THE DIAMONDBACK TERRAPIN
Malaclemys terrapin

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The diamondback terrapin (*Malaclemys terrapin*) has one of the narrowest, but longest, geographic distributions of any single turtle species. Occurring exclusively in brackish-water coastal habitats, the terrapin inhabits the restricted margin of such systems found along the Atlantic and Gulf Coasts of the United States, from Cape Cod, Massachusetts, to Corpus Christi Bay, Texas. Seven subspecies have been described along its meandering range: the northern (*M.t. terrapin*), Carolina (*M.t. centrata*), Florida east coast (*M.t. tequesta*), mangrove (*M.t. rhizophorarum*), ornate (*M.t. macrospilota*), Mississippi (*M.t. pileata*), and Texas (*M.t. littoralis*). Although morphological differences have been noted and documented, variation between and within these subspecies has not been fully investigated.

The only turtle in the world known to be entirely restricted to estuarine habitat (Dunson and Mazzotti 1989), the terrapin inhabits coastal marshes, tidal mudflats, tidal creeks, estuaries, lagoons and sounds behind barrier islands, some brackish-water impoundments, and occasionally near-shore sandy islands. An excellent swimmer, it heads for water if approached, but otherwise appears to spend its daylight hours basking on tidal mudflats, prowling through tidal marshes in search of food, or lying in muddy depressions (Ernst and Barbour 1972). It is tolerant of high temperatures, with an apparent thermal maximum of about 42 degrees C (107 F).

Diamondback terrapins have a history as a gourmet food and were taken extensively for that purpose in the late 1800's and early 1900's. The meat was sold in restaurants throughout the eastern United States as the key ingredient in turtle soup (Roosenburg 1990). Catches in Maryland ranged as high as 89,000 pounds in 1891, but had been reduced to a low of 823 pounds by 1920. Attempts were made to commercially raise and market the species, but with limited success (Carr 1952). With a serious depletion of populations evident in many areas, restrictions on its harvest were eventually implemented. Since that time, the terrapin has recovered somewhat and has sustained a variable fishery within certain portions of its range.

DESCRIPTION:

Ernst and Barbour (1972) describe the diamondback terrapin as a small to medium-sized (10-23 cm) turtle whose oblong carapace (upper shell) is marked with concentric grooves and ridges on each large scute (enlarged scale) of the shell. These scutes are not shed as the terrapin grows, but are simply pushed up by layers of new growth, resulting in a pyramidal appearance (and the name "diamondback"). The carapace is slightly serrated posteriorly, and sports a central vertebral keel that may be low and inconspicuous (generally in the Atlantic coast races), to prominent and knobby (most often in the Gulf coast subspecies). The enlarged posterior scales may be curled upward. Color of the carapace is gray, light brown, or black. The plastron (lower shell) is oblong, yellow to greenish in color, marked with dark blotches or flecks, and not hinged. The skin is gray to black, with black flecks or spots, and the head is small and flat, with dark flecks or curved markings. Eyes are black and prominent. The jaws are light in color, the chin blackish, and hind feet are large and strongly webbed.

The basic appearance of terrapins can vary widely throughout its range, or be confusingly similar. The Texas diamondback terrapin (*M.t. littoralis*) is marked by an oval carapace that is prominently keeled, often with knobs along the keel (possibly more pronounced in females than in males). The carapace is deep, with its highest point toward the rear, and rather uniform in color, without light centers in the scutes. The plastron is narrow and light-yellow to white in color, and the upper lip and top of the head are white. The head and neck are marked with dark spots or flecks, as are the greenish-gray legs and tail (Carr 1952, Ernst and Barbour 1972, Ernst and Bury 1982, Garrett and Barker 1987).

The Texas diamondback terrapin's nearest neighbor is the Mississippi terrapin (*M.t. pileata*), which occurs from the Texas/Louisiana border to western Florida. The carapace and plastron of the Mississippi terrapin are both generally darker in color than the Texas subspecies, and the skin is less heavily spotted with black (Cagle 1952). The top of the head is dark in the Mississippi terrapin (Marion 1986), but white in the Texas subspecies (Ernst and Barbour 1972). However, the appearance of terrapins may vary widely where the range of these two subspecies overlap (Cagle 1952).

SEXUAL DIMORPHISM:

Size differences between the sexes are extremely pronounced in terrapins, with females decidedly larger than males. The size disparity may be the greatest of any North American turtle (Carr 1952). Adult females generally grow to a carapace length of 15-23 cm (6-9 inches), while males reach only 10-14 cm (4-5.5 inches) (Ernst and Barbour 1972).

In Florida (Seigel 1984), mean plastron length of females was 15.4 cm (6.2 inches) and mean weight was 886 grams. In contrast, mean length of males was 10.4 cm (4.2 inches) and mean weight 283 grams, a female-to-male ratio of 1.48 and 3.13 for length and weight, respectively. Therefore, females were only 1.5 times male length, but more than 3 times male weight. Similarly, in South Carolina (Lovich and Gibbons 1990), adult females were mean plastron length 14.8 cm (5.9 inches), while males were 10.2 cm (4.1 inches), a female-to-male ratio of 1.45. Mean female and male mass was 705 grams and 242 grams, respectively, for a female-to-male ratio of 2.91.

Additional differences in morphology include broader and blunter heads in females, as well as deeper shells and shorter, narrower tails than in males. In females, the anal opening is closer to the body and situated in front of the posterior carapacial margin, while males have theirs posterior to the margin (Ernst and Barbour 1972, Palmer and Cordes 1988). Females in some populations may be lighter in color than males. Seigel (1984) reported that Florida east coast males had larger carapacial keels than do females.

GROWTH AND SEXUAL MATURITY:

In diamondback terrapins, male and female growth appears to be similar and relatively constant for the first 3 years of life (with a general increase in plastron length of 2.5 cm each year), but begins to diverge after that, as male growth declines, but female growth continues at a steady rate until 6-7 years of age (Allen and Littleford 1955, Cagle 1952, Seigel 1984).

Reported age at sexual maturity in male and female terrapins has varied with latitude, habitat, environmental conditions, extent of activity, availability of food, and many other factors. However, sexually mature terrapins have been reported at the following minimal sizes (plastron length), weights, and ages for various locations (ordered north to south):

New Jersey (M.t. terrapin): (Montevecchi and Burger 1975)
Female: 13.2 cm
No information for males

Maryland (M.t. terrapin): (Roosenburg 1990)

Female:	17.5 cm	1200 grams	8-13 years of age
Male:	10.0 cm	300 grams	4-7 years

North Carolina (M.t. terrapin): (Hildebrand 1932)*
Female: 13.7 cm 7 years
Male: 9.0 cm 5 years
[* = captive population; active May-October]

South Carolina (M.t. centrata): (Lovich and Gibbons 1990)
Female: 13.8 cm 7 years
Male: 9.1 cm 3 years

Florida (M.t. tequesta): (Seigel 1984)*
Female: 13.5-14.0 cm 4-5 years
Male: 9.0- 9.5 cm 2-3 years
[* = active season February-November]

Louisiana (M.t. pileata x littoralis): (Cagle 1952)
Female: 16.0 cm 6 years
Male: 9.9 cm 3 years

Texas terrapin females probably attain sexual maturity at 6-7 years of age, possibly at plastron length 14-16 cm (5.6-6.4 inches). Males may reach maturity at 3 years of age, probably at plastron length 9-10 cm (3.6-4.0 inches) (Ernst and Barbour 1972, Hildebrand 1932, Palmer and Cordes 1988). The sexes may not be distinguishable until these sizes have been achieved (Hildebrand 1932).

FEEDING ECOLOGY:

Terrapins probably feed primarily on crustaceans and mollusks, but may also scavenge on dead fish and other carrion. The jaws of terrapins are broad and heavily-muscled, and can easily crush the bodies of snails, crabs, small clams, mussels, and marine annelids. They may also feed on shoots and rootlets of marsh plants, and enter grassy lowlands during high tide to search for insects (Carr 1952, Marion 1986). South Carolina terrapins fed on salt-marsh periwinkles, fiddler crabs, blue crabs, and small bivalve clams (Gibbons and Lovich 1990). Roosenburg (1994) found remains of soft-shelled and razor clams in Maryland terrapins. Cagle (1952) found small clams and snails in Louisiana terrapins. Captives have readily fed on crabs, snails, oysters, clams, insects, chopped fish, and beef (Ernst and Barbour 1972, Palmer and Cordes 1988). Allen and Littleford (1955) noted that terrapin hatchlings preferred shellfish and snails, and Dunson (1985) reported that hatchlings readily fed on chopped minnows, squid, and clams.

