a higher concentration of prey can attract and support higher concentrations of predators (Goodenough et al.,

2001), if only seasonally. Aquatic predators may cue in on a hatchery site as one that spatially and temporally concentrates a predictable source of food.

We estimated the productivity of Juno Beach at 590,000 hatchlings for the year 2000. This estimate suggests that Juno Beach is one of the most important beaches for loggerhead nesting in Florida, and points to its critical role for recruitment of hatchlings in the U.S. loggerhead population. Ninety-five percent of the Juno Beach hatchlings escaped predation in shallow nearshore waters. Even though additional hatchlings may be taken by predators as they continue their migration, hatchling survival rate should increase due to lower predator densities beyond the reef (Witherington and Salmon, 1992). As the turtles age and grow, they become less susceptible to predation and the daily mortality rate undoubtedly declines (Petersen and Wroblewski, 1984). While a 95% survival rate in the first 15 min at sea may seem trivial relative to the lifespan of a loggerhead turtle, prior to this study there was no estimate of nearshore mortality for loggerhead hatchlings produced by natural nests. The survival rate at the beginning of the migration (presumably the most dangerous time for hatchlings) now has an empirical baseline for at least one major rookery. If survival was as low as 20, or even 50%, turtles would have to have much higher annual survival rate in the pelagic stage if they were to achieve a stable population level (Congdon et al., 1993).

There are relatively few empirical data for in-water life stages to incorporate into many sea turtle population models, and the best 'guesses' are used to move forward. Models can improve as empirical data become available. One of the research recommendations suggested by the TEWG (2000) is the quantification of empirically derived parameters that can help define annual survival rates of different age classes of turtles. The empirical data we collected can be incorporated into a population model for loggerheads nesting in SE Florida, the largest of the 4–5 subpopulations currently identified (Encalada et al., 1998; TEWG, 2000). Our survival rate can be used in population models to adjust the fertility parameter for adult females and improve the accuracy of estimates of female productivity. Fertility (F), in terms of offspring production per female, should be: $F = \{(\# \text{ eggs} \times \# \text{ nests}) / \text{remigration interval}\} \times \text{sex ratio} \times \text{nest survival} \times \text{nearshore survival}$, or $F = \{(103 \times 4) / 2.5\} \times 1 \text{ (sex ratio may not be 1:1)} \times 0.84 \times 0.95 = 132 \text{ hatchlings female}^{-1} \text{ yr}^{-1}$ for the Juno Beach study. If our survival estimate was incorporated into the first year survival rate parameter of a model, we could refine survivorship estimates to age one.

In conclusion, risk to hatchlings from nearshore predators is very low at the Juno Beach rookery. Hatchling survival nearshore is similar across sites and seasons. This stretch of beach appears to be equally risky for hatchlings swimming over different bottom substrates —and much less risky than hatchery sites. We estimated that recruitment to the pelagic stage was ~590,000 loggerhead hatchlings for the year 2000. These data illustrate the important contribution of this small beach to the south Florida loggerhead population. This study is the first to quantify the initial risk to hatchlings from a natural loggerhead rookery and the production once hatchlings have crossed the first nearshore reef. At a fundamental level, these data provide a much needed productivity baseline. Such data will assist managers in the development of more robust conservation strategies by improving the data used in population and simulation models that form the basis of recovery plans. Further, such data may assist managers in the development of sound spatially explicit nesting beach management policies. If predation on hatchlings is significantly higher near hatcheries than at natural beaches, perhaps conservation alternatives should be re-examined to reduce the mortality risk associated with placing hatcheries in places where survival of hatchlings will be very low. These comparative

data suggest that attention to natural processes shaped by evolution, will provide the context for robust conservation plans. Reduction or mitigation of negative anthropogenic effects (lighting, traffic, beach use, homes, and multiple-family dwellings, etc.) will allow the reproductive strategies of the turtles to function and should be more successful than intensive management at hatcheries.

ACKNOWLEDGEMENTS

We gratefully acknowledge field assistance from: J. Biery, N. Blackson, G. Chace, A. Cornett, S. Evans, C. Johnson, B. Kneen, A. Michielini, J. Myers, K. Nelson, J. Pennell, A. Quarles, G. Ramdin, L. Rape, E. Redfearn, M. Satriano, A. Semple, A. Simler, T. Sposato, and B. Wilkins. Logistical support and advice was provided by P. Davis, B. DeBay, B. Howard, B. Kollmer, M. Kollmer, C. Johnson, J. Weege, and J. Wheeler. Valuable discussions throughout the study were provided by S. Epperly, A. Nash, P.C.H. Pritchard, M. Salmon, and B. Witherington. The quality of the manuscript was improved by L. Crowder and S. Heppell. This work was made possible with the cooperation of the Marinelife Center of Juno Beach, and was funded by FAU Graduate Grants (to KRS), the Pompano Beach Fishing Rodeo, and personal funds. This study was conducted under Florida Turtle Permit # 073 issued to J. Wyneken. This study was approved and conducted in accordance with Florida Atlantic University IACUC guidelines – approvals # A00-11 and # A00-012.

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DATE SUBMITTED: 31 May, 2002.

DATE ACCEPTED: 8 September, 2003.

ADDRESSES: *Department of Biological Sciences, Florida Atlantic University, 777 Glades Road, Boca Raton, Florida 33431-0991. E-mail: <jwyneken@fau.edu>.* CORRESPONDING AUTHOR: (K.S.) *E-mail: <kelly.stewart@duke.edu>.* PRESENT ADDRESS: *Duke University Marine Laboratory, 135 Duke Marine Lab Road, Beaufort, North Carolina 28516.*

