
**Status and Distribution of the Carolina
Diamondback Terrapin, *Malaclemys*
terrapin centrata, in Duval County**

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Status and Distribution of the Carolina Diamondback Terrapin, *Malaclemys terrapin centrata*, in Duval County

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Abstract: From May 1995 through April 1997 my colleagues and I studied diamondback terrapins (*Malaclemys terrapin*) in Duval and Nassau counties. We recorded terrapins or terrapin sign in most tidal creeks and on many shorelines and islands associated with the Intracoastal Waterway between the St. Johns and Nassau rivers.

We captured 23 males, 182 females, 3 immatures, 2 hatchlings, and 1 yearling. The mean plastron length (PL) for males was 101.7 mm and for females was 161.1 mm. The smallest gravid female had a PL of 144.0 mm. We calculated a mean clutch size of 6.7 based on 102 x-rayed females and 20 excavated nests. Dwarf surf clams (*Mulinia lateralis*), marsh periwinkles (*Littorina irrorata*), and unidentified crabs were the most important food items found in 84 fecal samples.

Of the capture methods we attempted, snorkeling and seining were inappropriate for the study area, and turtle trapping and dip netting did not work. We captured some terrapins using gill nets and modified crab traps, but our most efficient method was otter trawling at low tide. Cast netting is useful if a mullet net is used and the fisherman is skilled. We captured most terrapins by hand at a beach as they came up to nest.

Terrapin activity, as interpreted by head counts, varied significantly with air and water temperatures, but was not related to changing salinities within the study area. We saw no terrapin heads from December through February, and terrapins became active in March of both years. No terrapin heads were recorded in waters less than 19°C.

New nests or gravid females were found 2 May–19 July. Most females were captured on the beach between 2 hours before and 90 minutes after daytime high tide. For 18 nests, mean depth to the top of the uppermost egg was 94.1 mm and to the bottom of the nest flask was 139.9 mm. Mean measurements of 122 eggs were: length = 37.2 mm, width = 22.7 mm, and mass = 11.5 g. From the end of April through the end of September in 1996 we discovered 671 raided nests at the nesting beach, representing 289.1 depredated nests/ha. Raccoons (*Procyon lotor*) were the major nest predators, and fish crows (*Corvus ossifragus*) also contributed.

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In addition to the UNF students mentioned above, I thank Mark Clark, Annie Kruse, and Christina Zabinski for field assistance. Marie Green was indispensable in the field, and she organized the depredated nest survey. It is a tribute to her collegiality that she was able to gain the following of the dozen or so volunteers each month for that project.

I am thankful to John Rossi, D.V.M., for enabling us to take our x-rays in his clinic. Ken Sulak of the National Biological Service graciously sent Gary Hill with his crews, including Cathy Campbell, Marcie Leffingwell, and Les Parker, to otter trawl with us in both 1995 and 1996. David Auth of the Florida Museum of Natural History supplied me with a list of all the terrapins in the museum. Also from the museum, Kurt Affenburg, Dan Cordier, and Roger Portell helped with identification of voucher specimens and fecal samples for the diet study. Bob Joseph, Director of the Talbot Islands Geological Park, provided campsites for the volunteers during the week-long survey and helped arrange for disposal of trash from the beach cleanup.

Peter Auger and Rich Seigel contributed much insight into terrapin ecology that has helped me assess this population. I thank Peter Floyd, Tom Mann, Willem Roosenburg, and Roger Wood for suggestions on crab trap modifications and other information. Karl Studenroth informed me of hatchling terrapin captures at the nesting beach before the study began.

The following were volunteers for the week-long beach survey: Liz Barker, Suzanne Blakeman, Bob Brechtel, Alex Cannon, Martha Clutter, Steve DeCresie, Jayna Fox, Donna Heinrich, James Jewell, Marina Liem, Carla McGowan, Cheryl Volpe, Tim Walsh, Laura Wewerka, and Donely Wright.

Martin Cooper and Randall Green cast netted for the project. Bill Chestnut allowed me to keep and clean the boat on his property near the launch site.

In addition to the 177 beach cleanup volunteers, we received assistance for that project from UNF, Boyd Hill Nature Park, Little Talbot Island State Park, Keep Jacksonville Beautiful, BEAKS Inc., Duval Audubon Society, Northeast Florida Sierra Club, Center for Marine Conservation, Museum of Science and History, E. Dale Joyner Nature Preserve, Tree Hill Nature Center, and a high school ecology club.

Finally, I remain deeply indebted to George Heinrich for his tireless assistance throughout this project. George moved to Jacksonville from St. Petersburg for 2 months to help with the first year of the study. His insights, field experience, and enthusiastic drive were invaluable. It was entirely on his volition that the week-long beach survey was accomplished, and it is something he arranged again in 1997 and is planning as a yearly event. George also did most of the leg work for the beach cleanup, which was a huge success. To everyone who reads this, I wish you a field colleague as great as George Heinrich!

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INTRODUCTION

The diamondback terrapin (*Malaclemys terrapin*) ranges in brackish coastal marshes from Massachusetts to Texas, and 7 subspecies are recognized (Ernst et al. 1994). The Carolina diamondback terrapin (*M. t. centrata*), listed as a priority candidate for monitoring efforts and research attention in Florida by Millsap et al. (1990, Tables 12 and 13), is found from Cape Hatteras south to northern Florida and is replaced to the south in Volusia County by the Florida east coast terrapin (*M. t. tequesta*).

Early in this century diamondback terrapins, prized for their meat, were artificially farmed for market. Studies on these captive terrapins defined propagation methods and growth rates under artificial conditions (Coker 1906; Hay 1917; Barney 1922; Hildebrand 1929, 1932). The food value of terrapins, however, led to the exploitation and decline of some natural populations (Babcock 1926, McCauley 1945, Finneran 1948). The popularity of terrapins waned after the First World War for various reasons (Pritchard 1979), and some wild populations gradually recovered (Coker 1951).

Subsequent studies of natural terrapin populations have yielded information on reproduction and nesting (Reid 1955; Burns and Williams 1972; Burger and Montevecchi 1975; Montevecchi and Burger 1975; Burger 1976, 1977; Seigel 1980*b,c*; Palmer and Cordes 1988; Roosenburg 1991*b*, 1992, 1994, 1996; Goodwin 1994; Roosenburg and Kelley 1996), growth and maturity (Cagle 1952, Montevecchi and Burger 1975, Seigel 1984, Lovich and Gibbons 1990), mortality (Seigel 1978, 1980*a*; Bishop 1983; Roosenburg 1991*a,b*; Wood 1997; Wood and Herlands 1997), and barnacle fouling (Jackson and Ross 1971, Ross and Jackson 1972, Jackson et al. 1973, Seigel 1983). A few projects have attempted to estimate density, age, or sex structures of natural populations (Cagle 1952; Hurd et al. 1979; Bishop 1983; Seigel 1984; Lovich and Gibbons 1990; Roosenburg 1991*a,b*; Morreale 1992; Mann 1995). Site fidelity has been demonstrated through recapture (Lovich and Gibbons 1990; Roosenburg 1994; R. Wood, personal communication), and some movements of females to nesting beaches have been documented (Hurd et al. 1979; Roosenburg 1993, 1994).

Seigel (1993) revealed the apparent decline of a population of *M. t. tequesta* in east-central Florida at Merritt Island, and reiterated the call for long-term studies of reptile populations suggested by Gibbons (1987) and Dodd (1992). Hurd et al. (1979) suggested that development of coastal areas is sometimes detrimental to terrapin populations, and this has been supported by others (Roosenburg 1991*a*, Mann 1995, Wood 1997).

Many terrapins drown in crab traps (Bishop 1983, Mann 1995, Roosenburg et al. 1997, Wood 1997), and raccoons (*Procyon lotor*) kill adults and destroy many nests (Burger 1977, Seigel 1980a, Roosenburg 1991b, Goodwin 1994, Roosenburg and Place 1994). Seigel (1993) also suggested several abiotic factors that could have contributed to the decline of Merritt Island populations.

Diamondback terrapins have never been studied in northeastern Florida. They have recently been sold for food by shrimpers at Fernandina Beach in Nassau County (B. Cook, Florida Fish and Wildlife Conservation Commission, personal communication), and a roadkill was found in 1992 near Guana River State Park in northern St. Johns County (B. Charest, Florida Department of Environmental Protection [FDEP], personal communication). No terrapin records for Duval County are listed in Ashton and Ashton (1985), and the Florida Museum of Natural History has only 3 specimens from Duval County, all of which have vague collecting site data such as "Ft. George Island" and the "St. Johns River" (D. Auth, personal communication). There is a 20-year-old record of diamondback terrapins at Ft. Caroline National Monument, but they have not been seen lately (D. Tardona, Timucuan Ecological and Historic Preserve, personal communication). Terrapins have been sighted by rangers and brought in by visitors for identification at Little Talbot Island State Park during both 1992 and 1993 (M. Wingate, FDEP, personal communication).

Although sparse, these records attest to the historic and continuing presence of *M. t. centrata* in northeastern Florida. The tidal creeks and marshes in Duval and Nassau counties comprise over 50 nautical miles of ideal habitat for this species. To begin research on the terrapin it was necessary to locate their populations within these creeks, begin marking individuals, and attempt to define their habitat preferences. These preliminary studies will be the basis for future research on movements during all seasons (a telemetry study), population levels and temporal fluctuations, reproduction, mortality, and other ecological parameters.

I began this project with 5 major objectives. The first was to locate basking and/or nesting aggregations of terrapins in Duval and Nassau counties. The second was to, using the mark-recapture method, commence collection of baseline data on the distribution, sex ratios, and size classes of Carolina diamondback terrapins. Thirdly, the most effective method of capturing terrapins in this area would be determined by testing currently used procedures. The fourth objective was to assess terrapin habitats in terms of

water depth, seasonal air and water temperatures, and salinity. Finally, I wanted to formulate recommendations for the management and conservation of diamondback terrapins in the area.

Early in the study my colleagues and I located an important terrapin nesting beach, and additional objectives concerning the use of the beach by terrapins were formulated. These included determining the time of day of most frequent nesting, locating nests to determine clutch sizes and egg dimensions, identifying nest predators and assessing the intensity of nest predation over time, and identifying the plant species on the beach.

METHODS

Schedule

In 1995 we did terrapin research 5 days a week during May and June and 3 times a month July–October. We did not return to the field until 5 March 1996, and we went out twice weekly in March and April, 5 days a week in May and June, and 3 times monthly from July through the following February. In March and April 1997 we went out twice weekly.

Study Area

Most area names referred to herein were taken from U. S. Geological Survey topographic maps entitled Amelia City (DMA 4745 III SW), Hedges (DMA 4645 II SE), Mayport (DMA 4744 IV NW), Eastport (DMA 4644 I NE), and Fernandina Beach, Fla.-Ga. (DMA 4745 NW). Some unlabeled places we named ourselves for convenience, and these are indicated in Fig. 1 and in the text. The study area included tidal creeks, salt marshes, and mudflats of the Intracoastal Waterway between the Nassau River to the north and the St. Johns River to the south (Fig. 1). We also studied Harrison and Walker creeks north of the Nassau River, and worked westward into Pumpkin Hill, Edwards, Hannah Mills, and Clapboard creeks. Most of the area is in Duval County, but that north of the Nassau River is in Nassau County. Most of the study site is within the Timucuan Ecological and Historic Preserve, the Nassau River–St. Johns River Marshes State Aquatic Preserve, and the Talbot Islands State Geological Park. Tides in the area fluctuate 2–3 m.

The predominant marsh grass is *Spartina alterniflora*, with needlerush (*Juncus roemerianus*) a close second, and glasswort (*Salicornia* sp.) as a ground cover. In drier areas southern red cedar (*Juniperus silicicola*) is the predominant shrub, and sea ox-eye (*Borrchia frutescens*) is a common flower.

The most densely populous bird in the salt marsh is the marsh wren (*Cistothorus palustris*). Other very common birds are the snowy egret (*Egretta thula*), great egret (*Casmerodius albus*), great blue heron (*Ardea herodias*), tricolor heron (*Hydranassa tricolor*), wood stork (*Mycteria americana*), double-crested cormorant (*Phalacrocorax auritus*), least tern (*Sterna albifrons*), and osprey (*Pandion haliaetus*).

Aquatic mammals include the bottlenose dolphin (*Tursiops truncatus*), the less frequently seen manatee (*Trichechus manatus*), and the rarely encountered river otter (*Lutra canadensis*). The most frequently met mammal in the

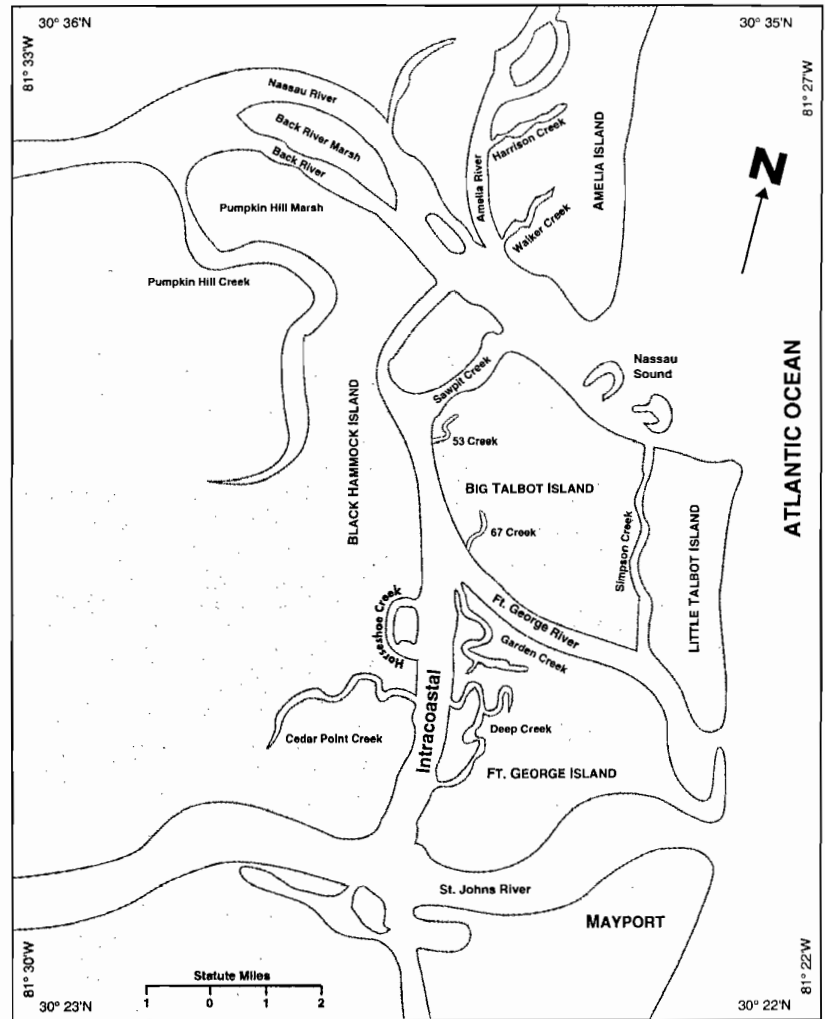


Fig. 1. The diamondback terrapin study area in northeastern Florida.

saltmarsh is the raccoon, and it is an important predator to many invertebrates and vertebrates in this habitat.