Extensive studies of feeding habitat requirements have not been conducted, but shallow tidal creeks and subtidal mudflats, vegetated with such marsh grasses as *Spartina alterniflora*, are probably the most important to terrapins (Palmer and Cordes 1988). Bishop (1983) believed that elevated April-May captures of South Carolina terrapins in subtidal mudflats were due to a tendency to concentrate and feed in these areas to meet post-hibernation and pre-reproduction energy demands. Marion (1986) reported that most feeding by Mississippi terrapins occurred at high tide, when they could search flooded marshes for snails, crabs, and other invertebrates. He noted a preference for marshes that contained channels with moving water. In southern Florida, large numbers have been found in the interior lagoons of coastal islands, where they may bury themselves in the soft sediment (Dunson and Mazzotti 1989). Roosenburg (1994) described typical terrapin habitat as salt marshes and lagoons behind barrier dunes, where gastropod mollusks are available. However, marshes along the Patuxent River in Maryland are small and do not support large gastropod populations. As a result, terrapins in this region were most often found in open waters of the river, where the sandy bottom supported soft-shelled and razor clams.

very different from here (NC)
SC → closer to shore

SALINITY TOLERANCE:

Living in brackish water environments, diamondback terrapins are exposed to a broad spectrum of salt concentrations which may fluctuate with location and seasonal weather conditions. They have been captured in water salinity varying from 4.3 to 31.8 ppt (Bishop 1983, Dunson 1970, Palmer and Cordes 1988, Seigel 1983), yet there appears to be little difference in salinity olerance in terrapins taken from different points of its range (Dunson 1985) 'he species possesses a number of effective physiological and behavioral ıdaptations that allow it to adjust to changes in salinity (Dunson and ſazzotti 1989). A low integumentary permeability to salts and water, the ıccumulation of urea in blood plasma to conserve water, and a behavioral :endency to drink only low-salinity water, all allows them to minimize both vater loss and sodium intake during early stages of dehydration.

Recent turtle studies suggest that an important factor in salinity tolerance is amount of seawater taken in with food ingestion (Dunson and Mazzotti 1989). The main source of sodium intake by terrapins at high salinity seems to be the incidental swallowing of water during food intake, rather than salt content of the food itself. The appetite of terrapins held in seawater, without access to freshwater, gradually becomes depressed, reducing their normal intake of food by 46-78 percent (Davenport and Ward 1993), and possibly reducing their incidental intake of sodium.

The terrapin is the only member of the family Emydidae to possess a lachrymal salt gland, which allows it to excrete excess sodium ions during prolonged dehydration, although at a slower rate than in true sea turtles (Dunson 1985). The terrapin also has a remarkable ability to expand extracellular fluid volume to very high levels, probably as a means of storing water for periods of dehydration (Robinson and Dunson 1976). This ability may be related to their tendency to exploit the temporary occurrence of rainwater and other freshwater sources when possible. To an unusual degree for a marine reptile, terrapins appear to rely on drinking fresh or brackish water to replenish body water stores (Dunson 1985). Early trappers holding terrapins for sale found that providing freshwater ensured greater survival (Dunson 1970), and reported seeing them drinking rainwater in the wild. In captivity, dehydrated terrapins will drink freshwater from any available water source, including puddles and water spigots.

Adult terrapins are capable of spending several weeks in seawater without access to freshwater, but they cannot survive indefinitely. Hatchlings are also severely affected by long exposure to seawater. In the laboratory, hatchlings were not capable of growth in concentrations of 100 percent seawater. Limited growth was achieved in 50 percent and 35 percent seawater with periodic access to freshwater, and in pure freshwater. However, a very distinct growth optimum was seen in hatchlings raised in 25 percent seawater concentration (Dunson 1985).

Terrapin hatchlings are small (5-8 g) and probably have limited dispersal capability. Therefore, the placement of nests by adult females determines the salinity conditions that young will be exposed to at hatching and for some time afterward (possibly until body weight of 50 g). In various portions of the terrapin's range, salinity near nest sites can be quite high, even approaching seawater concentrations (Dunson 1985), which would inhibit growth and possibly reduce survival. Rainfall may provide the periodic freshwater needed by hatchlings for proper growth and rehydration. Areas that offer frequent and regular access to rainwater, possibly in the form of runoff from banks or collection in brackish pools, may be the most favorable for terrapin hatchling growth.

Terrapins may be the most specialized living example of a reptile that is neither fully marine nor fully freshwater. Hatchlings appear to grow best if allowed a certain degree of salt intake, which they cannot obtain from pure freshwater. Dunson (1985) speculated that reduced terrapin growth in freshwater indicated an evolutionary adaptation by the species that would maximize its efficiency in brackish estuarine systems, but consequently diminish it if exposed to conditions found outside of that environment.

HIBERNATION:

In the winter, terrapins reportedly burrow into the submerged mud of tidal creeks, ponds, and tidal flats (Carr 1952, Coker 1906, Ernst and Barbour 1972, Hay 1904) to hibernate until the following spring. In a 1973-74 study of terrapin hibernation on Cape May Peninsula, New Jersey, Yearicks et al. (1981) found that terrapins used three distinct types of hibernation sites. Some terrapins rested on the bottom of creeks, often in natural depressions and covered with a layer of mud, where water depth was 1.5-2.5 m at low tide. Other terrapins buried themselves 0.15-0.5 m deep into the sides of creek banks near the upper tide limit. Preferred sites appeared to be areas where the bank had begun slumping down into the creek. Still other terrapins buried themselves in groups beneath undercut banks within the intertidal zone. These hibernating groups often used natural cavities scoured out by the current on the outer bends of creeks. A thin layer of mud protected them from exposure during low tide.

There is at least one report of a terrapin hibernating in beach sand (Lawler and Musick 1972). On November 7, 1967, a terrapin was discovered buried in moist sand above the high tide level on a beach of the lower York River in Virginia. The juvenile terrapin, 5.4 cm (2.2 inches) carapace length and 4.6 cm (1.8 inches) plastron length, was buried about 0.3 m (1 foot) deep, approximately 8 m (26.4 feet) from high tide mark and 3 m (10 feet) into a stand of grass. The terrapin was periodically unearthed through the winter in order to determine movements. When unearthed, it was always inactive, with extremities withdrawn, but small vertical and horizontal movements of 2-8 cm (0.8-3.2 inches) were evident several times. On April 2, the terrapin had moved about 15 cm (6 inches) toward the surface and was active with all extremities extended. Air temperature of the previous week had reached 26 degrees C. The turtle was inactive on April 9 and April 16; air temperature had ranged 8-24 degrees C. At mid-day on April 23, the terrapin was active and within 3-5 cm (1.2-2 inches) of the surface. At 9:30 p.m., it was very active and lightly covered with sand. It was weighed and found to have lost no weight since discovery in November. After being placed on the sand about 4 m (13 feet) from the water's edge, the terrapin crawled directly toward water. After being upended several times by waves, it left the water, walked on the beach for 10 minutes, then re-entered the water and swam away. Air temperature at 2:00 p.m. was 12 degrees C, and water temperature was 13 degrees C.

Most observations of Atlantic coast terrapins indicate they begin hibernation in mid- to late-October or early November (Carr 1952, Coker 1906, Hildebrand 1932). Yearicks et al. (1981) reported that, from late-spring to early-fall, terrapins at Cape May, New Jersey, were active and dispersed throughout the study area. From mid-November to late-December, terrapins moved from open sounds and became concentrated within narrow creeks. As water temperatures dropped to 6-10 degrees C, terrapins became sluggish and could be seen lying or moving on the bottom of creeks and sounds in water less than 1 m deep. Under laboratory conditions, terrapin appetite has remained stable at ranges of 20-35 degrees C, but a sharp decline is seen at temperatures below 20 degrees C, indicating depressed metabolic states (Davenport and Ward 1993).

After December, Cape May terrapins were never seen in the study area, even on the warmest days, until they became active again in April or May (Yearicks et al. 1981). Stomach analysis of 10 terrapins showed all to be empty. This is contrary to observations of terrapins from other localities, where individuals were reported to emerge during winter warm spells in order to feed, and then return to hibernation (Carr 1952, Coker 1906, Ernst and Barbour 1972, Hay

1904, Hildebrand 1932). Further research is necessary to determine whether this is due to latitudinal differences or to other circumstances.

Mortality during hibernation may be very low. Yearicks et al. (1981) found almost all hibernating terrapins to be alive, and only a few carcasses were ever found during and after winter over several years time, including after a record cold winter in 1976-77. It is assumed that hibernating terrapins rely on reduced and, possibly, anaerobic metabolism to survive.

Terrapins along the Atlantic coastline generally emerge from hibernation March to early-April (Carr 1952, Coker 1906). However, emerging terrapins may not be continuously active and feeding regularly until early-May, instead spending a period of time shallowly buried in mud banks (Ernst and Barbour 1972, Hildebrand 1932).

Hibernation of hatchlings has not been rigorously studied. Young may over-winter in the nest after hatching in autumn, remaining buried until the following spring, or may emerge and then burrow into the ground to remain buried until spring (Carr 1952, Ernst and Barbour 1972).

MATING BEHAVIOR:

Hay (1904) reported that Carolina terrapins mated soon after leaving hibernation. Although terrapins in Florida were active by mid-February, mating was not observed until late-March (Seigel 1980a), and continued until April 25. Sperm from the male may be stored by the female and remain viable for a number of seasons. Therefore, one mating may produce fertile eggs for several years, although the degree of fertility appears to decline after the first season (Carr 1952, Ernst and Barbour 1972).

Seigel (1980a) observed large terrapin aggregations in late March and early April, which he speculated formed to increase chances for successful mating. Concentrations of 6-75 individuals were noted in the canals, but local residents reported as many as 250 terrapins in one 200 square-meter area.

Carr (1952) and Ernst and Barbour (1972) indicated that mating takes place at night or early morning. However, in Florida, mating was observed only during daytime between 10:40 a.m. and 4:10 p.m. (Seigel 1980a). No nocturnal or early morning mating was seen. Water temperatures were 24.8-27.0 degrees C, and air temperatures 22.8-27.0 degrees C. Matings were observed only in the canals and ditches rather than larger lagoons (Seigel 1980a), and all were initiated and completed in the water. Courtship began with the female floating at the water surface, and the male approaching from the rear to nuzzle or nudge the female's cloacal region. If the female remained motionless, mating occurred. No head-bobbing by the male was seen.

NESTING SEASON:

Ernst and Barbour (1972) state that terrapin nesting is April-July, depending on latitude. The following nesting seasons have been reported for various locations (ordered by latitude from north to south):

Massachusetts: June 10-July 20 (Lazell and Auger 1981)
New Jersey: June 9-July 23 (Burger 1976a, Burger and Montevecchi 1975)
Maryland: June-July (Roosenburg 1993, 1994)
Virginia: includes early-June (Reid 1955)
South Carolina: May-July (Ernst and Barbour 1972, Lovich et al. 1991)
Mississippi: late-April to early-August (Mann, unpub. data; Marion 1986)
Louisiana: includes May (Dundee and Rossman 1989)
Florida: April 28-July 1 (Seigel 1980b, 1984)
Texas: April-May (Garrett and Barker 1987).

NESTING HABITAT:

Diamondback terrapins are aquatic animals and, therefore spend most of their life in the water. However, to successfully reproduce, females must come onto dry land to construct nest cavities and lay eggs that will mature and hatch young. The hatchlings must then dig their way out of the nest and seek suitable habitat. Most terrapin nests are located near the adult's aquatic habitat, and females generally travel only a short distance to reach nesting grounds. In New Jersey, most nesting routes were less than 100 m (328 feet) in length (Burger and Montevecchi 1975). However, at another New Jersey location, it appeared that females traveled up to 450 m (1500 feet) from the ocean to find suitable nesting sites (Ernst and Barbour 1972). In Massachusetts, terrapins traveled nearly 1600 m (5,249 feet) to reach suitable nesting grounds (Roosenburg 1994) and, in Delaware, one female was seen laying eggs about 8 km (4.8 miles) from the area in which she was originally captured and tagged (Hurd et al. 1979).

Nest Elevation:

Nesting activity often coincides with the occurrence of high tide, which may serve to reduce the distance traveled to reach nesting areas. However, nesting at this time may also insure that nests are placed above the high-tide mark. All accounts of nesting activities indicate that nests are consistently constructed above the level of normal high tides (Dunson 1985, Palmer and Cordes 1988, Roosenburg 1994). In some locations, wind-driven high tides may occasionally flood nests located near the high-tide mark, but terrapin embryos can usually survive short-term flooding. However, prolonged inundation can result in embryo mortality, depending on incubation stage and length of time nests remain submerged (Roosenburg 1994).

Sandy Soils:

Another consistent factor of terrapin nest sites is the occurrence of sandy substrate. Sandy soils have large particle sizes, allowing greater gas diffusion and lower water demand than in clay or loamy soils. The use of sandy habitats may be critical to successful development of embryos. In Maryland, terrapin nesting was attempted within a sandy-clay bank where the slope was flat enough to allow digging by the female. Eggs from this type of habitat usually did not survive; clay particles in the soil clogged egg pores, resulting in insufficient gas exchange to support the developing embryos (Roosenburg 1994).

Terrapin nesting habitat has included the sandy edges of salt-marshes and rivers, and the sand dunes of coastal beaches. Terrapins in Massachusetts tended to select elevated sand dune sites for nesting. Females often employed significant face-probing before selecting a site, possibly a method of testing soil texture (Lazell and Auger 1981, Roosenburg 1994).

In New Jersey, nesting terrapins were observed on Little Beach Island (Burger 1976a, 1977; Burger and Montevecchi 1975). The site contained approximately equal areas of low, flat sand dunes and high dunes, and a *Spartina* salt marsh separated the dunes from a cove. Observations of 25 nesting terrapins revealed that they generally walked through the marsh, and then wandered over the dunes searching for a suitable nest site. Nearly 90 percent of nests were constructed within the high dune area, indicating a high preference for this area over the low dunes. However, specific nest sites within the high dunes were generally on low, gentle slopes, minimizing the mechanical problems of digging on an incline and reducing the potential for erosion on nests.

Roosenburg (1994) studied nesting habitat of terrapins on the Patuxent River, an estuary of Chesapeake Bay, in Maryland. True sand dunes do not form along the Patuxent. Instead, narrow sandy strips form at the interface of open water and land. Terrapins primarily chose the flat, upper reaches of these beaches for nesting, and nesting densities were usually higher on beaches that were isolated from the mainland by salt marshes. Of four disparate sites chosen for nesting in Virginia, the common feature was the presence of sandy soil at about the high tide line (Dunson 1985).

In South Carolina, nests were found only on small sandy islands and the exposed dunes of sandy beaches (Lovich and Gibbons 1990, Lovich et al. 1991) while, in Mississippi, terrapins typically nested on "sand ramps" formed along beaches, with open ocean on one side and salt-marsh on the other (Tom Mann, unpub. data). Shell mounds were used in some instances, and muskrat trails were often used as terrapin "highways" by nesting females. At Merritt Island in Florida, dike construction eliminated the original salt marsh habitat, so terrapins were confined to lagoons or small impoundments. Although sand dunes, spoil islands, and the borders of lagoons were all available for nesting, nesting was observed only on dike roads (Seigel 1980b). However, terrapins on the southern tip of Florida generally appeared to nest on sand berms formed along island edges (Dunson 1985).

Vegetative Cover:

At known terrapin nest sites, degree of vegetative cover has been variable. In New Jersey, most sites selected on the dunes for nesting supported minimal vegetative cover of beachgrass and shrubs, usually less than 20 percent. This probably served to reduce both the female's chances of encountering roots while digging, as well as the chances of plant roots hampering egg development (Burger 1977, Burger and Montevecchi 1975). However, nesting females still tended to nest less than 20 cm from the closest clump of vegetation. Nests averaged a distance of 11.2 cm from the nearest vegetation and had a mean cover of 8.2 percent (Burger and Montevecchi 1975, Palmer and Cordes 1988).