Commonly encountered fish include mullet (*Mugil* sp.), red drum (*Sciaenops ocellatus*), flounder (*multiple genera*), crevalle jack (*Caranx hippos*), spotted seatrout (*Cynoscion nebulosus*), croaker (*Micropogonias undulatus*), spadefish (*Chaetodipterus faber*), and sheepshead (*Archosargus probatocephalus*).

Surveys

The most common way we confirmed terrapin presence was by sighting heads at the water surface, although in some cases this was enhanced by noting basking individuals, nesting behavior, or finding carcasses. Early in 1995 we visually surveyed north to Harrison Creek in Nassau County just west of Amelia Island, south to the St. Johns River, and west to Clapboard, Pumpkin Hill, and parts of Edwards creeks (most in Fig. 1). We concentrated much of our effort on tidal creeks adjacent to the Intracoastal Waterway between the Nassau and St. Johns rivers. In addition to numerous unnamed creeks, we surveyed Sawpit, Broward, Simpson, Myrtle, Garden, Horseshoe, Cedar Point, Deep, and Hannah Mills creeks, along with the Fort George and Mud rivers.

We also searched some islands and shorelines on foot during 1995 and 1996 for evidence of terrapins or terrapin nesting (i.e., carcasses or depredated nests). Terrapins nest above the tide line in sand rather than mud or clay (Burger and Montevercchi 1975, Auger and Giovannone 1979, Seigel 1980c, Goodwin 1994, Roosenburg 1994), so we concentrated on these areas. One search took us as far north as the city of Fernandina Beach between Jackson and Lanceford creeks. In 1995 we did most of our land exploring in the summer, but in 1996 we did it from March through mid-May. Doing it early was more practical because the biting flies were not yet active, and winter weather had caused the small ground cacti, which readily puncture shoes, to die back.

Baseline Data

Records and Measurements.—Each time a terrapin was captured we recorded the date, time, place, and sex; noted its activity; assessed the weather; palpated anterior to the hind limbs of females to determine if they were gravid; measured any barnacles present; and noted any abnormalities. With vernier calipers we measured maximum carapace length (CL), plastron length (PL), shell width (W), shell height (SH) all to 0.1 cm, and head width to 0.1 mm.

Mass (M) was determined by weighing terrapins with Pesola scales (10.0-g accuracy). Terrapins were marked with drill holes in their marginal scutes (Cagle 1939) and released within 50 m of their capture site.

X-ray.—We kept gravid females overnight in separate 19.0-L buckets with about 5.0 cm of fresh water. The next morning they were transported to a local veterinary hospital and x-rayed to determine clutch size (Gibbons and Green 1979).

Diet.—We kept some males, as well as the females, overnight, and some of each sex defecated in the buckets. When this occurred we carefully poured off the water and collected shells and other fecal debris so we could determine their diets by fecal analysis. Tucker et al. (1995) did such a dietary analysis of South Carolina terrapins and concluded that soft-bodied prey were not a major part of the diet during their study, and we assumed the same in ours. All terrapins were released within 48 hours, whether they had defecated or not. We dried and stored the feces in small plastic vials labeled with the date and terrapin number.

As part of this aspect of the project, we collected voucher specimens of possible food items in the area such as bivalves, gastropods, barnacles, and crabs. With the assistance of the Florida Museum of Natural History we identified vouchers and compared them to fecal components to determine which items terrapins had eaten.

Fecal Coliforms.—Another faculty member in my department (Dr. Valerie Harwood) was interested in determining if terrapins carried fecal coliform bacteria. The presence of fecal coliforms is used by many government agencies as an indication of human fecal contamination of various water supplies (American Public Health Association 1995). A criticism of this method is that organisms other than humans harbor coliforms, thus a positive coliform test should not necessarily indicate human contamination. As this debate ensues, researchers are attempting to determine which animals carry fecal coliforms and the contributions of each to various environments. Mitchell and McAvoy (1990) showed that some natural turtle populations shed intestinal bacteria, and Dr. Harwood wanted to find out if terrapins did, so we agreed to collect cloacal swabs for her.

We inserted a sterile cotton-tipped swab into the cloaca while holding the tail. Swabs were placed in a buffer solution, refrigerated, and taken to the laboratory within 24 hours for further processing, in which my group was not involved.

Capture Methods

We tried raking tidal debris, cast netting, turtle trapping, gill netting, otter trawling, hand capture, and modified crab trapping to capture terrapins. Early in the project we ruled out several possible capture methods for our study area. The water throughout the area was continually roiled, so snorkeling to capture terrapins (Morreale 1992) was impossible. Seining was also futile because soggy bottoms caused us to sink to our thighs in the mud. Dip-netting from the boat did not work because it was impossible to predict where terrapins would surface, and we could not get close enough to them even with a 6-m extension net.

Raking.—Juvenile and hatchling terrapins are known to take refuge under various types of surface and tidal debris (Pitler 1985, Lovich et al. 1991). In 1995 we raked tidal debris on several islands for a total of 90 man-minutes in May. In April 1996 we raked debris on the nesting beach for a total of 240 man-minutes. Throughout the study, we also regularly overturned all boards, logs, and other such items on islands we visited and on the nesting beach.

Cast Netting.—None of us was proficient at cast netting, but we were fortunate to meet a fisherman in the marshes who took an interest in our project. He and I spent about 70 minutes one day in 1995, during which time he threw his 2-m-radius bait net from the boat about 2 dozen times into a pool where terrapins were active.

Turtle Trapping.—We deployed a 0.9-m-diameter hoop turtle trap (Memphis Net and Twine Co., Memphis, Tennessee) baited with crushed crab continuously for 77.5 hours in Deep Creek at a place where many terrapins had been sighted. We attached floats to the sides of the trap and tied it to PVC poles we had stuck into the mud. We left enough excess rope so the trap could rise and fall with the tides.

Gill Netting.—We set a 58-m x 3-m gill net (Memphis Net and Twine Co., Memphis, Tennessee) with 5-cm mesh (unstretched) at various points on Deep Creek and Cedar Point Creek for a total of 63.5 man-hours. We simply suspended the net across the width of the creek and waited 30 minutes. We then checked the net by pulling it up by sections along its length. When we finished checking, the net would still be in place, and we waited another 30 minutes.

Otter Trawling.—Our small, 9.9-hp jon boat could not pull an otter trawl, but in both summers the National Biological Service sent a boat and volunteers to assist in our project. Their boat had a 150-hp engine, but trawling can

probably be done with one as small as 100 hp. We used their 4-m-diameter trawl. This technique required 1 person to drive the boat and 2 others to deploy and pull in the trawl. Each trawling event covered about 100–300 m and lasted about 3–13 minutes. On 23 June 1995 we trawled 13 times in Deep Creek (Fig. 1) and spent approximately 4 hours and 45 minutes ($\times 3 = 14.25$ man-hours). On 24 June 1996 we again trawled 13 times in Deep Creek and spent 2 hours and 57 minutes ($\times 3 = 8.85$ man-hours).

Modified Crab Trapping.—Several authors have noted the propensity of terrapins to enter crab traps, where they usually drown (Bishop 1983, Burger 1989, Roosenburg 1993, Roosenburg et al. 1997, Wood 1997). Our goal was to test a modified version of the crab trap, using an extended upper chamber that would allow terrapins to surface for air (Mann 1995, Roosenburg et al. 1997). Such a trap would allow capture of adult males, some adult females, and immatures.

We began trapping in May 1996 using modifications first described by Mann (1995). The original top of the trap was entirely removed and a cone of netting was attached that would extend slightly beyond the water surface during high tide (Fig. 2). The netting was held upright by a metal pole extending through the trap into the muddy channel bottom. These modifications were used for only several days due to 2 major complications. When we tried to deploy and check the traps, the netting continually became entangled on other parts of the trap such as the edges of the entrance funnels, the hog rings used to attach the netting, or the bait well. More importantly, blue crabs (*Callinectes sapidus*) captured in the traps were able to snip the netting with their claws, and within 3 days 2 nets had been destroyed. We abandoned this trap version very early in the season.

Instead of the nets, we decided to use chicken-wire cylinders to connect the traps to the air. Chicken wire was relatively inexpensive (I used funds from the Central Florida Herpetological Society for this); more rigid than netting, thus eliminating the tangling problem; and strong enough to hold up against crab claws. Because cones would have been somewhat difficult to fashion from chicken wire, we decided on cylinders. To attach the cylinders to the traps, we had to reattach a roof to the trap and cut a hole in it. All new attachments were made with nylon ties. Our original cylinders were about 2.7 m long and about 22 cm in diameter, which we were certain would accommodate the body length of a large female.

The cylinders were awkward to transport and had to be attached to the traps in the field. When assembled, the traps with cylinders stood 3.3 m high. We used the metal poles as before to keep the traps anchored in place. To be

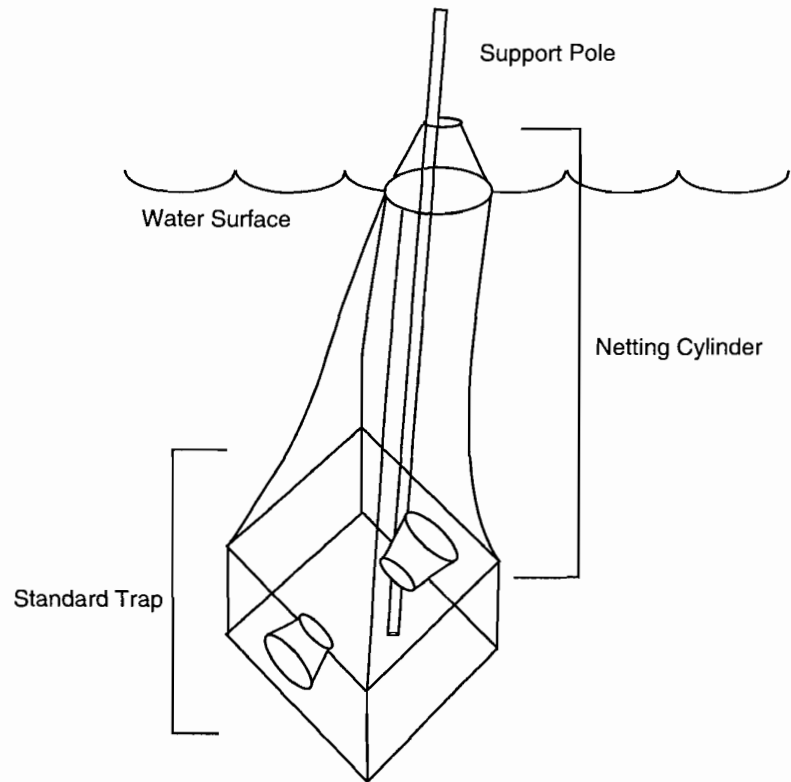


Fig. 2. Modified crab trap with net extension to the water surface (after Mann 1995).

sure that even large females could enter, we enlarged the entrance funnels to allow passage of a shell that was 13.7 cm wide and 7.8 cm high. By 9 May we had placed our first cylinder trap.

We set traps at the edges of tidal creeks at depths such that traps were not inundated at high tide nor completely exposed at low tide. Most of the time we used crushed blue crab for bait, but a few times we used fish when crab was not available. We checked traps Monday–Friday, 9 May–28 June. During checking, 1 person drove the boat and took field notes, while 2 others pulled traps, removed captives, and baited the traps. We spent about 90 minutes/day for 37 days, for a total of 55.5 hours ($\times 3 = 166.5$ man-hours). We used up to 11 modified crab traps for a total of 379 trap-days.

Hand Capture.—On 23 May 1995 we discovered the nesting beach, and this allowed us to capture large numbers of female terrapins simply by picking them up as they used the beach to nest. Several researchers noted a preference of terrapins to nest at times near high tide (Burger and Montevercchi 1975, Auger and Giovannone 1979, Goodwin 1994), so in 1995 we tried to coincide our nesting beach visits near those times.

In 1996 we wanted to better elucidate preferred nesting times, so from 5 to 11 May George Heinrich arranged for 15 volunteers to help collect terrapins at the nesting beach at Big Talbot Island. We chose a week when high tide occurred during daylight, and our protocol was to have 7 people at a time on the beach in shifts throughout the daylight hours. Volunteers were spaced about 80–100 m apart and watched for terrapins from discrete venues, such as behind a tree or clump of marsh grass. When a terrapin was captured, the time and whether it was heading to or from the surf were noted.

Head Counts, Temperatures, and Salinity Records

Beginning in March 1996, each day at the Deep Creek and Cedar Point Creek study sites we counted terrapin heads as we initially rode through these areas at idle speed. It generally took about 9–12 minutes at Deep Creek and 3–4 minutes at Cedar Point Creek. We measured surface salinity with a refractometer (American Optical, Keene, New Hampshire) and air and water temperatures (1 m deep) with a Model 43 telethermometer (YSI Inc., Yellow Springs, Ohio) at the same sites in these creeks. We measured channel depths at high tide in both creeks with a 4-m pole marked in 0.5-m increments, and we used these measurements to determine where to place crab traps.