In New Jersey, nest predation was related to vegetative cover. Predation of terrapin eggs by crows and gulls was highest in open sand areas; predation of hatchlings by fox and raccoons was highest in areas surrounded by grass or shrubs. Distance to vegetation was significantly greater for nests that were not preyed upon compared to those that were (Burger 1977).

In Maryland, nesting was primarily done in open, sparsely vegetated areas. Densely vegetated and shaded areas were avoided (Roosenburg 1994). The same was true for South Carolina, where nests were typically in areas of sparse vegetative cover, exposed to considerable insolation (Lovich and Gibbons 1990, Lovich et al. 1991). Nests in Florida, as well, averaged only 20 percent vegetative cover (Seigel 1980b).

However, in Mississippi, terrapin nests were often in highly-vegetated areas, although unvegetated areas were also used. Some sites included *Baccharis*, and one area used by eight females supported *Juncus* and *Spartina* (Tom Mann, unpub. data). In Massachusetts, nests were about equally distributed between vegetated and unvegetated dune faces (Lazell and Auger 1981). Females there employed significant face-probing while selecting a nest site, possibly a method of detecting vegetation and avoiding a form of nest predation by plant roots.

Environmental Sex Determination (ESD):

The effect of ESD, in which incubation temperature determines sex of the offspring, complicates the issue of nest site selection by terrapins (Roosenburg 1994). Potential nesting areas vary considerably in their thermal characteristics, and females must have a range of microhabitats available in order to maintain balanced sex ratios within a population. Moreover, a number of other factors, including soil substrate and moisture within the nest, will affect survivability of the eggs and embryos, length of the incubation period, and energy resources of the resulting hatchlings. Therefore, availability of suitable nesting sites is a critical requirement for terrapin reproductive success within a given area.

NESTING BEHAVIOR:

Eggs are deposited in triangular or flask-shaped nest cavities dug and then covered by females (Ernst and Barbour 1972). Total depth of nests (from soil surface to bottom of egg compartment) has ranged 11-20 cm (4-8 inches) and, in New Jersey, averaged 15 cm (6 inches) (Coker 1906, Hay 1904, Ernst and Barbour 1972, Montevecchi and Burger 1975, Reid 1955). Depth from soil surface to top of egg compartment has ranged 5-17 cm (2-7 inches) with a mean of 10.6 cm (4 inches) (Montevecchi and Burger 1975, Reid 1955). In New Jersey, egg compartments averaged 4.7 cm (2 inches) deep and 7.3 cm (3 inches) wide.

In New Jersey, the female used her front feet to excavate a hole about 105 mm wide, 175 mm long, and 50 mm deep. At that point, she walked forward and proceeded to dig with the hind legs. Burger (1977) found that a triangular pattern (mean width 3.8 cm and mean length 5.2 cm) was formed as nests were covered, and that nests, which were usually in the center of the triangle's base end, could be located by this pattern.

Terrapins in Florida were seen nesting only in daytime, primarily 10:40 a.m. to 4:10 p.m. (Seigel 1980b). Nesting near Brigantine, New Jersey, occurred between 7:00 a.m. and 7:00 p.m., although one turtle was seen nesting between 7:00 p.m. and 11:00 p.m. Early-morning censuses found no evidence of turtle activity during the night (Burger and Montevecchi 1975). However, near Cape May, New Jersey, terrapins apparently nest at any time of the day, both day and night (Roger Wood, unpub. data). This was also the case in Massachusetts, as well as in Maryland, where nesting occurred both day and night, but with a peak in activity 11:00 a.m. to 1:00 p.m. (Roosenburg 1994).

In Florida, nesting was observed at air temperatures of 28-36 degrees C, with 83 percent occurring at 29-33 degrees C (Seigel 1980b). More nesting occurred during fair weather than during cloudy or overcast days. Females nested more frequently during high tide, except during heavy or prolonged rain (Burger and Montevecchi 1975, Lazell and Auger 1981). However, if the rains stopped and sun was present during high tide, the number of nesting females were higher than at high tide on a prior rainless day. For any given tide time, fewer females nested on cloudy days (Burger and Montevecchi 1975).

Both Burger (1977) and Roosenburg (1994) found that nesting females could be disturbed quite easily. In New Jersey, females searching for a nest site moved rapidly to cover if approached. A digging female would cease digging and leave a nest hole if approached. Females that had laid fewer than three eggs also left the nest if disturbed. However, females that had laid four or more eggs usually completed their clutch and covered the nest completely before leaving (Burger 1977).

Burger (1977) reported that some searching females poked their snouts into sand, and some females tested as many as 10 sites before selecting one, but reasons for rejection were not apparent. The number of rejected holes was greater after rains. Time elapsed between initial digging and nest-covering was generally 20 minutes. Actual egg-laying usually took less than two minutes. Indications were that females came onto the dune area, dug their nests, laid and covered eggs, and returned to the cove within an hour. There was no indication of re-nesting by individual females (Burger 1977).

In Massachusetts, terrapins took a much longer time to select nests, and often made non-nesting and false nesting excursions. They nearly always engaged in facial probing or "sand-sniffing" before selecting a site. Lazell and Auger (1981) speculated that this activity was intended to detect rhizomes of the dune-grass *Ammophila breviligulata*. They had found the grass to infiltrate as much as 25 percent of the area terrapin nests and feed on the eggs' nutrient and moisture stores.

In Maryland, terrapins completed the entire nesting process in as little as 15 minutes or as long as 2 hours (Roosenburg 1994). The variation was primarily a function of time spent searching for a nesting site. Females frequently abandoned nesting for various reasons, the primary one being threat of predation.

Roosenburg (1993) noted that females usually approached nesting beaches in groups of 2 to 25 or more individuals and cautiously examined the beach from the water, sometimes for several hours. Successful nesting often occurred when these aggregations were present prior to nesting, although only a few individuals came ashore and nested at any one time. Numbers within groups decreased as the nesting season progressed, probably the result of turtles completing reproduction for the year and moving to other habitats.

Observance of terrapin aggregations indicated that they occurred in waters adjacent to nesting beaches throughout the nesting season. The occurrence of appropriate nesting conditions could encourage such aggregations if the amount of suitable nesting habitat is limited. It is also possible that such groups facilitate recognition of suitable nesting habitat by members, or that groups more effectively spot predators at nesting sites. Some terrapins have been seen to "jaw-drop" while being handled and may use this as a form of warning signal (Roosenburg 1993).

CLUTCH SIZE AND INCUBATION:

Terrapin eggs are oblong/ellipsoidal in shape, pinkish-white in color, and have thin, delicate, leathery shells. The shells may be coated with calcareous bumps which fill out during early stages of incubation (Ernst and Barbour 1972, Montevecchi and Burger 1975, Palmer and Cordes 1988).

The following clutch sizes have been reported for terrapins from various locations (ordered north to south):

Massachusetts:	max. 37 eggs double-clutching rare/no triple-clutching (Peter Auger)
Rhode Island:	16 eggs/clutch (Caitlin Goodwin)
New Jersey:	mean 9.76 (range 4-18) (Burger 1977) range 8-12 (Roger Wood)
Maryland:	mean 13 (range 7-22) (Roosenburg 1990) 1-3 clutches/year
Virginia:	7 eggs (one nest) (Reid 1955)
North Carolina:	mean 8-9 (range max. 15-16) (Montevecchi and Burger 1975) mean 5.29 (Coker 1906, Montevecchi and Burger 1975)
Florida:	mean 6.7 (range 5-10) (Seigel 1980b) up to 3 clutches/year (based on 3 individuals)
Mississippi:	range 5-15 (Tom Mann) range 5-12; 2-5 clutches per year (Marion 1986)
Louisiana:	mean 8.5 (range 5-12) (Burns and Williams 1972) 14 and 18 eggs from examination of two specimens (Cagle 1952) range 4-12 eggs/several clutches/year (Dundee and Rossman 1989) 5 eggs (one clutch excavated in 1952) (Dundee and Rossman 1989)
Texas:	4-18 eggs (Garrett and Barker 1987)

The following egg dimensions (in centimeters) have been recorded:

New Jersey: mean length 3.16 (2.60-3.65)
mean width 1.98 (1.59-2.19)
mean weight 7.7 grams (5.0-11.0)
(Montevecchi and Burger 1975)

Maryland: mean length 3.11 (2.85-3.50)
mean width 2.12 (2.00-2.25)
(McCauley 1945)

Louisiana: mean length 3.73 (3.40-4.01)
mean width 2.39 (2.19-2.70)
(Burns and Williams 1972)

mean length 3.97 (3.85-4.10)
mean width 2.43 (2.40-2.50)
(Dundee and Rossman 1989)

Florida: mean length 3.90 (3.61-4.08)
mean width 2.23 (1.90-2.40)
mean weight 12.48 grams (11.20-13.20)
(Seigel 1980b)

Both Montevecchi and Burger (1975) and Seigel (1980b) identified a trend in terrapin clutch size from larger clutches in the north to smaller in the south. However, a more significant geographic trend may exist for egg size (Seigel 1980b), with a shift indicated toward larger eggs in the south than in the north. An increase toward larger eggs and hatchlings could result in higher survivorship of the young, compensating for smaller clutch sizes.

In New Jersey, clutch size and clutch weight were positively correlated with each other (Montevecchi and Burger 1975). Egg size decreased as the laying season advanced. In both Florida and New Jersey, larger females tended to lay larger clutches and of greater weight (Montevecchi and Burger 1975, Seigel 1980b).

Ernst and Barbour (1972) reported that the average incubation period for terrapins was 90 days, but that total time varied considerably with incubation temperature. In New Jersey, the developmental period was 61-104 days (mean of 76.2 days), with hatching August 20-October 12 (Burger 1976a, 1977). Eggs from Virginia nests hatched after 69 days of artificial incubation (Reid 1955). In Mississippi, terrapin incubation may be 70-84 days, and young may over-winter in the nest (Marion 1986). The mean incubation time for eggs from five Florida clutches was 65.6 days at 20-34 degrees C (Seigel 1980b). Eggs taken from Virginia nests and from a clutch laid by a captive Florida female, and incubated in captivity at 28-30 degrees C, hatched in 53-60 days (Dunson 1985).

In New Jersey, about 10 percent of eggs laid were infertile (Burger 1976a, 1977). Many of these were in nests that were very deep or very shallow, and were probably affected by temperature. In nests which hatched eggs in 1974, 69 percent of the eggs hatched successfully and 76 percent of the hatchlings emerged successfully. Within individual nests, eggs hatched over a 1-4 day time period, with the top eggs always hatching first and amount of time positively correlated with number of eggs and nest depth. Individual hatchlings emerged 1-9 days (mean of 2.5 days) after hatching and time elapsed seem to be related to air temperature, with 25 degrees C involving the shortest interval of time. Emergence of hatchlings from an individual nest ranged 1-11 days, so that the young might emerge together, in groups, or separately. Most hatchlings emerged during the day, and predation while in the nest was lower for those that emerged early (Burger 1976a, 1977).

Environmental Sex Determination (ESD):

The incubation period of the diamondback terrapin is a vulnerable stage of its life cycle, having lasting effects on individuals. Similar to other turtle species, terrapins experience environmental sex determination (ESD), a process in which temperature during incubation influences sexual development of the developing embryos and determines their sex. Roosenburg and Kelley (in review) examined the effects of incubation temperature and egg size on sex, hatchling size, and juvenile growth of terrapins, and found that males were produced at 26 degrees C, and females at 32 degrees C. Initial egg mass appeared to be the main determinant of hatchling size, with little apparent effect from incubation temperature. Average incubation time was 47 days at 32 degrees but 81 days at 26 degrees C, a 34-day difference.

In Massachusetts, the planting of beach-grass for erosion control may be adversely affecting the normal sex ratio of hatchling terrapins. Current sex ratios of terrapin populations in study areas appear to be highly skewed toward males, possibly the result of nests being placed in areas that have been planted with herbaceous vegetation. If cooler subsoil temperatures are created, a greater percentage of males may be produced than would normally occur under unmodified conditions (Peter Auger, unpub. data). The overall sex ratio of developing embryos may be influenced by a number of incubation parameters, such as mean temperature within the nest, temperature range, and length of time the temperature remains above or below a threshold point.

HATCHLING BEHAVIOR:

Hatchlings are patterned much like adults but are usually brighter in color. The shells are round, and head and tail are proportionately large in comparison with adults (Ernst and Barbour 1972). Recorded hatchling sizes have ranged as shown below (Burger 1977, Burns and Williams 1972, Reid 1955, Seigel 1980b):

New Jersey:	carapace length:	2.50-3.07 cm	(mean of 2.75)
	carapace width:	1.85-2.59 cm	(mean of 2.23)
	weight:	5.0-9.0 grams	(mean of 6.8)
Virginia:	carapace length:	2.70-2.85 cm	(mean of 2.74)
	carapace width:	2.70-2.85 cm	(mean of 2.74)
Florida:	carapace length:	2.88-3.40 cm	(mean of 3.19)
	weight:	6.0-10.8 grams	(mean of 8.83)
Texas:	carapace length:	2.94-3.04 cm	(mean of 2.99)
	carapace width:	2.27-2.45 cm	(mean of 2.35)
	weight:	7.2-9.1 grams	(mean of 8.1)

Significantly little is known regarding behavior and ecology of juvenile terrapins from the time that a hatchling emerges from the nest until it reaches sexual maturity some years later. Most studies have noted a distinct absence of hatchling and very young terrapins in their capture samples. One early study noted a scarcity of hatchlings and small juveniles in certain North Carolina marshes (Coker 1906, Palmer and Cordes 1988). Data from a two-year study in Delaware indicated minimal recruitment of juveniles (Hurd et al. 1979). Although hatching was known to occur nearby, no specimens 3.0-9.0 cm in length were ever located. Lovich and Gibbons (1990) also found an absence of hatchlings and juveniles 0-3 years of age in their sample of over 670 marked individuals, despite repeated efforts to locate them with various collecting techniques. They reported that, after entering the water, juveniles in their South Carolina population were rarely seen again until they attained sexual maturity some 3-6 years later.

Emerging hatchlings were observed in New Jersey by Burger (1976a, 1977). She found that most hatchlings emerged during the day between noon and late afternoon. Subsequent movements were primarily influenced by presence and location of vegetation, with most hatchlings heading toward the nearest clump of vegetation, regardless of degree or direction of slope. In unvegetated areas, hatchlings tended to move down-slope, but otherwise moved randomly.

In an attempt to resolve missing information on their South Carolina populations, Lovich et al. (1991) also observed the behavior of terrapin hatchlings. They removed eggs from wild nests, artificially incubated them, and released the resulting hatchlings along the shoreline of an island known to have nesting activity. The island supported a dense cover of *Spartina patens*, and the marsh consisted of *Spartina alterniflora* stands that were exposed at low tide. The hatchlings were released in the water within 1-2 m of the shoreline or on the island, and the behavior of each one was monitored for one hour.

Lovich et al. (1991) found that all hatchlings avoided open water and, instead, swam toward shoreline vegetation. This occurred even when observers were on the shoreline in direct view of hatchlings. The orientation of release, relative to the sun, did not appear to influence this behavior; hatchlings on both north and south sides of the island all swam toward shore when released. Even hatchlings released in the water, and facing away from the island, turned and swam toward shore. Once on shore, all hatchlings moved toward a line of tidal wrack (primarily *Spartina* stems). Upon encountering the wrack, they burrowed into it by pushing stems apart with their forelimbs. This behavior was consistent among the hatchlings, and was repeated by individuals pulled out of the mat and again released. Burrowing in the tidal wrack always occurred at high tide line; no terrapins were observed entering the island's interior.

Over a three-year period of time, from late-May to October, Pitler (1985) discovered 12 juvenile terrapins within a New Jersey tidal mudflat. They varied 2.5-7.5 cm in shell length, and all were found in well-drained areas approximately 91 m from the water's edge. Most were found under mats of *Spartina* grass and surface debris, but a few were discovered under rocks, boards, and a low bush.