Nesting Beach Studies

Crawls, Nest and Egg Measurements, and Clutch Size.—In 1995 we did little more on the nesting beach than capture females, but in 1996 we learned to recognize terrapin crawls. Depending on the dryness of the sand these crawls could sometimes be very clear, and one could tell if they were heading to or from the water. In some cases the to-and-from crawls formed a V-shape, the point of which often yielded a terrapin nest. We discovered many nests in this manner, and we excavated 20.

We recorded the depth to the uppermost egg and to the bottom of the nest with a ruler (1.0 mm). As we encountered eggs, we marked the upper egg surface with a small dot from a permanent marker, so we would not damage the embryo by turning the eggs. We placed each egg on the sand in order, and, when all were excavated, we measured maximum length and width with vernier calipers (0.1 mm), and mass with a Pesola scale (1.0 g). Eggs were then replaced in the nests in their original order and approximate arrangement. The nest clutch sizes were recorded and combined with those from x-rays to determine mean clutch size in this population.

Depredated Nest Survey.—The way we discovered the nesting beach in the first place was by finding large numbers of depredated terrapin nests. At the end of both May and June 1995, 3 of us surveyed the entire beach for raided nests in 2-day periods. When we discovered a nest, we collected and removed the shells from the beach and measured nest depth with a ruler (1.0 mm). With the assistance of volunteers from the Museum of Science and History (Jacksonville) and members of my herpetology class, I was able to resurvey the beach on 30 September.

In 1996 a senior University of North Florida (UNF) student did a more complete nesting beach survey as an independent studies course. She and groups of up to 14 volunteers surveyed the beach the last weekend of each month from April through September. The protocol was for the group to start at one end of the beach, line up at arm's length parallel to the river, and walk across the sand away from the river until they reached the marshy area behind the beach. They then turned and repeated the procedure, only now walking toward the river, until the entire beach had been traversed. When a nest was found another volunteer marked it with a numbered survey flag. This took about 2 hours.

When all nests were marked, the group went back through and assessed each one. The placement of nests in relation to grasses, shrubs, trees, and tidal debris was noted. All shells were collected, nest depths measured as before, and the distance of the nest from the high tide line was recorded (0.01 m).

Incubation.—On 5 May 1996 a terrapin was discovered depositing a nest, and 6 eggs from that nest were excavated. I artificially incubated the eggs in a covered plastic container on a bed of moist vermiculite in a closet at room temperature, which varied from 21–26°C.

Plant Composition on the Beach.—Dr. John Randall of the UNF Department of Natural Sciences identified the plant species present on the nesting beach.

Beach Cleanup.—George Heinrich played a major role in helping to organize a coastal cleanup of the nesting beach on 13 October 1996.

RESULTS

Surveys

Table 1 lists all creeks where we saw terrapin heads, areas where we saw basking terrapins, and 2 nesting beaches we discovered in 1995. We never saw terrapins in the St. Johns River and very seldom in the Intracoastal Waterway. We did not see heads in Clapboard or Edwards creeks, but we visited them each only once. We saw more heads in Deep and Cedar Point creeks than anywhere else. Some notable areas where we searched and found no terrapins in 1995 are the southern shore of Amelia Island, Huguenot Park, Sandpits, Quarantine Island (beneath the Dames Point Bridge), Shell Island, and Fort George Island.

In 1996 we looked for more defined evidence of terrapins and their predators on shorelines and islands, and we found terrapin sign at 60% of the sites we visited (Table 2).

Table 1. Terrapin sighting areas in Duval and Nassau counties, 1995.

Map	Area	Latitude	Longitude
Fernandina	Rayonier, Inc. Nesting Beach	30°39'36"N	81°28'12"W
Amelia City	Big Talbot Island Nesting Beach	30°31'08"N	81°27'22"W
	Mesa Marsh	30°32'25"N	81°28'38"W
	Harrison Creek	30°33'46"N	81°28'05"W
		30°34'23"N	81°27'44"W
	Black Hammock Island	30°32'25"N	81°29'24"W
Mayport	Unnamed creek	30°27'14"N	81°27'00"W
	Horseshoe Creek	30°27'42"N	81°27'34"W
		30°26'20"N	81°27'44"W
		30°26'26"N	81°27'25"W
	Cedar Point Creek	30°26'01"N	81°27'57"W
	Deep Creek	30°25'27"N	81°27'07"W
		30°25'27"N	81°26'55"W
		30°25'35"N	81°26'46"W
	Simpson Creek	30°26'41"N	81°25'27"W
		30°27'25"N	81°25'36"W
		30°28'37"N	81°25'50"W
	Hannah Mills Creek (on road)	30°23'58"N	81°28'32"W
Hedges	Pumpkin Hill Creek	30°32'33"N	81°31'01"W

Table 2. Shorelines and islands in Duval County surveyed on foot for sign of terrapins and raccoons during the period 14 March–16 May 1996.

Sign ^a	Marker ^b	Latitude	Longitude
Amelia City Map			
S, N, R	47–49	30°30'33"N	81°28'10"W
S, R	49–50	30°30'09"N	81°28'10"W
Mayport Map			
S	51–53	30°29'42"N	81°27'47"W
S, N, R	57	30°29'23"N	81°27'30"W
R	63	30°28'15"N	81°27'28"W
R	65	30°28'03"N	81°27'22"W
S, N, R	67–69	30°27'41"N	81°26'55"W
S, R	71	30°27'16"N	81°26'49"W
0	75	30°26'30"N	81°27'16"W
R	77	30°26'02"N	81°27'21"W

^aS = terrapin shell, N = depredated nest, R = raccoon feces or skeletal remains, 0 = no sign found.

^bClosest Intracoastal channel marker.

Baseline Data

Records and Measurements.—We captured 74 terrapins in 1995, 141 in 1996 (including 6 recaptures), and 2 in March 1997. The total represents 23 males, 182 females, 3 immatures, 2 hatchlings, and a yearling. Most adults and immatures were captured during May and June (5 females in July and 1 male in September), and the hatchlings and yearling were all found in March. Mean PL for adult males was 101.7 mm (SD = 8.5, range = 93.0–123.0), and that for females was 161.6 mm (SD = 10.3, range = 119.0–184.0). The smallest gravid female had a PL of 144.0 mm. Capture sites and other notes for these are available from the Florida Fish and Wildlife Conservation Commission's Wildlife Observation database.

X-ray.—In 1995 we x-rayed all females, and 19 were gravid. We detected eggs in all the gravid ones by palpation, so the following year we only x-rayed ones in which we could feel eggs. In 1996 we x-rayed 83 gravid females. Mean clutch size was 6.8 (SD = 1.5; range = 3–10; $n = 102$); means from May and June did not differ in either year, and yearly means were also similar.

Diet.—We collected 46 fecal samples in 1995 and 38 in 1996. Table 3 lists food items found in fecal samples from both males and females. It is apparent that dwarf surf clams (*Mulina lateralis*), crabs, and marsh periwinkles (*Littorina irrorata*) are major food items for terrapins in northeastern Florida. Crab (unidentified and *Sesarma cinereum*) was found in

Table 3. Number of times food items were identified in 84 terrapin fecal samples.

Food Item	Female <i>n</i> = 63	Male <i>n</i> = 21	Total (%)
Unknown crab	36	10	46 (54.8)
<i>Mulina lateralis</i> dwarf surf clam	22	20	42 (50.0)
<i>Littorina irrorata</i> marsh periwinkle	29	2	31 (36.9)
Unknown plant	10	4	14 (16.7)
<i>Ilyanassa obsoleta</i> eastern mud whelk	6	3	9 (10.7)
<i>Balanus</i> sp. barnacle	3	0	3 (3.6)
<i>Sesarma cinereum</i> gray marsh crab	0	2	2 (2.4)
Unknown bivalve	1	1	2 (2.4)
Unknown gastropod	1	1	2 (2.4)
Unknown operculum	1	0	1 (1.2)
Unknown fish	1	0	1 (1.2)

57.1% of the fecals and was the most frequently occurring food item. However, when considered as a percentage of combined fecal mass of both sexes, *M. lateralis* constituted 83.1%, crab 7.5%, and *L. irrorata* 6.7%.

Table 4 compares results of analyses of fecal sample from males and females, and it is clear that *M. lateralis* constituted most of the fecal mass of each sex. While crab and *L. irrorata* were of some importance to females, they were less so to males. Also, there was a distinct dietary shift from year to year in females that was not apparent for males. In 1995 *M. lateralis* constituted 82% of females' fecal mass, while in 1996 it made up only 50.0% of the mass (Table 4). Females had more *L. irrorata* and crab in the 1996 fecal samples.

Table 4. Importance of various food items in the diets of male and female terrapins expressed as a percentage of the mass of fecal samples, 1995 and 1996.

Food Item	Males			Females		
	1995 <i>n</i> = 11	1996 <i>n</i> = 10	Total <i>n</i> = 21	1995 <i>n</i> = 35	1996 <i>n</i> = 28	Total <i>n</i> = 63
<i>M. lateralis</i>	98.4%	96.4%	97.8%	82.0%	50.0%	78.5%
Crab	1.2%	3.0%	1.9%	8.1%	17.1%	9.2%
<i>L. irrorata</i>	0.01%	0.07%	0.08%	5.5%	32.1%	8.6%
sample wt. (g)	22.9	13.9	36.8	105.3	14.0	119.3

Fecal Coliforms.—We collected cloacal swabs from 26 terrapins. Dr. Harwood's group found 2 terrapins positive for *Escherichia coli*, and none had *Salmonella* sp.

Dr. Harwood suggested that the overnight holding time was too long, and that, with adjustments, future cultures will yield more positives for fecal coliforms. Indeed, in 1997, with a holding time of 8 hours or less, 52% of 29 terrapin fecals were positive for coliforms.

Capture Methods

Raking.—We never found any terrapins while raking debris. Other than 1 nesting female found under tidal debris, we never found them under any type of refuge. We had hoped for success with this method because several terrapin hatchlings had been captured under tidal debris on the Big Talbot Island nesting beach in 1992, before the current study had begun (K. Studenroth, personal communication).

Cast Netting.—One male was captured in 1995 and another in 1996 (Table 5). In October 1996 I learned the art of cast netting and spent about an hour trying to net terrapins. The terrapins were never quite close enough to the boat for me to actually throw the net over them, so I was casting blindly into an area where we were seeing many heads. I caught nothing this way.

Turtle Trapping.—We had no success with this trap after over 3 consecutive days in 1995 in an area where terrapins were abundant. Thereafter we abandoned this method.

Gill Netting.—We captured 8 terrapins representing both sexes with this method (Table 5). This represents a capture rate of 0.13 terrapins/man-hour.

Otter Trawling.—In 1995 our largest single-day total capture of 11 terrapins came using the otter trawl (Table 5). We captured terrapins in 9 of 13 trawls, and on 3 occasions we caught 2 terrapins at once. Of the 11 captures 6 were males, making this was our best method for capturing males. This is a capture rate of 0.77 terrapins/man-hour.

By contrast, otter trawling in 1996 in the same area yielded only 2 terrapins (Table 5) for a rate of 0.23 terrapins/man-hour. The likelihood of a tidal influence on capture rate is discussed later.

Modified Crab Trapping.—We trapped 18 terrapins in 9 trapping events, and adult males and females as well as immatures were captured (Table 5). On

4 occasions we trapped terrapins in multiples of 2–5. Our captures represent 0.047 terrapins/trap-day, which is lower than other reports (Bishop 1983, Mann 1995, Roosenburg et al. 1997, Wood 1997). Capture events occurred within 1–14 trap-days (mean = 8). We captured 0.11 terrapins/man-hour (not including time spent building and setting traps).

Hand Capture.—In 1995 we captured 47 female terrapins at the nesting beach (Table 5). Early in the study we realized that terrapins were on the beach most often within 2 hours before and after high tide, so we were sure to be at the beach during daylight high tides.

In that year we hand-captured 7 terrapins that were not on the nesting beach. Two were crossing roads, and 5 others were basking. George Heinrich captured 3 of the basking terrapins by jumping off the boat and “swimming” up the mud bank to grab them. (We called this the Heinrich Maneuver!) This type of capture is not usually effective, because terrapins invariably immediately dive into the water at the sight of the boat. The 2 other basking turtles were situated somewhat far from the water on or near an oyster shell mound. Both were gravid and might have been preparing to nest.

In 1996 we hand-captured 116 females at the nesting beach. Three were recaptures from 1995, and 3 were recaptures from earlier in the 1996 season. Volunteers captured 56 of the new terrapins and 3 recaptures during the day. They also visited the beach twice during nocturnal high tides and captured 3

Table 5. Number of male, female, and immature terrapins captured by each technique.

Technique	Males	Females	Immatures
Raking	0	0	0
Cast Net			
1995	1	0	0
1996	1	0	0
Gill Net	3	5	0
Otter Trawl			
1995	6	5	0
1996	2	0	0
Modified Crab Traps	8 ^a	8 ^b	2
Commercial Crab Traps ^c	10	3	1
Hand Capture			
1995	1	52	1
1996	0	116	0
Dip Net	1	0	0

^aOne dead.

^bFour dead.

^cAll but 1 adult male dead

terrapins then. All the nocturnal captures were gravid, and 1 had begun to nest at 0029 hour.

From the accurate records kept by the volunteers we developed a histogram of diurnal terrapin captures in relation to high tide (Fig. 3). The diagram shows that most of the terrapins (79.7%) were captured on the beach prior to or at high tide, and by 1 hour after high tide 91.0% of the captures had been made.

Head Counts, Temperatures, and Salinity Records

We began collecting these records on 5 March 1996 (all data are presented in Appendix A). We first saw terrapins at both sites on 26 March. From then we saw terrapins at both sites on nearly every day we took records through November. We saw no terrapins from December 1996 through February 1997. Terrapins reappeared in Deep Creek on 4 March 1997, and we recorded them there nearly every day through the end of the study. In spring 1997, terrapin sightings in Cedar Point Creek were infrequent. The highest head count was 4.2 heads/minute on 24 June 1996 in Deep Creek.