These observations indicate that very young terrapins may utilize the underside of mats of vegetation and other debris found along shorelines as their general habitat. These would be likely and suitable use sites for them for several reasons (Lovich et al. 1991). Tidal wrack and flotsam provide cover to terrapins at sizes at which they are highly vulnerable to predation. Periodic flooding of mats would maintain moist and cool conditions. Lastly, food in the form of small invertebrates (small fiddler crabs, square-backed crabs, marsh periwinkles, other small insects and amphipods) would be available. Despite intensive searches, however, Lovich et al. (1991) were unable to locate very small terrapins in other locations. They proposed that such small age-classes might normally exist at very low numbers within a natural population due to heavy predation on small juveniles.

MOVEMENT ECOLOGY:

Nest-site fidelity, or philopatry, is the return of individual females of a species to the same nesting beaches for repetitive nestings. Long-term research of Maryland terrapins has revealed a high degree of site fidelity by female terrapins during the nesting season (Roosenburg 1993). Recapture rates on two nesting beaches has approached 95 percent, compared to 50 percent for non-nesting sites.

The maintenance of healthy terrapin populations may be dependent upon the protection of specific nesting areas. Terrapins in New Jersey and Massachusetts are selective about nesting sites, resulting in a clumped distribution of nests (Roosenburg 1994). In Maryland, a very small number of nesting attempts have been made in marginal habitats. Nest-site fidelity may be the cause, by forcing some females to attempt nesting in areas that were once suitable nesting spots but which have deteriorated with time. Human encroachment onto suitable nesting sites may force terrapins to nest in less-appropriate areas, or shoreline bulkheading may block access to formerly suitable sites (Roosenburg 1994).

Evidence indicates that terrapins, in general, inhabit areas as discrete populations, with very little movement between them. In Maryland, movement of terrapins during the early part of their active season was specifically investigated along one segment of the Patuxent River (Roosenburg 1993). The results indicated that terrapins move very little. Over half of all recaptures occurred within the original capture site. No marked terrapins were captured more than 14 km from the original capture site. Recaptures were considerably lower at distant sites, and lowest in areas farthest from the main study site. However, recapture rates were greater at distant sites but on the same shoreline as the study site, than on nearer sites on the opposite shore, suggesting that movement by terrapins may be oriented along shorelines and that movement across open bodies of water is generally avoided (Roosenburg 1993).

Terrapins in South Carolina also exhibited extremely high site-fidelity on a year-to-year basis (Lovich and Gibbons 1990). Individual males and females were often recaptured within several meters of the original point of capture in as many as three successive years, including during periods before and after storms and hurricanes. In only six cases (2 males and 4 females) were major displacements of 100-200 m (330-660 feet) evident. In New Jersey, as well, turtles marked at one mangrove island were never found at any other island (Roger Wood, unpub. data).

This site-fidelity and apparent restriction of range renders them extremely vulnerable if a new source of mortality is introduced into an area, such as intensive incidental take by crabbers. It also renders some population estimates questionable if they are based on figures determined for only a limited area, because population densities may not be uniform throughout the assumed range. The study of terrapins in mangrove islands off New Jersey revealed density differences between islands, even though some islands appeared to be similar in character (Roger Wood, unpub. data). Seasonal differences were also found. In early spring, females tended to be in upper creek reaches but, as the season progressed, moved elsewhere, often in groups, indicating some degree of sociality.

Movement by terrapins within and between populations requires further research. Past studies have indicated considerable geographic variation in the life history characteristics of the various terrapin races, suggesting minimal migration between populations. If terrapins normally move very little between various areas, the tendency for development of genetically distinct populations would be high. Further research is needed to determine the home range of individual terrapins, their daily activity patterns, and differences in seasonal habitat uses. The need for genetic analysis to determine degree of movement and of genetic isolation between adjacent populations is strongly indicated.

SEX RATIOS:

Estimates of sex ratios for terrapins of various populations have ranged from strongly female-biased to strongly male-biased. The following male-to-female ratios have been recorded for terrapins:

New York: 0.63-1.73 (Steve Morreale, unpub. data)
Delaware: 0.75 and 1.22 (Hurd et al. 1979)
Maryland: 0.46 (Roosenburg 1993)
South Carolina: 2.27 overall (range 0.51-13.67) (Bishop 1983)

South Carolina: 1.78 (Lovich and Gibbons 1990)
Florida: 0.10-1.18 (Seigel 1984)
Louisiana: 4.38 (Cagle 1952)
Captivity: 0.17-0.23 (Hildebrand 1932)

Lovich and Gibbons (1990) used a variety of techniques to capture a total of 414 turtles (265 males and 149 females) on Kiawah Island, South Carolina. The proportions of first captures and of total captures were both significantly biased toward males. Sex ratios were male-biased in all years, some significantly so. Monthly variation was generally male-biased. Captures made in all major habitats of the study area were male-biased.

Lovich and Gibbons (1990) identified four demographic factors that could affect the sex ratio of natural populations: the sex ratio at hatching (or the primary sex ratio), differential mortality of the sexes, differential emigration and immigration between the sexes, and differential age at maturity between the sexes. They considered all four factors in their analysis of male-biased captures in their South Carolina population, but differential age at maturity was believed to be the primary reason for their findings. They postulated that the sex that matures earlier in a species will always predominate numerically in natural populations.

In contrast, sex ratios of captured terrapins in Maryland were female-biased approximately 2:1 (Roosenburg 1990). This might indicate greater movement by females, but could also result from males having very wide ranges, larger than could be detected within the selected study area. Another possibility is differential survivorship between sexes. The sex ratio of terrapins over 10 years of age was 3:1 female-biased, possibly indicating continued differential survivorship between males and females as they age, with males exhibiting higher mortality.

The perception of population sex ratio can vary as a function of collecting technique, the micro-habitat sampled, differences in the behavior of the sexes, the ability to determine the age or size at maturity, or a combination of these factors (Lovich and Gibbons 1990). The potential to create sample bias by selection of collecting technique is of serious concern in regard to terrapins. All captures by Lovich and Gibbons (1990) were male-biased. However, their male-biased estimates derived from seining were two times greater than those from trammel nets, indicating possible sample bias. In South Carolina, yearly sex ratios differed greatly: 0.5:1, 3.3:1, 13.7:1 for three consecutive years (Bishop 1983). Sample bias was suspected due to size restrictions imposed by crab-pots, which would prevent entry of large females. Male catches generally outnumbered females in unbaited pots.

In the Patuxent River study, sites were chosen for their ease in capturing terrapins (Roosenburg 1990). Three sites were suspected nesting beaches, and captures here would target females. Moreover, capture methods at these sites were limited to only fyke nets and hand-capture of nesting females, again biasing results toward females. A fourth study site was selected due to the observed presence of many terrapins there in early May. Capture success at this site was high in early-May, but decreased considerably by late-May, and recaptures indicated that turtles moved away from this site, but not toward it. These findings all suggested that the site was an over-wintering area. It is important to note that the sex ratio of captures at this site approached 1:1, possibly reflecting the true ratio of males and female terrapins within the entire study site (Roosenburg 1990).

In Florida, sex ratios of captured terrapins varied seasonally, but included a female-biased high of 5:1 (Seigel 1984). The least-skewed captures were in March-April, during the spring mating season, when males reach their greatest representation in local populations. Bishop (1983) believed that catch dominance of males in the spring reflected their heightened activity and aggressiveness during the breeding season. A decline in catches of either sex after April or May tended to support this belief.

MORTALITY:

Predation:

Predation on eggs and hatchlings may represent the primary source of terrapin mortality in most populations. Within the terrapin's range, potential predators are many, and include crows, gulls, hogs, muskrats, raccoons, otters, skunks and foxes.

In New Jersey, Burger (1977) found predation rates of 51 and 73 percent for two successive years. Crows and laughing gulls were the primary avian predators, and were effective during the egg-laying period. Gull predation occurred when a gull disturbed a female laying eggs, who then left the nest with freshly-laid eggs exposed. Crows generally approached and dug up nests with their bills after the females had covered them and left. Raccoon and red fox were the primary mammalian predators. They were active at night and throughout the developmental period of the eggs, but increased their predation as hatchlings became present in nests. Mammalian predation was highest in protected dune areas surrounded by trees and shrubs, and avian predation was highest in open sand areas. Distance of a nest to the nearest vegetation was significantly greater for those that were not preyed upon. Areas with a greater density of nests experienced higher predation rates. Nests initiated in June had lower predation rates than those begun in July.