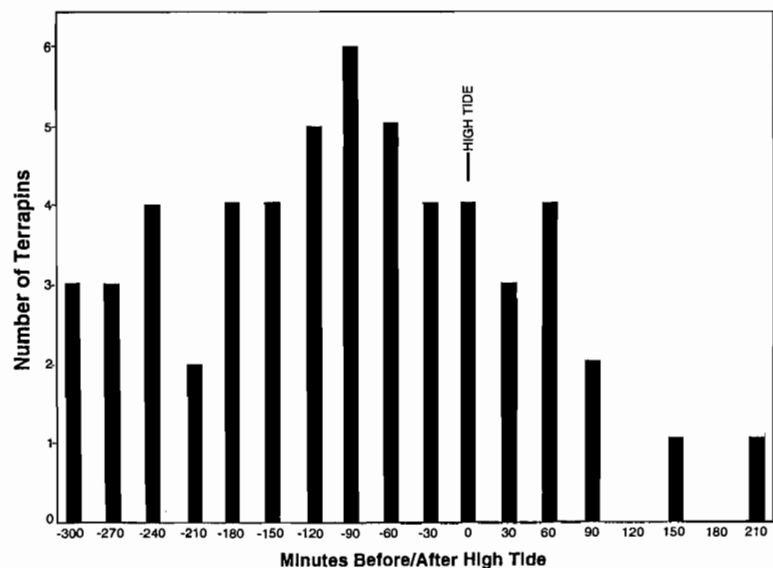


Fig. 3. The relationship between daytime terrapin capture times and time of high tide in May 1996 in

Throughout the study the range of air temperatures (T_A) was 3–36°C, water temperatures (T_W) 8–32°C, and salinity 10–32 ppt. The lowest temperatures at which terrapins were sighted were $T_A = 19^\circ\text{C}$ and $T_W = 18^\circ\text{C}$. We saw fewer terrapin heads at high tide than at any other times.

Fig. 4 depicts monthly mean values and 95% confidence intervals for head counts, T_W , and salinity. One way ANOVAs showed no relationships between T_W and salinity, or head count and salinity; but there is a strong positive correlation ($P = 0.0082$) between T_W and head count. Means of T_A and T_W were not significantly different.

Nesting Beach Studies

Crawls, Nest and Egg Measurements, and Clutch Size.—The earliest clutch was 2 May 1995 and the latest was 19 July 1996. Nesting was frequent in May and June. We visited the nesting beach 7 times in July, 6 in August, and 4 in September to search for terrapins, crawls, or other evidence of terrapin use. We captured single adult females on the beach on 2 and 5 July, 2 on 19 July, but none after that. The one on 2 July was captured as she covered her nest. The others had no eggs when captured. We were able to discover nests by following crawls on 2, 17, and 19 July. These were obviously recently deposited nests, because crawls are periodically destroyed by rain and tides. These data confirm terrapin nesting in northeastern Florida through mid-July, but the extent of nesting at that time seems much reduced from May and June.

In May and June terrapin crawls were quite numerous, and although we did not record crawl counts at that time, there were perceptibly fewer crawls from early July to the end of the month. On 3 days in August, 1 or 2 crawls were found, and on 3 others none was found. We found no crawls in September.

In May and June terrapin heads were visible offshore from the nesting beach, particularly at high tide. We recorded seeing heads at the beach only through 17 July. We believe that fewer terrapins captured at high tide, fewer crawls, and fewer head sightings at the beach from July on signaled the decline of terrapin nesting.

Mean nest depth to the uppermost egg was 94.1 mm (SD = 24.1, range = 49.0–132.0, $n = 18$) and to the bottom of the nest was 139.9 mm (SD = 14.1, range = 113.0–169.0, $n = 18$). For 122 eggs the mean length was 37.2 mm (SD = 1.7, range = 33.7–43.3), width was 22.7 mm (SD = 1.1, range = 20.7–24.9), and mass was 11.5 g (SD = 1.4, range = 9.0–14.0).

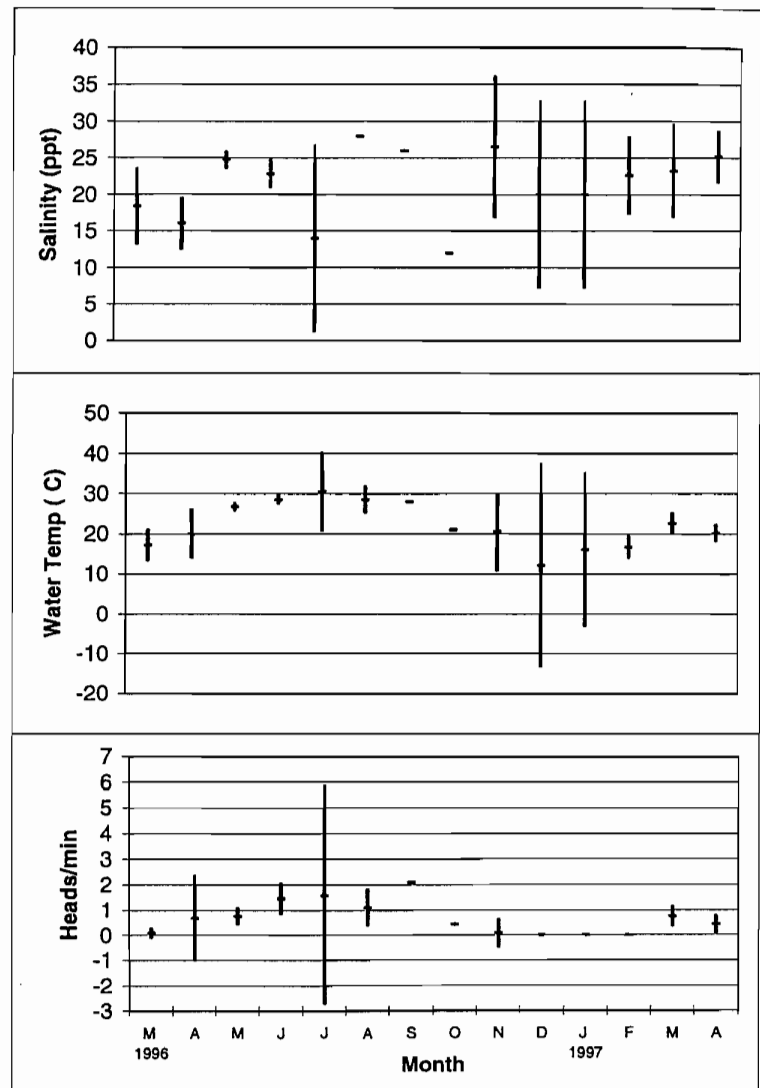


Fig. 4. Relationship between monthly means of terrapin heads counted per minute, water temperature, and salinity from 2 creeks in northeastern Florida over a 14-month period. Bars represent 95% confidence intervals.

Mean clutch size determined from 20 excavated nests was 6.1 (SD = 1.0, range = 4–8). This was not significantly different from clutch size determined by x-ray; the combined mean clutch size was 6.7 (SD = 1.5, range 3–10, $n = 122$).

Depredated Nest Survey.—We found 671 raided nests in 1996, representing 289.1 nests/ha. Nest counts by month are depicted in Fig. 5. Raided nests were located in every month of the survey, but counts increased to peak levels in June and July and decreased in August and September.

Eggshell counts from raided nests yielded a mean clutch size of 3.65 (SD = 0.97; range = 1–11). This figure is much lower than the mean clutch size of 6.7 reported above. Sometimes predators devour shells along with their contents (we found raccoon feces with terrapin eggshell fragments). Some

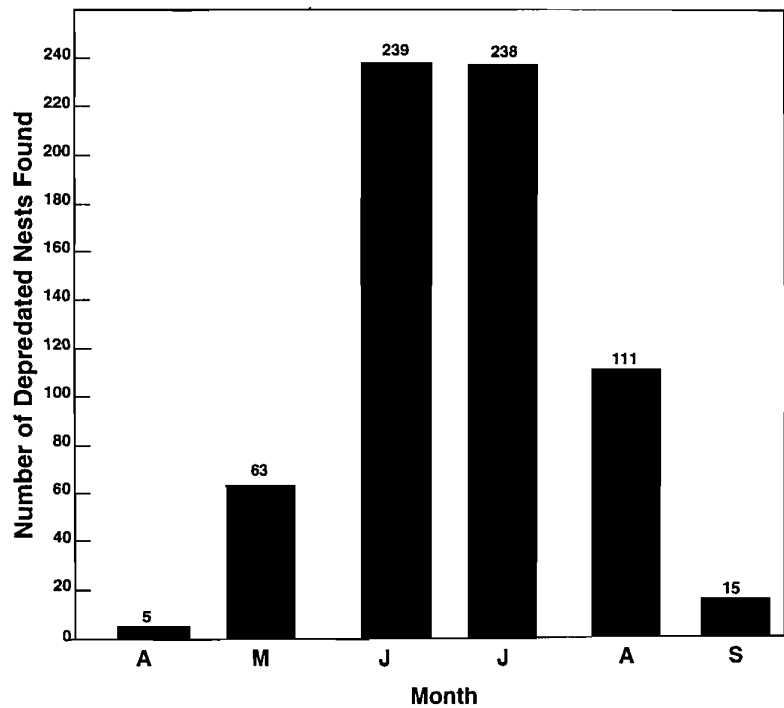


Fig. 5. Depredated terrapin nests found on the nesting beach in 1996

shells are probably carried away from the nest site by predators, or sometimes wind may scatter them. Also, when fragments were counted, the researcher had to estimate the number of eggs represented. For these reasons, this is not an accurate method for estimating clutch size (Goodwin 1994).

Raided nests were found in tidal debris, in open sand, associated with grasses and other plants, at the edges of shrubs, and under cedar trees. We could not discern a favored set of conditions. The mean nest distance from the high tide line was 14.9 m (SD = 4.7, range = 0.0–54.0).

Mean raided nest depth was 74.8 mm (SD = 11.4, range = 20.0–150.0, $n = 522$). Because these depths were measured only once a month, some of the nests had weathered and partially filled in. For that reason, we believe that the mean depth recorded for the 18 nests that we excavated (139.9 mm; see above) is more accurate.

Incubation.—Four of 6 eggs began hatching after incubation of 97–100 days; the others did not hatch. This is longer than most reported terrapin incubation periods (Burger 1977, Auger and Giovannone 1979, Seigel 1980b, Goodwin 1994), and probably reflects the relatively cool incubation temperature of the artificial habitat. Hatchlings freed themselves from the shells 2–4 days after pipping.

Mean measurements of hatchlings on the day of emergence from the egg were CL = 29.5 mm (SD = 1.2, range = 28.4–31.1), PL = 26.4 mm (SD = 0.8, range = 25.7–27.4), W = 24.7 mm (SD = 0.9, range = 24.0–25.9), SH = 15.9 mm (SD = 0.8, range = 15.0–16.7), and M = 6.8 g (SD = 1.0, range = 6.0–8.0).

Plant Composition on the Beach.—Appendix B lists 52 plant species identified on the nesting beach. No attempt has been made to assess dominance or percent cover.

Beach Cleanup.—One hundred twenty-two volunteers worked for 5 hours removing 177 bags of garbage, 17 tires, a television, mattress, 2 sinks, etc. It took 3 dump truck loads to clear away the garbage bags!

DISCUSSION

Surveys

We recorded terrapin sightings or evidence of terrapin activity in most of the areas we visited, which greatly expands our knowledge of the range of this species in northeastern Florida. We did not sight terrapins in some of the more inland creeks (Edwards and Clapboard), but, because our time was limited, we searched less intensively in areas that were initially unproductive. Therefore, I cannot say with any certainty how far upstream from the St. Johns or Nassau rivers terrapins live. Roosenburg (1993) reported Chesapeake terrapins 70 km inland from the mouth of the Patuxent River.

Without accurate population estimates for our area, we still believe our populations are not as high as those reported for Merritt Island, Florida (Seigel 1984), or the Chesapeake Bay (Roosenburg 1991a,b).

Baseline Data

Records and Measurements.—Lovich and Gibbons (1990) reviewed the literature concerning sex ratios of terrapin populations and showed them to rarely approach 1:1 (see their Table 5, p. 129). Some ratios were strongly biased in favor of males, while others were the opposite. They suggested reasons for this that included environmental sex determination, sexual differences in mortality, immigration, emigration, maturity, and bias due to sampling techniques. The overall ratio of adult male to female terrapins captured in our study was 0.12, which is very similar to that reported by Seigel (1984). Seigel's ratio was based on a trapping study adjacent to a terrapin nesting site, and this probably skewed his ratio toward females. Our overall ratio was heavily influenced by us making more captures at the nesting beach than anywhere else, and is unmistakably linked to sampling bias.

If we consider only captures with methods less likely to favor one sex (i.e., gill netting, otter trawling, modified crab trapping, dip netting, and cast netting), we caught 22 males and 15 females (ratio = 1.47). Male terrapins mature earlier than females (Cagle 1952, Seigel 1984), and this ratio is consistent with the contention that the sex that matures earliest is more prevalent in the population (Lovich and Gibbons 1990). However, it is possible that many females were away from the creeks and at the nesting areas at the time we employed our capture techniques. In that case we would have a male bias.

Mean PLs for both males and females were similar to other published records (Seigel 1984; Roosenburg 1991*a,b*; Morreale 1992). Our smallest females were smaller than those of Montevecchi and Burger (1975), but their sample was only of nesting females, and ours includes some females too young to nest. Both male and female PL ranges reported by Morreale (1992) were wider than ours, as were Mann's (1995) female PLs. Morreale's (1992) sample was much larger than ours, but both previous authors applied techniques that proved successful at capturing some smaller terrapins. Also, we did not include 3 immature terrapins with PLs as small as 84 mm, because we were not certain of their sex.

The PL of the smallest gravid female was 144.0 mm. Of 10 terrapins with PLs 144.0–149.0 mm found at the nesting beach, 8 were gravid, and it is likely the other 2 had oviposited before they were captured. We captured only 6 terrapins between 140.0 and 143.0 mm, and only 1 was at the nesting beach. We captured no females between 130.0 and 139.0 mm. Our smallest gravid female was somewhat larger than the 132 mm reported in New Jersey (Montevecchi and Burger 1975), 135 mm in Central Florida (Seigel 1984), and 138.0 mm in South Carolina (Lovich and Gibbons 1990). The smallest gravid females from Mississippi (Mann 1995) and Maryland (Roosenburg 1991*b*) had PLs of 147.1 mm and 175.00 mm, respectively, and ours was smaller than that.

X-rays.—Clutch sizes determined from x-rays were combined with those from excavated nests. Both are discussed below.

Diet.—Numerous records of dietary preferences of captive terrapins exist (Coker 1906, Hildebrand and Hatsel 1926, Hildebrand 1929, Allen and Littleford 1955), but most accounts for wild-caught terrapins are anecdotal (Coker 1906, Hurd et al. 1979, Bishop 1983). A variety of items such as crabs, mussels, clams, gastropods, annelid worms, and fish have been recorded. Davenport et al. (1992) determined the sizes of periwinkles, mussels, and crabs that captive male terrapins would eat. Tucker et al. (1995) did a systematic study of terrapin diets in nature in South Carolina.

Several aspects of our results differ from previous studies. The most important food item for terrapins in South Carolina was the salt marsh periwinkle, which made up 76–79% of the dietary mass (Tucker et al. 1995). In our study periwinkles were a very distant third, accounting for only 6.7% of the total fecal mass.

Conversely, the dwarf surf clam was most important in our study (83.1% total fecal mass), but this species had not been recorded previously as a dietary item for terrapins despite the fact that this clam is present throughout the terrapin's range. Tucker et al. (1995) list the marsh clam (*Polymesoda caroliniana*) as a food item, but probably only of limited importance to smaller (presumably male) terrapins.

Dwarf surf clams live in the mud in the creek bottoms in intertidal zones, while periwinkles climb *Spartina* during high tide and may roam the mud surface at low tide. Both species were common in the study area, and abundance of clams in fecal samples may be due to locally differing terrapin behavior.

Shine (1989) suggested that dimorphic characteristics such as terrapin head size, which confer no apparent reproductive advantage, may serve to cause a dietary niche shift between males and females such that they do not compete for resources. We did not note the resource partitioning due to sexual dimorphism in terrapin head size reported by Tucker et al. (1995). Females in our study did take slightly more crabs and periwinkles than did males, but the dwarf surf clam was most important to both. It could be that surf clams were in such extreme abundance during the study that they were simply easiest for both sexes to acquire. If that was the case, the sexes were not actually competing for a limited resource (Pianka 1974).

We recorded a major shift in food usage by females from 1995 to 1996. While surf clams were most important in both years, their percentage of fecal mass in 1996 was only half that in 1995. Because we did not monitor clam populations, we can only speculate on the cause for such a shift. It could be that an excess of surf clams from 1995 was waning in 1996, and female terrapins shifted toward periwinkles as clams became more difficult to find.

Capture Methods

Raking.—Burger (1976) established that hatchling terrapins seek shelter under the nearest vegetation as soon as they emerge from the nests. Pitler (1985) found hatchlings and juveniles under matted cord grass, boards and other flotsam, and large rocks from late May through October in New Jersey. Lovich et al. (1991) recorded that hatchlings released in a salt marsh avoided open water and instead sought refuge under tidal debris. We found no terrapins by raking tidal debris or looking under flotsam, although 5 hatchlings had been taken at this beach on 1 March 1992 under mats of tidal debris (K. Studenroth, personal communication). We discovered 2 hatchlings on the nesting beach on 5 and 7 March 1996, but one was in the open and the other

was amongst some sea ox-eye. This suggests that either hatchlings in northeastern Florida do not often use debris as cover, or perhaps they use it fleetingly very early in the season. Also, our raking efforts were concentrated in April and May; it is possible that hatchlings use tidal debris as cover at other times, such as hatching season, which is July–September.

Cast Netting.—While we had little success with this method during the study, I must add that in the 1997 season (after the period covered in this report) we were successful with a cast net. We used a 2.7-m-radius mullet cast net with a mesh size of 2.5 cm and heavier weights than we used before. The larger mesh and heavier weights caused the net to sink around the terrapins more quickly. We also were fortunate to have a skilled net thrower. The method was more successful at low tide and when there was an actual terrapin to target (as opposed to blind throws).

Turtle Trapping.—Our lack of success with hoop traps was similar to the experiences of Morreale (1992) and Mann (1995) with his “floating crab pots.” The method is not effective for terrapins, perhaps because they forage on the bottom when in the water.

Gill Netting.—Seigel (1984), Lovich and Gibbons (1990), and Morreale (1992) have successfully used trammel nets (similar to gill nets) to capture terrapins. Mann (1995) had less success and added that using these was very labor-intensive in terms of removal of by-catch and continuous monitoring of the net. Some researchers who have used this method with more success were able to use 2 nets placed at some distance from one another, so that terrapins between them were more likely to be captured (Seigel 1984). We were advised by the Division of Marine Resources (FDEP) that we could not be exempted from the new Florida Statutes which allow only 1 gill net in the water per boat (DNR 46-4.0081 1b). We believe that, had we been allowed to use 2 nets at a time, this method would have been more useful. We were able to collect both sexes with this method, and our rate of 0.13 terrapins/man-hour ranks ahead of modified crab trapping in terms of efficiency.

Otter Trawling.—We captured 0.77 terrapins/man-hour in 1995 and 0.23 terrapins/man-hour in 1996, and this was the best technique we used other than hand capture. Hurd et al. (1979), Yearicks et al. (1981, in the summer), and Auger (1989) also found most success with this method, but Lovich and Gibbons (1990), Morreale (1992), and Mann (1995) reported otherwise. Mann (1995) noted that when channels are very convoluted the net cannot be pulled fast enough to prevent turtles from escaping; also, some channels were too shallow for trawling at low tide. Another problem in our area was that we had to avoid oyster mounds, or they would tear the net.

Both Hurd et al. (1979) and Auger (1989) found trawling to work best when tides were low. This was true for our study; our rate in 1995 was recorded near low tide, while that for 1996 was at high tide. In shallow water the terrapins are apparently more concentrated.

This method allowed us to capture adult males as well as females; we caught more males (ratio 8:5) whereas Auger (1989) caught more females. Since our sample is quite small, no conclusions can be drawn from this.

Modified Crab Trapping.—Our capture rate of 0.047 terrapins/trap-day captured in modified crab traps is lower than the rate for South Carolina (0.11, Bishop 1983), Mississippi (0.48, Mann 1995), Maryland (0.17, Roosenburg et al. 1997), and New Jersey (0.45, Wood 1997). Our methods did not differ notably from the others, and we took our results (and other evidence including visual surveys) to suggest that our population density was lower than the others.

We moved our traps infrequently because they were not readily transportable on the boat, and our time was limited. Capture events occurred within 1–14 trap days (mean = 8), and we believe that had we moved traps more frequently, perhaps our yield would have increased. Other than Mann (1995), who fished traps for 50 trap-hours at a time, authors have not addressed this issue.

On 4 occasions we trapped terrapins in multiples of 2–5. Others have reported this gregarious tendency (Bishop 1983, Mann 1995, Roosenburg et al. 1997, Wood 1997) and noted its potentially destructive impact to terrapin populations where crab trapping is prevalent. From time to time we checked commercial traps that did not belong to us (Table 5). Twice in Deep Creek in the spring we found terrapins in these traps before the trapper abandoned the area by late April 1996. On 1 of these occasions there was a single dead male, and on the other there was a group of 6 dead males, 1 dead immature female, and 1 live male. In mid-June we found 3 adult females and 2 adult males, all dead, in a commercial trap on Harrison Creek (see Fig. 1).

We trapped 16 terrapins in May and only 2 in June, despite a similar number of trap days in each month. Bishop (1983) trapped more terrapins in April and May than in other months, and attributed this pattern to feeding and reproductive behaviors at this time of year. Maybe if we had trapped earlier in the season, and not in June, our yield would have been higher.

In terms of all adult terrapins found in traps (including commercial traps) we had a male-biased sex ratio (18:11), but the ratio was 1:1 for our modified traps. Male-biased ratios have been reported for this technique by others, because the trap funnel openings were too small for larger females to enter (Bishop 1983, Mann 1995, Roosenburg et al. 1997, Wood 1997). We enlarged our entrances because our purpose was to capture all sizes and sexes of terrapins.

Of the 18 terrapins we trapped, 5 drowned. This was very hard on all of us because, of course, the idea was to develop a trap that could be used to study live terrapins. The season was too brief to test conclusively all the corrections we tried for keeping terrapins alive in the traps. Nevertheless, they are worthy of discussion so that similar situations can be avoided. The corrections we made concerned the church, cylinder size, and weekend bait.

Mann (1995) experienced some terrapin deaths with his version of the modified crab trap. In normal crab traps the capture chamber is divided into upper and lower compartments by a mesh partition attached to opposing inside walls just above the entrance funnels. Captives enter through the funnels, and the partition has openings so that captives can reach the upper area. The partition peaks in the middle of the trap in the shape of a church, hence its name. Mann suggested removing the church from the trap, so nothing would impede the terrapins from finding their way to the surface. We initially left churches in 6 of our traps. We had 4 terrapin deaths (3 events) in traps that had churches. However, all terrapins had found their way above the church, so it is unclear how the churches could have caused the deaths. It is possible that limited space between the church and trap roof made it too confusing to find the cylinder opening. We removed all churches by early June, but our fifth death occurred in a trap with no church.

We also thought that, especially in cases of multiple captures, our cylinders were not wide enough to accommodate the terrapins. By late May we decided to replace the cylinders with new ones of 40-cm diameter (our originals were 22-cm diameter). We did the change-outs in the field, and this was quite time-consuming, thus limited the time we could have used to relocate traps. After the new cylinders were attached, we only had 2 more captures, and 1 of these died, indicating problems still existed with the trap design. We thought that because terrapins could find their way through the church (and all ours did), they should be able to find the cylinder opening as well. It may be that the 10 cm of trap roofing on all sides confused the terrapins such that they could not find their way. Perhaps the best trap

modification for catching live terrapins is one where the sides continue straight up to the water surface with no roof at all (Roosenburg et al. 1997). The problem with such a trap is that it would be even more awkward to transport in the jon boat. (We tried a version of Roosenburg et al.'s [1997] trap in 1997 and had no mortality.)

Three of our terrapin deaths occurred on Mondays after the traps had not been checked for 2 days. Terrapins may have become trapped soon after traps were set and just grown too exhausted to stay at the surface. Tom Mann (personal communication) suggested that terrapins are more attracted to crushed crab as bait than to fish. On our last 4 Fridays we baited traps with fish rather than crab, so terrapins would be less likely to enter. (In a sense then, we were not trapping for terrapins on the last 4 weekends of the study, so our 379 trap-days is probably inflated by 81 trap-days. In that case our trapping rate was 0.06 terrapins/trap-day.) We caught no more terrapins on weekends, but whether that was due to the fish bait is unclear. After all, crab trappers often bait with fish, and terrapins enter their traps.

We captured our bait crab in our own traps, or we purchased it from a fish market. In an effort to catch more bait, we had 1 unmodified crab trap baited with fish for 21 trap-days. We sought to reduce terrapin catch in this trap by using Wood's (1997) by-catch reduction apparatus. This is just a length of wire coat hanger attached to the innermost extent of the funnel opening to limit its size to 5 cm x 10 cm. We captured no terrapins in this trap, while capturing 12 crabs.

Hand Capture.—Seigel (1984) and Auger (1989) found terrapins basking on spoil islands, mud banks, or in the marshes and had success searching on foot and capturing them. We seldom saw the terrapins in our population basking, but when we did we were in the boat, and they immediately dove into the water. Mann (1995) found “marsh walking” somewhat successful, but in all the island and marsh searching we did (exclusive of the nesting beach) we found only 2 gravid females on an oyster mound at the mouth of Pumpkin Hill Creek (see Fig. 1).

Although we did not keep track of man-hours when searching the nesting beach for terrapins and, therefore, cannot compare time spent to that for other techniques, we captured most of our terrapins this way, making this our most successful capture method. Montevicchi and Burger (1975), Auger (1989), and Goodwin (1994) also had much success capturing females at nesting beaches, and Seigel (1980b) collected them as they nested on dikes.

Several problems are inherent in this method, and perhaps the most important is that researchers cannot depend on discovering nesting beaches in order to study terrapins. We have searched nearly all shorelines and islands within the study area, and this is the only nesting beach we located (the one in Fernandina is outside the area). The other major problem is that only nesting females are captured, making it difficult to conclude anything meaningful about demographics. If sex ratios of natural terrapin populations were consistent, then inferences about the population could be made with data from only one sex. However, reported sex ratios in terrapin populations have been contradictory (Seigel 1984, Lovich and Gibbons 1990, Roosenburg et al. 1997), and even that would not answer questions concerning juvenile stages.

On the other hand, this method has allowed us to determine the relationship of nesting behavior to tidal fluctuations, time of day, and season. Terrapin collections during the volunteer week confirmed that most females prefer to nest from several hours before to about 1 hour after high tide (Fig. 3), and this was the case for other terrapin studies (Burger and Montevecchi 1975, Auger and Giovannone 1979, Goodwin 1994). An exception was in Maryland (Roosenburg 1991*b*), where tidal fluctuation is minimal.

Most of our nesting females were collected during the day (a function of our effort), but nocturnal nesting does occur in northeastern Florida. Nocturnal nesting did not occur in New Jersey (Burger and Montevecchi 1975), Rhode Island (Goodwin 1994), or Merritt Island, Florida (Seigel 1980*b*), but was recorded infrequently in Maryland (Roosenburg 1991*b*, 1994) and in 45% of the cases in Massachusetts (Auger and Giovannone 1979).

In late June 1996 we recaptured 3 terrapins that had been previously captured in May. All 3 had eggs upon recapture. One also had had eggs 5 weeks previously, and another was captured 3 weeks previously as it covered up its newly deposited eggs. This is strong evidence that these terrapins produce multiple clutches. Multiple clutches in natural terrapin populations have been reported by Auger and Giovannone (1979), Seigel (1980*b*), Roosenburg (1990), and Goodwin (1994).

Hand capture of females at the nesting beach also allowed us to collect baseline data on a significant portion of the female population, begin a recapture study, and assess site fidelity. In addition, it enabled us to study many aspects of the nests (discussed elsewhere in this document).