Roosenburg (unpub. data) noted predation on terrapin eggs by an ant species which fed on calcium. Lazell and Auger (1981) reported a form of predation by the beach-grass *Ammophila breviligulata*. They found that 25 percent of terrapin nests studied at a Massachusetts site had been infiltrated by rootlets of this grass. They speculated the grass actively sought out nests and used the eggs as a source of nutrients and moisture.

Adult terrapins are also susceptible to predation. Seigel (1980c) reported predation of an adult female terrapin at Merritt Island, Florida, by a raccoon. The raccoon broke the turtle's neck, severed the left hind leg, and pulled out internal organs through the resulting hole. A number of other freshly-killed terrapins were found along the dike, 86 percent of them adult females. Although dikes were surveyed year-round in 1977-78, signs of predation were evident only during the terrapin nesting season (late-April to early-July), a time requiring significant overland activity by adult females. As much as 10 percent of the adult female population may have been killed by raccoons during this period.

In a longer-term study of terrapins at Merritt Island, Seigel (1984) found a marked difference in population size structure between two lagoons. Thirty-one percent of females from one lagoon were more than 17.0 cm in plastron length, compared to only 3 percent from the second. Differential mortality, rather than sampling bias, was considered to be the cause. Females in the second location appeared to suffer heavy predation by raccoons during the nesting season, but not so in the first lagoon. Each time a female at the second lagoon came ashore to nest, she faced a high risk of encountering a predator and being eliminated, resulting in a lower proportion of females surviving to reach the larger, and older, size classes. It is possible that man-made changes of the Merritt Island habitat encouraged predation. A series of dikes built on the refuge in 1958 to control mosquitoes destroyed most of the area's salt-marsh habitat. A local resident claimed that raccoon populations increased sharply at that time (Seigel 1980c).

In Maryland, Roosenburg (1994) found predation by raccoons to be a primary cause for apprehension in terrapin females. Raccoons preyed upon both young and old terrapins, but primarily adult females coming ashore to nest. Terrapins were killed with a bite on the back of the head and, similar to those in Florida, eviscerated through the inguinal (groin) region. Nest predation was 55-95 percent and seemed to be density-dependent. He estimated only 1-3 percent survivorship of eggs to hatchlings due to predation on nests (Roosenburg 1990).

Motorized Vehicles:

Mortality of both adults and hatchlings from motorized vehicles (boats, automobiles, bikes, etc.) may be significant in some areas. In Massachusetts, Peter Auger found off-road vehicles (ORV) to be a major problem for emerging hatchlings which utilized ORV trails to move away from the nest. The hatchling mortality rate in such areas was 90 percent. Survivorship improved significantly with relocation of ORV trails.

In some areas, road kills cause a significant loss of adult females. At Cape May, New Jersey, as many as 267 female terrapins have been killed in one nesting season as they attempted to reach nearby nesting grounds (Roger Wood, unpub. data). Terrapins there appear to nest at any time of the day, both day and night, and are susceptible to road mortality at all times. A campaign has been initiated by local citizens and schools to patrol stretches of road and remove terrapins from danger.

In New York (Morreale, unpub. data), there was no apparent sign of motorboat impact or propeller damage to terrapins, although motorboat impact remained the primary source of impact to resident sea turtles. However, work carried out in Rhode Island (Caitlin Goodwin, unpub. data) revealed that propeller damage to female terrapins by motorboats was a significant problem. In Maryland as well, Roosenburg (1990) found motorboat impacts to be a chief cause of female mortality. Since 1987, nine terrapins have been found which had died as a result of propeller cuts. Of these, eight were mature females. Moreover, nearly 20 percent of captured adult females have had scars from propeller cuts, but only 2 percent of captured males. The higher frequency of propeller cuts among females may be a function of their larger size and reduced ability to escape oncoming boats as quickly as males. Moreover, certain terrapin behavior may increase opportunity for motorboat impacts. Roosenburg (1990) has observed as many as 200-300 terrapins basking on the water surface on calm sunny days when the upper inches of the water column are warmer than lower layers, making these terrapins particularly vulnerable to boating accidents. These aggregations often occur in channel areas where both boat traffic and boat velocities are high.

Habitat Loss and Modification:

Roosenburg (1990) believed habitat destruction to be a source of major impact on terrapins in Maryland. Construction of waterfront property eliminates terrapin nesting habitat directly, and bulkheading eliminates access to any remaining nesting areas. Because of their site-fidelity to nesting grounds, entire terrapin breeding colonies may be lost. Nesting activity may also be crowded into smaller and smaller areas, reducing the survival of nestlings. Some terrapins may continue to lay eggs where sandy areas remain seaward of bulkheads, but these eggs are destroyed as high tides inundate them. The drainage or impoundment of salt-marshes also results in habitat loss, and the alteration of normal freshwater flow into estuaries may adversely modify suitable terrapin use areas.

Roosenburg (1990) noted that planting sod-forming beach-grasses for erosion control could result in mortality of terrapin eggs and hatchlings. Rhizomes of such grasses frequently penetrate and kill terrapin eggs, or prevent emergence of hatchlings by entanglement (Lazell and Auger 1981). Introduced beach-grasses can quickly invade and colonize large areas of open sandy beaches previously used for nesting. Grasses may also affect beach microclimatology by altering soil temperature and moisture, subsequently altering the normal sex ratios of terrapin nestlings.

Shoreline development also increases predation upon nests and adult terrapins.

Predators such as raccoons are well-adapted to human encroachment and can expand their populations rapidly. The concentration of terrapin nests within smaller areas, due to loss of nesting habitat elsewhere, further increases predation loss (Burger 1977, Roosenburg 1993).

Significantly little is known regarding the behavior and ecology of hatchlings and very young juveniles, and many studies have noted a distinct absence of these age-classes in capture samples (Coker 1906, Hurd et al. 1979, Lovich and Gibbons 1990, Palmer and Cordes 1988, Seigel 1984). Some reports indicate that hatchlings and juveniles may depend on clumps of vegetation on beaches, or on tidal wrack containing marine vegetation, for cover (Burger 1976a, Lovich et al. 1991, Pitler 1985). In the case of Hurd et al. (1979), such areas were scarce and remote from nesting areas due to development and dredge-spoil placement. If hatchlings born in the area could find little or no suitable habitat in which to survive and grow, the missing age classes may have reflected a catastrophic and continuing source of mortality of young terrapins.

Other:

Seigel (1983) found that barnacles in Florida could do extensive damage to terrapin carapaces. Of two populations of terrapins, 76 percent were infested with any of three different species of barnacles. Barnacles most often settled on the carapace, where the primary impact was gradual shell erosion. In a few cases, such erosion was severe enough to cause fatal injuries. Infestation of the plastron was less frequent, but occurrence of barnacles here could interfere with mating and nesting activity. Seigel (1983) suggested that barnacles be considered parasites of terrapins rather than commensals.

CRAB-TRAPPING:

COMMERCIAL TAKE:

Known or suspected commercial terrapin harvesting occurs in at least eight states (New York, New Jersey, Maryland, North Carolina, Georgia, Florida, Alabama, Louisiana), and the demand may be increasing. Restrictions on this commercial take exist in some areas, but some prohibitions may require modification in order to better protect reproducing adults. The harvest of species for human consumption is generally targeted toward the largest individuals of a population; in the case of terrapins, these would be mature females. In Chesapeake Bay, commercial take of terrapins is limited to those at least 15 cm (6 inches) in plastron length, almost exclusively mature females (Roosenburg 1990). Possibly 8,000-12,000 of these individuals are taken annually. At the time of a study by Bishop (1983), South Carolina law prevented commercial terrapin harvest April-July 15. At all other times, however, the minimum legal size was 12.5 cm (5 inches) plastron length, eliminating almost all males and immature females from commercial exploitation; of 195 captured males, only two exceeded the legal size. However, mature females (usually over 12.7 cm in length) could be legally taken. As a result, probably the most important segment of a healthy terrapin population, reproductively mature females, may be selectively targeted for commercial harvest by many state regulations.