Head Counts, Temperatures, and Salinity Records

The most important information from this aspect of the study is that terrapins in northeastern Florida were not observed using the channels from December through February, and sometimes into March. We never saw terrapins in the water at temperatures less than $T_w = 18^\circ\text{C}$. Davenport and Ward (1993) reported appetite depression in terrapins when water temperatures were below 20°C , which they suggested was caused by decreased metabolic rate.

Yearicks et al. (1981) reported that hibernation in New Jersey terrapins occurs from December to April or May, and that the turtles bury themselves in the mud in the creek bottoms or banks. We do not know whether our terrapins actually hibernate, because we have not seen them do so. However, we observed a marked decrease in their apparent abundance in the winter.

Our head counts changed in proportion to T_w , and this was particularly apparent in spring and fall (Fig. 4). Although our females did aggregate at the nesting beach, our data in the tidal creeks did not show the large spring aggregations reported by Seigel (1980a), and our highest mean head counts occurred June–September. (Means other than May and June are based on only 2–4 records and are, therefore, less reliable.)

Nesting Beach Studies

Crawls, Nest and Egg Measurements, and Clutch Size.—Our 78-day nesting season is the longest reported for wild terrapins. Northern populations have brief seasons of 5–6 weeks (Burger 1977, Goodwin 1994), and Maryland's season varied from 56 to 71 days (Roosenburg 1991b). The earliest Seigel (1980b) found gravid females or nests in Central Florida was 28 April in one year, and the latest was 1 July in another year. Combining the dates, his season would be 65 days, which is still shorter than ours by 2 weeks—we found nesting evidence through 19 July. If the trend is for nesting seasons to be longer in warmer climates (Goodwin 1994), the season in Central Florida should be as long as or longer than ours.

Terrapin nest measurements have not been reported often, but our mean depths to the uppermost egg (94.1 mm) and bottom of the nest (139.9 mm) are similar to those reported by Montevecchi and Burger (1975) and Roosenburg (1992).

The mean egg measurements for terrapins in northeastern Florida overlapped those from Central Florida (Seigel 1980b) and Maryland

(Roosenburg and Kelly 1996), and were substantially larger than those reported from northern areas (Montevecchi and Burger 1975, Goodwin 1994). However, while our mean clutch size (6.7) was exactly that reported by Seigel (1980b), it was substantially lower than those from more northern areas (Burger 1977, Goodwin 1994, Roosenburg and Dunham 1997).

Montevecchi and Burger (1975) noted a geographic trend in terrapins for clutch sizes to decrease in the southern part of their range. Latitudinal decreases in clutch size within species have been reported in other turtles (Tinkle 1961, Powell 1967, Christiansen and Moll 1973, Moll 1973), some other reptiles (Fitch 1985), and birds (Lack 1954, Cody 1966). With terrapins the trend is somewhat unclear; while most reported mean clutch sizes decrease with latitude from a high of 15.8 in Rhode Island (Goodwin 1994) to a low of 6.7 in Florida (Seigel 1980b, this study), Maryland's clutch size of 12.3 (Roosenburg and Dunham 1997) is higher than that of New Jersey (Burger 1977). Gibbons and Tinkle (1969) noted that local factors sometimes override this trend.

Egg sizes for terrapins in the southern range (Seigel 1980b, this study) are larger than those from extreme northern parts of the range (Burger 1977, Goodwin 1994), but are similar to those from Maryland (Roosenburg and Kelley 1996). Moll and Legler (1971) reported increasing egg size in the southern range of *Kinosternon* and suggested that larger eggs may produce larger hatchlings, which would be less vulnerable to predation. Table 6 shows that hatchling sizes in our study ($n = 4$) did not differ from those in Central Florida (Seigel 1980b) nor from those in New Jersey (Burger 1977) or Rhode Island (Goodwin 1994). However, the Central Florida hatchlings were substantially larger than those in Rhode Island, but not those in New Jersey.

Table 6. Mean dimensions of terrapin hatchlings from several areas throughout their range.

Place	<i>n</i>	CL ^a	PL ^b	W ^c	M ^d	Source
Northeast Florida	4	29.5 (1.2) ^e	26.4 (0.8)	24.7 (0.9)	6.8 (1.0)	This study
Central Florida	29	31.9 (1.5)	27.9 (1.4)	ND	8.83 (0.15)	Seigel 1980b
New Jersey	207	27.5 (1.1)	24.4 (1.1)	22.3 (1.6)	6.8 (0.9)	Burger 1977
Rhode Island	39	28.4 (1.4)	26.2 (1.4)	ND ^f	ND	Goodwin 1994

^aCL = carapace length in cm.

^bPL = plastron length in cm.

^cW = shell width in cm.

^dM = mass in g.

^eNumbers in parentheses are standard deviations.

^fND = no data.

With these conflicting data, and considering that hatchlings in Florida are still quite small with relatively soft shells, it is difficult to consider them less vulnerable to predation.

Therefore, the combined trends for terrapins are that decreasing clutch size is accompanied by increasing egg size as latitude decreases (clutch size exception of Roosenburg and Dunham 1997). Moll (1979) described 2 nesting strategies exhibited by turtles. Type I females lay large clutches of small eggs in a well-defined area and season; Type II females lay smaller clutches of large eggs at various times and areas. Temperate species usually fall into Type I and tropical species conform to Type II. Seigel (1980b) suggested that terrapins in Central Florida were intermediate between the types, as they lay small clutches of large eggs, but the season and nesting areas are well defined. Terrapins in northeastern Florida are similar to those in Central Florida. Goodwin (1994) characterized terrapins in Rhode Island as Type I.

Depredated Nest Survey.—Goodwin (1994) reported 88% nest predation, all of which occurred near the time nests were deposited. Some authors have found predation to be bimodal, with peaks during egg deposition and at the time of hatching (Auger and Giovannone 1979, Roosenburg 1992). Burger (1977) reported a peak during hatching. We have shown that nesting in northeastern Florida occurs from early May through mid- to late July. Our predation peaks once, then plateaus for 2 months (Fig. 5) in what would be the middle and end of the laying season. Low predation in May, an important nesting month, may be due to predators not keying in on this food source as the season commences (Burger 1977, Roosenburg 1992, Goodwin 1994).

High predation in August, after nesting has stopped, suggests that predators are keying in on hatching scents. Indeed, we discovered 1 dead hatchling terrapin in a depredated nest with eggshells in July, and a hatchling carapace in August. Reported mean incubation periods vary from 66 (Seigel 1980b) to 108 days (Auger and Giovannone 1979). This means that eggs deposited in early May would likely hatch in early July, so our high number of raided nests in July probably also reflects predation on hatched nests. The nesting season in northeastern Florida is long enough that nesting continues as hatching begins in July; therefore the bimodal effect is masked. More puzzling is the very low predation in September, when July nests should be hatching.

Raccoons and fish crows (*Corvus ossifragus*) were nest predators in our study area. Raccoons were the most important nest predators in this and all other studies (Burger 1977, Goodwin 1994, Roosenburg and Place 1994). We have confirmed the presence of raccoons on the beach with skeletal remains,

sightings, and tracks to and from raided nests. We realized crows were predators when we noticed several crows watching as we processed nests, and then searching the sites after we left. On several occasions we watched crows digging with their beaks (also reported by Burger 1977), and these sites proved to be nests. We sometimes used this crow behavior to discover nests. Sometimes terrapin crawls with concentrated crow tracks around them also yielded nests. We even watched 1 crow follow a terrapin up the beach.

Burger (1977) also listed red foxes (*Vulpes fulva*), American crows (*Corvus brachyrhynchos*), and laughing gulls (*Larus atricilla*) as nest predators in New Jersey. The red fox generally is replaced by the gray fox (*Urocyon cinereoargenteus*) in Florida, but we recorded no evidence of fox presence anywhere in the study area. It is possible that we mistook some common crows for fish crows, but we always heard the characteristic 2-part call of the fish crow. Laughing gulls were on the beach very infrequently, and we never saw them associated with nests. Arndt (1991, 1994) reported ghost crabs (*Ocypode quadrata*) as terrapin hatchling predators, and this species is abundant on the beach. Although we recorded no predation by ghost crabs, it is a possibility. Goodwin (1994) noted skunks (*Mephitis mephitis*) and otters as nest predators. We recorded no skunks in the study area, and we infrequently saw otters, although not at the nesting beach. Roosenburg and Place (1994) recorded foxes and otters as nest predators in Maryland.

MANAGEMENT RECOMMENDATIONS

Surveys and Baseline Data

- Extend the boundaries of the study area.
- Continue long-term monitoring and research on the current population.
- Initiate telemetry studies.

This study has been successful in establishing the presence of the Carolina diamondback terrapin in most of the tidal creeks associated with the Intracoastal Waterway from the St. Johns River north to southern Amelia Island. The nearest Florida population studied previously is that on Merritt Island (Seigel 1980*a,b,c*, 1984, 1993). I recommend that the study area be extended north and south beyond the present boundaries to determine if terrapin distribution is continuous or disjunct in northeastern Florida.

With 211 terrapins marked (320 after the 1997 season), it is important to continue capturing, marking, and monitoring the population within the study area. The northeastern Florida population appears to be less dense than some others (Roosenburg 1991*a,b*), and without a long-term history, we cannot say if this is normal for the area (Gibbons 1987, Dodd 1992). Long-term monitoring of terrapins can also establish them as an indicator species with respect to the ecological status of the saltmarsh habitat. Telemetry studies can help determine which specific areas of the marsh are being used by terrapins and how this usage shifts seasonally.

Capture Methods

- Attempt to locate other nesting beaches.
- Use otter trawling at low tide in tidal creeks inhabited by terrapins.
- Use cast netting where aggregations of terrapins are apparent.

We captured terrapins with most of the techniques we used. Some methods, such as snorkeling (Morreale 1992), seining (Lovich and Gibbons 1990), and looking under debris (Pitler 1985), that have been very successful in other areas, did not work in our area. Considering the effort put forth, gill netting and modified crab trapping were not very efficient. Gill netting would presumably be more efficient if 2 nets could be used at a time. The most successful method we used was hand-capture at the nesting beach. We found most terrapins between several hours before and 1 hour after daytime high tide. However, it is probably not appropriate to plan to find a nesting beach for a population study; we were very fortunate to have discovered one. Also, this method eliminates all but reproductive females.

The most efficient technique we used to catch adults and juveniles of both sexes was otter trawling. This is best done in tidal creeks where terrapins are known to be, and trawling at low tide is more successful than at high tide. Although our data do not show it, one of the best methods was cast netting with a mullet net. As explained previously, the lightweight bait net used in 1995 and 1996 did not sink fast enough to trap terrapins. A larger and heavier mullet net worked well at low tide in 1997. While otter trawling requires a larger boat and motor, cast netting can be done with a minimum of equipment.

Crab Trapping

- Use modified crab traps to capture terrapins from April through June for research.
- Restrict commercial trapping to deep waters of the Intracoastal Waterway and perhaps the St. Johns River, and allow no commercial trapping in tidal creeks from April through June.
- Require wire excluder devices described by Wood (1997) in all entrance funnels of commercial crab traps.

In a recent workshop on diamondback terrapins, the most commonly listed threat to their existence, in the opinions of researchers in each state within the terrapin's range, was crab trapping (Seigel and Gibbons 1995). Although our modified crab traps captured relatively few terrapins, we did establish that terrapins enter and drown in crab traps in northeastern Florida.

We only trapped in May and June (and July in 1997), and captured more terrapins in May than in June. In July 1997 we only caught 2 terrapins in traps the entire month. Bishop (1983) trapped more terrapins in April and May in South Carolina than in any other month between March and November; he caught very few or none from July on. These data suggest that terrapins are more vulnerable to crab traps from April through June in its southern range. This time period overlaps much of the terrapin nesting season in northeastern Florida, and Seigel (1980c) reported that courtship and mating begin in late March and April in Central Florida.

Although terrapins undoubtedly use the Intracoastal Waterway at certain times, we rarely sighted them there. Therefore, at least from April through July, I recommend that, in deference to terrapins, commercial crab trapping be restricted to the deeper waters of the Intracoastal Waterway and no traps be allowed in the adjacent tidal creeks where terrapins aggregate. In Maryland, crab traps are restricted to the deeper waters of the Chesapeake Bay all year round (Roosenburg et al. 1997).

An alternative (or perhaps additional) recommendation would be to require the use of wire excluder devices as described by Wood (1997). This entails threading a piece of wire coat hanger into the inner mouth of each entrance funnel to limit the size of the terrapin that can enter the trap. Reproductive females are too large and are spared; Wood (1997) also reported a possible increase in crab capture in traps with excluders.

Pet Trade

- Keep nesting beach locations confidential among researchers.
- Enforce current legal restrictions concerning possession and sale of terrapins.

Terrapins are unique and are attractive to some pet enthusiasts. This, coupled with the extreme vulnerability of females when they are on shore nesting, leaves them susceptible to exploitation by the pet trade. George Heinrich and I visited Tom Crutchfield's pet shop in Lake Panasoffkee, Florida, on 15 July 1995. The shop had 21 adult female diamondback terrapins for sale at \$30.00 each. They looked like *Malaclemys terrapin centrata*. Employees would only tell us that the terrapins came from eastern Florida. A friend of George's said he saw this group in the shop several days earlier with eggs in the bottom of the trough. Because these were all females, we suspected that the supplier collected them from a nesting beach. It is essential that nesting beach locations be kept strictly confidential among responsible researchers.

In 1996 the Florida Game and Fresh Water Fish Commission enacted legislation to control trafficking in terrapins by the pet trade. The ruling restricts the possession of diamondback terrapins to 2 per person, prohibits buying them, and prohibits their possession for sale.

Shrimp Trawling

- Study the effects of shrimp trawling on terrapins, particularly in the Nassau River where terrapins aggregate to nest.
- Consider restricting trawling during the nesting season in areas used by terrapins.

The aggregating behavior of courting and nesting terrapins makes them vulnerable. Shrimp trawling in these areas could be detrimental to terrapins. I have been told that trawling for live shrimp is not as dangerous to terrapins because the nets must be raised after time periods short enough to keep the shrimp alive (Bill Tahan, personal communication). If this is so, presumably

it would ensure that terrapins do not drown. I am particularly concerned with the waters of the Nassau River adjacent to the nesting beach. From May to July, at least hundreds of reproductive females are offshore. If caught in shrimp trawls and trawling lasts too long, they will drown. Also, our recent telemetry studies have shown that at least some of the terrapins that nest on the Big Talbot beach spend the rest of the year about 4.5 miles up the Nassau River in the Back River area or in Pumpkin Hill Creek (see Fig. 1). This makes trawling and crab trapping in the Nassau River and Pumpkin Hill Creek during nesting season problematic to terrapins. As I understand it, trawling is currently banned in Pumpkin Hill Creek. We should study the effects of shrimp trawling on terrapins before limiting it in the Nassau River, but this should be considered.

Nesting Beach

- Protect the identity of the nesting beach.

As noted above, because nesting females are quite vulnerable to collection, it is important that the location of the beach be kept confidential. The nesting beach is on a small island joined to Big Talbot Island by a bridge across Sawpit Creek. To the north it is joined to Amelia Island by a longer bridge. These bridges were at one time the only access from the Talbot Islands to Amelia Island, but a new bridge has been built from Big Talbot Island directly to Amelia Island. The old bridges were to be removed, but instead they were left as fishing bridges. Most people fish from the large bridge, and few use the island.

I have considered recommending some type of formal protection and/or posting of the beach as critical habitat. This has been done successfully for some bird nesting areas. However, it seems that the beach has survived without detection until now, and I hesitate to identify it publicly as a turtle nesting area. Unless a ranger were present almost continuously during the nesting season, identifying the beach might notify interested collectors, and that could be devastating to the population.

Development

- Protect the entire area from development and channelization.
- Prevent bulkheading and use of rip rap.
- Dredging operations should avoid nesting areas during that season.

Another threat to terrapins identified at a recent workshop was habitat loss/development (Seigel and Gibbons 1995). Much of our study area is

within state or federal preserves, except for the western shoreline of the Intracoastal Waterway, which is Black Hammock Island. With the strong tidal influence and extensive marshes, the area would not seem to be in danger of excessive development.

The northern shoreline of Black Hammock Island, on the Nassau River, is heavily bulkheaded and invested with rip rap, preventing the possibility of terrapin nesting. Perhaps terrapins nested there prior to development. If they did not, it would mean that they would bypass Black Hammock in order to get to the currently used beach—which they certainly might have done. To protect the terrapin within the study area, development of the marshes, channelization of rivers and creeks, and further bulkheading should be curtailed.

Dredging is done periodically to clear waterways of silt and oyster build-up. This should be done with consideration for the terrapin nesting season, and dredging near nesting areas should be avoided during this time.

Predator Control

- Conduct a long-term study of the relationship between terrapin nesting and their major predator, the raccoon, and attempt to discover if the current nest predation rate is excessive.

Raccoons were the major nest predators of terrapins in this and other studies (Burger 1977, Roosenburg 1992, Goodwin 1994). They are nest predators of other turtles, crocodilians, and ground nesting birds, and they affect the populations of several small mammals (MacLaren 1992). It has been suggested to me that when bridges to the nesting island are removed, I also remove the raccoons. I think that type of decision should not be made without more information. Terrapins and other species have been under predation pressure from raccoons for a long time, and it is likely that their reproductive strategies have evolved under such influences. Removal of this predation could have negative consequences for the terrapin population in the long run.

LITERATURE CITED

- Allen, J. F., and R. A. Littleford. 1955. Observations on the feeding habits and growth of immature diamondback terrapins. *Herpetologica* 11:77–80.
- American Public Health Association. 1995. Standard methods for the examination of water and wastewater. Nineteenth edition. American Public Health Association, Washington, D.C., USA.
- Arndt, R. G. 1991. Predation on hatchling diamondback terrapin, *Malaclemys terrapin* (Schoepff), by the ghost crab, *Ocypode quadrata* (Fabricius). *Florida Scientist* 54:215–217.
- . 1994. Predation on hatchling diamondback terrapin, *Malaclemys terrapin* (Schoepff), by the ghost crab, *Ocypode quadrata* (Fabricius). II. *Florida Scientist* 57:1–5.
- Ashton, R. E., Jr., and P. S. Ashton. 1985. Handbook of reptiles and amphibians of Florida. Part Two: lizards, turtles and crocodilians. Windward Publishing Company, Miami, Florida, USA.
- Auger, P. J. 1989. Sex ratio and nesting behavior in a population of *Malaclemys terrapin* displaying temperature-dependent sex determination. Dissertation, Tufts University, Boston, Massachusetts, USA.
- , and P. Giovannone. 1979. On the fringe of existence, diamondback terrapins at Sandy Neck. *Cape Naturalist* 8:44–58.
- Babcock, H. L. 1926. The diamond-back terrapin in Massachusetts. *Copeia* 1926:101–105.
- Barney, R. L. 1922. Further notes on the natural history and artificial propagation of the diamondback terrapin. *Bulletin of the U.S. Bureau of Fisheries* 38:91–111.
- Bishop, J. M. 1983. Incidental capture of diamondback terrapins by crab traps. *Estuaries* 6:426–430.
- Burger, J. 1976. Behavior of hatchling diamondback terrapins (*Malaclemys terrapin*) in the field. *Copeia* 1976:742–748.
- . 1977. Determinants of hatching success in the diamondback terrapin, *Malaclemys terrapin*. *American Midland Naturalist* 97:444–464.

- _____. 1989. Diamondback terrapin protection. *Plastron Papers* 19:35–40.
- _____, and W. A. Montevecchi. 1975. Nest site selection in the terrapin *Malaclemys terrapin*. *Copeia* 1975:113–119.
- Burns, T. A., and K. L. Williams. 1972. Notes on the reproductive habits of *Malaclemys terrapin pileata*. *Journal of Herpetology* 6:237–238.
- Cagle, F. R. 1939. A system of marking turtles for future identification. *Copeia* 1939:170–172.
- _____. 1952. A Louisiana terrapin population (*Malaclemys*). *Copeia* 1952:74–76.
- Christiansen, J. L., and E. O. Moll. 1973. Latitudinal reproductive variation within a single subspecies of painted turtle, *Chrysemys picta bellii*. *Herpetologica* 29:152–163.
- Cody, M. L. 1966. A general theory of clutch size. *Evolution* 20:174–184.
- Coker, R. E. 1906. The cultivation of the diamond-back terrapin. *North Carolina Geological Survey Bulletin* 14:1–169.
- _____. 1951. The diamond-back terrapin in North Carolina. Pages 219–230 in H. F. Taylor, editor. *Survey of marine fisheries in North Carolina*. University of North Carolina Press, Chapel Hill, North Carolina, USA.
- Davenport, J., M. Spikes, S. M. Thornton, and B. O. Kelly. 1992. Crab-eating in the diamondback terrapin *Malaclemys terrapin*: dealing with dangerous prey. *Journal of Marine Biology Association U.K.* 72:835–848.
- _____, and J. F. Ward. 1993. The effects of salinity and temperature on appetite in the diamondback terrapin *Malaclemys terrapin* (Latreille). *Herpetological Journal* 3:95–98.
- Dodd, C. K., Jr. 1992. Biological diversity of a temporary pond herpetofauna in north Florida sandhills. *Biodiversity and Conservation* 1:125–142.
- Ernst, C. H., J. E. Lovich, and R. W. Barbour. 1994. *Turtles of the United States and Canada*. Smithsonian Institution Press, Washington, D.C., USA.

- Finneran, L. C. 1948. Diamond-back terrapin in Connecticut. *Copeia* 1948:138.
- Fitch, H. S. 1985. Variation in clutch and litter size in New World reptiles. Miscellaneous Publication Number 76. University of Kansas Museum of Natural History, Lawrence, Kansas, USA.
- Gibbons, J. W. 1987. Why do turtles live so long? *BioScience* 37:262–269.
- _____, and J. L. Greene. 1979. X-ray photography: a technique to determine reproductive patterns of freshwater turtles. *Herpetologica* 35:86–89.
- _____, and D. W. Tinkle. 1969. Reproductive variation between turtle populations in a single geographic area. *Ecology* 50:340–341.
- Goodwin, C. C. 1994. Aspects of nesting ecology of the diamondback terrapin (*Malaclemys terrapin*) in Rhode Island. Thesis, University of Rhode Island, South Kingstown, Rhode Island, USA.
- Hay, W. P. 1917. Artificial propagation of the diamond-back terrapin. *Bulletin of the U.S. Bureau of Fisheries* 24:1–20.
- Hildebrand, S. F. 1929. Review of experiments on artificial culture of diamond-back terrapin. *Bulletin of the U.S. Bureau of Fisheries* 45:25–70.
- _____. 1932. Growth of diamond-back terrapins: size attained, sex ratios and longevity. *Zoologica* 9:551–563.
- _____, and C. Hatsel. 1926. Diamondback terrapin culture at Beaufort, N.C. U. S. Bureau of Fisheries, Economic Circular 60:1–20.
- Hurd, L. E., G. W. Smedes, and T. A. Dean. 1979. An ecological study of a natural population of diamondback terrapins (*Malaclemys t. terrapin*) in a Delaware salt marsh. *Estuaries* 2:28–33.
- Jackson, C. G., Jr., and A. Ross. 1971. Molluscan fouling of the ornate diamondback terrapin, *Malaclemys terrapin macrospilota*. *Herpetologica* 27:341–344.
- _____, _____, and G. Kennedy. 1973. Epifaunal invertebrates of the ornate diamondback terrapin, *Malaclemys terrapin macrospilota*. *American Midland Naturalist* 89:495–497.

- Lack, D. 1954. The natural regulation of animal numbers. Clarendon Press, Oxford, UK.
- Lovich, J. E., and J. W. Gibbons. 1990. Age at maturity influences adult sex ratio in the turtle *Malaclemys terrapin*. *Oikos* 59:126–134.
- _____, A. D. Tucker, D. E. Kling, and J. W. Gibbons. 1991. Behavior of hatchling diamondback terrapins (*Malaclemys terrapin*) released in a South Carolina salt marsh. *Herpetological Review* 22:81–83.
- MacLaren, P. A. 1992. Raccoon (*Procyon lotor*) depredation on listed and other species of native fauna. Florida Department of Natural Resources, Tallahassee, Florida, USA.
- Mann, T. M. 1995. Population surveys for diamondback terrapins (*Malaclemys terrapin*) and Gulf salt marsh snakes (*Nerodia clarkii clarkii*) in Mississippi. Technical Report Number 37. Mississippi Museum of Natural Science, Jackson, Mississippi, USA.
- McCauley, R. H., Jr. 1945. The reptiles of Maryland and the District of Columbia. R. H. McCauley Jr., Hagerstown, Maryland, USA.
- Millsap, B. A., J. A. Gore, D. E. Runde, and S. I. Cerulean. 1990. Setting priorities for the conservation of fish and wildlife species in Florida. *Wildlife Monographs* 111:1–57.
- Mitchell, J. C., and B. V. McAvoy. 1990. Enteric bacteria in natural populations of freshwater turtles in Virginia. *Virginia Journal of Science* 41:233–242.
- Moll, E. O. 1973. Latitudinal and intersubspecific variation in reproduction of the painted turtle, *Chrysemys picta*. *Herpetologica* 29:307–318.
- _____. 1979. Reproductive cycles and adaptation. Pages 305–332 in M. Harless and H. Morlock, editors. *Turtles: perspectives and research*. John Wiley and Sons, New York, New York, USA.
- _____, and J. M. Legler. 1971. The life history of a neotropical slider, *Pseudemys scripta* (Schoepff), in Panama. *Bulletin of the Los Angeles County Museum of Natural History and Science* 11:1–102.

- Montevecchi, W. A., and J. Burger. 1975. Aspects of the reproductive biology of the northern diamondback terrapin, *Malaclemys terrapin terrapin*. American Midland Naturalist 94:166–175.
- Morreale, S. J. 1992. The status and population ecology of the diamondback terrapin, *Malaclemys terrapin*, in New York. Report to the New York State Department of Environmental Conservation and The Nature Conservancy. Okeanos Ocean Research Foundation, Hampton Bays, New York, USA.
- Palmer, W. M., and C. L. Cordes. 1988. Habitat suitability index models: diamondback terrapin (nesting)—Atlantic coast. Biological Report 82(10.151). U.S. Fish and Wildlife Service, Washington, D.C., USA.
- Pianka, E. R. 1974. Niche overlap and diffuse competition. Proceedings of the National Academy of Science U.S.A. 71:2141–2145.
- Pitler, R. 1985. *Malaclemys terrapin terrapin* (northern diamondback terrapin). Behavior. Herpetological Review 16:82.
- Powell, C. B. 1967. Female sexual cycles of *Chrysemys picta* and *Clemmys insculpta* in Nova Scotia. Canadian Field Naturalist 81:134–140.
- Pritchard, P. C. H. 1979. Encyclopedia of turtles. T. F. H. Publications, Neptune, New Jersey, USA.
- Reid, G. K. 1955. Reproduction and development in the northern diamondback terrapin, *Malaclemys terrapin terrapin*. Copeia 1955:310–311.
- Roosenburg, W. M. 1990. Final report: the Chesapeake diamondback terrapin investigations for the period 1987, 1988, 1989. Publication Number 133. Chesapeake Research Consortium, Solomons, Maryland, USA.
- . 1991a. The diamondback terrapin: habitat requirements, population dynamics, and opportunities for conservation. Pages 227–234 in A. Chaney and J. Mihursky, editors. Proceedings of a conference: new perspectives in the Chesapeake system: a research and management partnership. Publication Number 137. Chesapeake Research Consortium, Solomons, Maryland, USA.
- . 1991b. Final report: the Chesapeake diamondback terrapin investigations, 1991. Publication Number 140. Chesapeake Research Consortium, Solomons, Maryland, USA.

- _____. 1992. Life history consequences of nest site choice by the diamondback terrapin, *Malaclemys terrapin*. Dissertation, University of Pennsylvania, Philadelphia, Pennsylvania, USA.
- _____. 1993. Final report: the Chesapeake diamondback terrapin investigations, 1992. Publication Number 146. Chesapeake Research Consortium, Solomons, Maryland, USA.
- _____. 1994. Nesting habitat requirements of the diamondback terrapin: a geographic comparison. *Wetlands Journal* 6(2):8–11.
- _____. 1996. Maternal condition and nest site choice: an alternative for the maintenance of environmental sex determination? *American Zoologist* 36:157–168.
- _____, and A. E. Dunham. 1997. Allocation of reproductive output: egg- and clutch-size variation in the diamondback terrapin. *Copeia* 1997:290–297.
- _____, and K. C. Kelley. 1996. The effect of egg size and incubation temperature on growth in the turtle *Malaclemys terrapin*. *Journal of Herpetology* 30:198–204.
- _____, and A. R. Place. 1994. Nest predation and hatchling sex ratio in the diamondback terrapin: implications for management and conservation. Pages 65–70 in S. Nelson, editor. *Proceedings of a conference: toward a sustainable coastal watershed: the Chesapeake experiment*. Publication Number 149. Chesapeake Research Consortium, Norfolk, Virginia, USA.
- _____, W. Cresko, M. Modesitte, and M. B. Robbins. 1997. Diamondback terrapin (*Malaclemys terrapin*) mortality in crab pots. *Conservation Biology* 11:1166–1172.
- Ross, A., and C. G. Jackson Jr. 1972. Barnacle fouling of the ornate diamondback terrapin, *Malaclemys terrapin macrospilota*. *Crustaceana* 22:203–205.
- Seigel, R. A. 1978. Simultaneous mortality in the diamondback terrapin, *Malaclemys terrapin tequesta* Schwartz. *Bulletin of the New York Herpetological Society* 14:31–32.

- _____. 1980a. Predation by raccoons on diamondback terrapins, *Malaclemys terrapin tequesta*. *Journal of Herpetology* 14:87–89.
- _____. 1980b. Courtship and mating behavior of the diamondback terrapin, *Malaclemys terrapin tequesta*. *Journal of Herpetology* 14:420–421.
- _____. 1980c. Nesting habits of diamondback terrapins (*Malaclemys terrapin*) on the Atlantic coast of Florida. *Transactions of the Kansas Academy of Science* 83:239–246.
- _____. 1983. Occurrence and effects of barnacle infestations on diamondback terrapins (*Malaclemys terrapin*). *American Midland Naturalist* 109:34–39.
- _____. 1984. Parameters of two populations of diamondback terrapins (*Malaclemys terrapin*) on the Atlantic coast of Florida. Pages 77–87 in R. Seigel, L. Hunt, J. L. Knight, L. Malaret, and N. L. Zuschlag, editors. *Vertebrate ecology and systematics: a tribute to Henry S. Fitch*. Special Publication Number 10. Museum of Natural History. University of Kansas, Lawrence, Kansas, USA.
- _____. 1993. Apparent long-term decline in diamondback terrapin populations at the Kennedy Space Center, Florida. *Herpetological Review* 24:102–103.
- _____, and J. W. Gibbons. 1995. Workshop on the ecology, status, and management of the diamondback terrapin (*Malaclemys terrapin*), Savannah River Ecology Laboratory, 2 August 1994; final results and recommendations. *Chelonian Conservation Biology* 1:240–243.
- Shine, R. 1989. Ecological causes for the evolution of sexual dimorphism: a review of the evidence. *Quarterly Review of Biology* 64:419–461.
- Tinkle, D. W. 1961. Geographic variation in reproduction, size, sex ratio, and maturity of *Sternotherus odoratus* (Testudinata: Chelydridae). *Ecology* 42:68–76.
- Tucker, A. D., N. N. FitzSimmons, and J. W. Gibbons. 1995. Resource partitioning by the estuarine turtle *Malaclemys terrapin*; trophic, spatial, and temporal foraging constraints. *Herpetologica* 51:167–181.

- Wood, R. C. 1997. The impact of commercial crab traps on northern diamondback terrapins, *Malaclemys terrapin terrapin*. Pages 21–27 in J. Van Abbema, editor. Proceedings: conservation, restoration, and management of tortoises and turtles—an international conference. New York Turtle and Tortoise Society, New York, New York, USA.
- _____, and R. Herlands. 1997. Turtles and tires: the impact of roadkills on northern diamondback terrapin, *Malaclemys terrapin terrapin*, populations on the Cape May Peninsula, southern New Jersey, USA. Pages 46–53 in J. Van Abbema, editor. Proceedings: conservation, restoration, and management of tortoises and turtles—an international conference. New York Turtle and Tortoise Society, New York, New York, USA.
- Yearicks, E. G., R. C. Wood, and W. S. Johnson. 1981. Hibernation of the northern diamondback terrapin, *Malaclemys terrapin terrapin*. Estuaries 4:78–80.

Appendix A. Air temperature, water temperature, salinity, and terrapin head counts at various tide levels from March 1996 through April 1997 in Deep Creek and Cedar Point Creek.

Date	Tide ^a	Deep Creek				Cedar Point Creek				
		T _A ^b	T _W ^c	Salinity ppt ^d	H/min ^e	Tide	T _A	T _W	Salinity ppt	H/min
March 1996										
5	H	- ^f	17	20	0.00	H	-	-	-	-
7	H	-	15	-	0.00	H	-	19	15	0.00
14	L	22	13	27	0.00	L	24	14	25	0.00
19	HL	16	17	20	0.00	HL	14	6	20	0.00
21	HL	16	14	16	0.00	HL	15	4	12	0.00
26	LH	25	20	14	0.08	LH	25	19	14	0.50
28	L	29	22	15	0.36	L	27	22	13	0.33
April 1996										
2	L	17	18	18	0.00	L	20	18	16	0.25
4	H	27	20	15	0.00	H	25	19	16	0.25
9	LH	19	18	16	0.22	LH	18	18	14	0.00
11	H	21	19	16	0.11	H	25	18	18	1.00
16	H	19	20	12	0.17	H	17	20	12	0.00
23	LH	27	24	14	1.80	LH	27	24	15	2.00
May 1996										
2	L	26	25	20	1.30	L	27	25	18	0.33
3	H	26	23	20	0.14	HL	29	25	22	0.00
6	H	29	26	22	0.55	H	30	25	20	0.25
7	H	30	26	20	1.55	H	31	25	20	0.20
8	LH	28	26	23	1.70	H	28	26	24	0.66
9	LH	29	27	22	1.60	H	30	26	22	0.50
10	LH	29	28	28	0.54	LH	31	27	22	0.75
13	L	28	25	24	0.18	L	26	26	24	4.75
14	HL	25	25	26	0.00	L	26	25	30	0.20
15	L	27	24	28	0.14	L	26	25	30	0.00
16	H	28	24	29	0.33	HL	28	25	30	0.60
17	H	28	26	32	0.07	H	30	26	30	0.25
20	H	34	28	20	0.21	HL	34	28	24	1.75
21	H	30	28	22	1.09	H	30	27	23	0.75
22	L	27	26	22	1.46	LH	28	27	22	3.67
23	H	31	29	22	0.30	H	31	28	25	0.25
24	L	30	28	25	0.81	LH	31	29	26	0.00
27	L	33	29	25	0.56	LH	32	30	24	0.67
28	L	32	29	26	1.20	L	31	29	24	1.50
29	L	30	27	24	0.60	L	29	27	24	1.00
30	HL	31	27	24	0.33	HL	32	27	24	-
31	HL	29	26	30	-	HL	28	25	34	-
June 1996										
3	H	30	25	30	0.00	H	26	25	30	0.67
4	H	31	27	29	0.33	HL	30	27	30	0.00
5	H	29	27	28	0.00	HL	30	28	30	0.00
6	LH	29	28	30	0.88	H	30	28	30	0.00
7	LH	30	28	32	0.38	L	30	28	30	0.50
10	L	27	26	24	1.00	L	28	27	22	0.00
11	L	28	29	23	2.33	L	30	27	22	2.25
12	HL	31	27	22	0.50	L	31	28	22	0.33

Appendix A. Continued.

Date	Tide ^a	Deep Creek				Tide	Cedar Point Creek			
		T _A ^b	T _W ^c	Salinity ppt ^d	H/min ^e		T _A	T _W	Salinity ppt	H/min
June 1996 (continued)										
14	HL	32	28	22	1.11	HL	30	28	22	1.00
17	HL	30	30	20	0.22	HL	31	29	22	0.00
18	H	30	30	22	0.14	H	30	29	25	0.00
19	H	31	30	23	0.43	H	31	29	24	0.00
20	LH	30	27	23	1.00	LH	30	28	22	0.67
21	LH	30	28	22	2.75	LH	31	28	21	0.67
24	L	34	30	20	4.20	H	32	31	18	0.00
25	L	33	31	20	2.80	L	32	31	19	0.67
26	L	36	32	20	2.30	L	36	32	19	3.00
27	-	-	-	-	-	-	-	-	-	-
28	L	27	26	20	0.67	L	28	27	24	0.67
July 1996										
5	H	31	29	18	0.13	H	31	29	20	0.00
19	HL	35	32	12	0.90	HL	35	31	12	2.00
26	L	30	29	16	2.25	L	29	30	15	1.00
August 1996										
2	LH	32	28	28	1.22	LH	30	28	28	0.00
9	L	30	29	28	1.00	L	29	29	28	0.50
September 1996										
3	H	30	30	25	0.10	H	30	29	27	0.00
10	L	-	-	-	-	L	30	29	22	0.50
24	L	31	28	26	2.10	L	31	27	25	0.00
October 1996										
1	H	30	28	22	0.11	H	30	28	27	0.00
15	H	25	23	10	0.00	H	25	23	10	0.00
22	L	25	21	12	0.44	L	26	20	10	0.17
November 1996										
5	H	26	22	20	0.00	H	26	22	22	0.00
19	L	22	19	28	0.17	L	22	19	26	0.00
26	L	16	22	25	0.00 ^g	L	20	21	22	0.00
December 1996										
5	L	18	16	18	0.00	L	18	16	16	0.00
10	H	16	14	16	0.00	H	16	16	18	0.00
20	L	3	8	22	0.00	L	3	10	20	0.00
January 1997										
7	L	17	19	18	0.00	L	17	19	16	0.00
16	H	22	16	25	0.00	H	21	15	25	0.00
21	L	17	13	22	0.00	L	18	12	20	0.00
February 1997										
4	LH	24	18	20	0.00	LH	25	18	22	0.00
18	L	20	17	26	0.00	L	19	17	24	0.00
25	HL	13	15	22	0.00	HL	13	15	24	0.00

Appendix A. Continued.

Date	Tide ^a	Deep Creek				H/min ^e	Tide	Cedar Point Creek			
		T _A ^b	T _W ^c	Salinity ppt ^d				T _A	T _W	Salinity ppt	H/min
March 1997											
4	L	32	25	16	0.82	L	30	24	16	0.00	
10	H	27	21	28	0.13	H	25	19	27	0.00	
11	H	28	20	24	0.00	H	26	20	25	0.00	
18	L	23	20	28	0.67	L	23	20	26	0.00	
20	L	26	22	26	0.39	L	24	21	24	0.25	
25	-	-	-	-	-	-	-	-	-	-	
27	HL	26	23	23	1.14	HL	28	22	22	0.00	
April 1997											
1	L	20	18	20	0.00	L	19	20	20	0.00	
3	LH	24	21	24	0.50	LH	24	20	25	0.00	
8	L	22	23	28	0.14	L	22	23	26	0.00	
10	H	22	21	28	0.00	H	22	20	28	0.00	
15	LH	20	19	25	0.75	LH	20	20	26	0.00	
17	L	25	20	29	0.75	L	23	20	28	0.50	
24	H	23	21	21	0.27	H	23	21	22	0.00	
25	H	24	21	22	0.27	H	26	22	24	0.00	

^aH = 2 hours before and after high tide, L = 2 hours before and after low tide, HL = greater than 2 hours after high tide but less than 2 hours before low tide, LH = greater than 2 hours after low tide but less than 2 hours before high tide.

^bAir temperature in °C.

^cWater temperature in °C.

^dParts per thousand.

^eHeads per minute.

^fNo data available.

^gHeads seen on 11/26, after our count had taken place for the day.

Appendix B. Plant species recorded on the Big Talbot Island nesting beach.

<i>Amaranthus pumilus</i>	<i>Lepidium virginicum</i>
<i>Ambrosia artemisiifolia</i>	<i>Limonium carolinianum</i>
<i>Ammophila breviligulata</i>	<i>Muhlenbergia filipes</i>
<i>Andropogon glomeratus</i>	<i>Myrica cerifera</i>
<i>Baccharis angustifolia</i>	<i>Oenothera humifusa</i>
<i>Batis maritima</i>	<i>Oenothera laciniata</i>
<i>Borrchia frutescens</i>	<i>Opuntia pusilla</i>
<i>Cakile edentula</i>	<i>Pluchea odorata</i>
<i>Callicarpa americana</i>	<i>Polypremum procumbens</i>
<i>Carduus spinosissimus</i>	<i>Portulaca oleracea</i>
<i>Cenchrus incertus</i>	<i>Rumex hastatulus</i>
<i>Conyza canadensis</i>	<i>Sabal palmetto</i>
<i>Croton glandulosus</i>	<i>Sabatia stellaris</i>
<i>Distichlis spicata</i>	<i>Salicornia europaea</i>
<i>Eupatorium capillifolium</i>	<i>Scirpus robustus</i>
<i>Gaura angustifolia</i>	<i>Sesbania macrocarpa</i>
<i>Heterotheca subaxillaris</i>	<i>Sesuvium portulacastrum</i>
<i>Hydrocotyle bonariensis</i>	<i>Setaria</i> sp.
<i>Ipomoea stolonifera</i>	<i>Smilax bona-nox</i>
<i>Iva frutescens</i>	<i>Sparganium</i> sp.
<i>Juncus megacephalus</i>	<i>Spartina patens</i>
<i>Juncus roemerianus</i>	<i>Sonchus asper</i>
<i>Juniperus silicicola</i>	<i>Tradescantia virginiana</i>
<i>Kosteletzkya virginica</i>	<i>Unicola paniculata</i>
<i>Lathyrus japonicus</i>	<i>Vitis rotundifolia</i>
<i>Latuca canadensis</i>	<i>Yucca filamentosa</i>