Without regulation, commercial harvesters could easily remove entire populations within a short period of time. Terrapins are long-lived species, probably surviving in excess of 40 years. However, females require about 7-9 years to mature and, once maturity is attained, fecundity may be relatively low and recruitment rates very low. Consequently, terrapin populations probably could not sustain long-term direct harvest if mature females were significantly exploitable. If the demand for terrapins should increase greatly, current regulations should consequently undergo review and possible revision in order to better protect the egg-laying members of terrapin populations.

INCIDENTAL TAKE:

Incidental take of terrapins by capture, and subsequent drowning, in shrimp nets and crab-traps has been documented and may represent a major impact. Terrapins are often mistakenly captured in pots baited for crabs, particularly when traps are placed in tidal creeks and shallow-water areas.

Occurrence:

Roosenburg (1990) considers entrapment of terrapins in crab-pots to be a significant problem in Maryland waters. Commercial crabbing is allowed only within the main channels of Chesapeake Bay (average depth 15 feet), where terrapin presence is unlikely. However, riparian landowners are allowed to place two crab-traps in waters off their properties for recreational food use. Generally, traps are placed in the water when landowners leave their site on a weekend, and checked for crabs when they return the next weekend. Along with crabs, the traps also capture and drown terrapins. Based on estimated numbers of active crab-pots, Roosenburg (1990) believes that 600-1500 terrapins may be drowning each year, a loss of as much as 20 percent of the population. He believes that this recreationally based incidental take may be more hazardous to terrapins than that from frequently checked commercial traps.

Bishop (1983) sampled various crabbing devices in South Carolina waters in an attempt to determine terrapin capture rates and the potential impact to the species from crabbing activities. In 1979, sampling was carried out at nine shallow-water stations using four devices (hard crab-pot, peeler pot, habitat pot, crab fyke). Hard crab-pots were baited with frozen fish, and peeler pots with live crabs; habitat pots and crab fykes were unbaited. Each station was fished and checked daily Tuesday-Friday April-November. In 1980, fishing efforts were confined to five stations and, in 1981, three stations. Sampling efforts at these locations began late March-early April and continued daily through June; capture gear was modified peeler pots and habitat pots.

Sampling results were highly variable for the three years. A total of 281 terrapins were captured: 65 in 1979 (0.5:1 male:female), 172 in 1980 (3.3:1 male:female), and 44 in 1981 (13.7:1 male:female). In 1979, hard crab-pots were the most successful with 71 percent of all captures. The habitat pot was the least effective, with only a one percent capture rate, and peeler pots and crab fykes were about equal in success. In 1980, peeler pots made four times more captures than habitat pots but, in 1981, habitat pots were three times more effective than peelers.

Terrapin capture was distinctly seasonal. Over 55 percent of all captures were made in April, 32 percent in May, and 5 percent in June. In 1979, no terrapins were caught after September, and catches after May (total of 25) were almost completely restricted to baited pots. In 1980, only five terrapins were caught after May and, in 1981, all captures were in April. Bishop (1983) believed that elevated April-May catches resulted from post-hibernation feeding and spring reproductive activity. Shallow-water mudflats are warmer in spring than are deeper waters. Crabs can often be found within such areas and so are often preferentially fished there by crabbers. Since Bishop's (1983) findings indicate that terrapins are also particularly active during this time, crabbing in shallow areas during this period may result in significantly high terrapin captures.

Terrapin catch per-gear-day in April-June ranged from a high of 0.24 for habitat pots in April 1981, to 0 for habitat pots in March and June 1980, and 0 for both habitat pots and peeler pots in May and June 1981. Hard crab-pots averaged 0.16 terrapins per gear day in April and May 1979. Using this capture rate, the number of licensed crabbers in South Carolina, an estimated average of 60 pots fished by each crabber, and the percentage of those fished close to shore in shallow water, an estimated April-May catch rate of about 2,853 terrapins daily can be determined for South Carolina waters.

Terrapin mortality from drowning, however, may not be equal to capture numbers. Bishop (1983) found that terrapins were rarely discovered drowned if traps were checked and emptied on a daily basis. Mortality under these conditions was estimated to be 10 percent of captures, but higher if daily checks were not possible. Assuming a 10 percent mortality rate, the number of South Carolina terrapins found drowned on a daily basis in spring in commercial crab-traps would be approximately 285. Further assuming a 10 percent mortality rate from crab-trapping throughout its range, the high number of crab-pots fished each year in U.S. waters within terrapin habitat could account for a substantial amount of post-juvenile terrapin mortality, possibly more than that resulting from any other single factor (Bishop 1983).

Although terrapins in northern climates appear capable of surviving inundation for a prolonged period, those in southern habitats may be much more vulnerable to drowning. Tom Mann (unpub. data) has found that terrapins in Mississippi waters can easily drown after only three hours within a crab-trap, indicating that crab-trap mortality may be much higher than currently assumed for some areas. His observations argue the need for more extensive studies of long-term effects of the crab fishery in various portions of the terrapin's range, particularly within the Gulf Coast region.

Size Restrictions:

Crab-pots are likely to capture a disproportionate number of terrapin males and young females. Roosenburg (1990, 1993) found that terrapin females of age 8 and above were generally too large, more than 15 cm plastron length, to easily enter crab-pots. Adult males, however, remained sufficiently small (average 11.2 cm plastron length) to enter traps, making all male age-classes vulnerable to capture. In a survey of crab-pot captures, Roosenburg (1993) found a 2:1 ratio of adult males to females, while a survey of all capture methods revealed an adult male:female ratio of 0.46:1. Young females also remained vulnerable. The average size of females caught in crab-traps was 10.9 cm plastron length, while the average size of females caught by all methods was 16.2 cm. Bishop (1983) also found that, in his crab-pot captures, males outnumbered females 2.3 to one, probably because the small openings (typically 11-12 cm in width) of tested crab-traps precluded entry of mature females. The size of captured males ranged 7.9-12.8 cm in plastron length, with a median of 10.0 cm. Females were 7.6-17.5 cm, with an average of 12.1 cm.

Ghost Traps:

Perhaps far more detrimental to terrapin populations is the existence of ghost pots, traps lost accidentally or intentionally released but no longer fished. Ghost pots are frequently carried to shallow areas through tidal action and, in such locations, may account for substantial terrapin mortalities. One pot found in April 1978 contained the decomposing bodies of 28 terrapins (plastron length 8.8-16.3 cm) (Bishop 1983). In Maryland waters, recreational crab-pots are frequently abandoned or lost at the end of summer, continuing to catch turtles throughout the fall and following spring (Roosenburg 1990, 1993). One abandoned crab-pot contained the entire shells of 49 terrapins and the remains of many others, representing as much as 1.6-2.8 percent of the terrapin population. It is also possible that the presence of a terrapin in a crab-pot serves as an attractant to other terrapins, increasing the likelihood of large kills (Bishop 1983, Roosenburg 1990). In Bishop's (1983) study, nearly half of all capture events in 1980-1981 involved two or more terrapins. In one case, 15 terrapins were obtained in a single catch. One was a female and was probably responsible for capture of the 14 accompanying males.

Protective Measures:

Terrapins in New Jersey are protected April through October, and crabbers are required to check their traps daily for terrapin. However, crab-traps may remain a significant cause of incidental terrapin mortality. To reduce the incidental take of terrapins, various forms of "diamondback excluder devices" (DED) may require investigation. One has been developed by Roger Wood (unpub. data) involving the placement of wire rectangles within the entrance funnels of a trap, making the entrances too small for most terrapins, but still allowing crabs to enter. The device appears to be 95 percent effective in excluding terrapins, but also allows a significantly higher number of crabs to be caught with minimal reduction in overall size. Another form of device may involve the placement of a small piece of PVC pipe placed on each side of a trap entrance.

Roosenburg (1993) has developed a modified crab-trap that increases the trap height, allowing terrapins access to the water surface and air. To be effective, however, the traps must reach above the highest tide level, restricting their use to relatively shallow water (two-foot tidal amplitude at most sites). The modified design has been tested and no difference in capture success of crabs was found, but a significant reduction in numbers of drowned terrapins was noted (Roosenburg 1993). The cost of all of the above devices or trap modifications is relatively small.

A similar source of mortality for terrapins (and other air-breathers) may stem from the use of nets with cod ends, such as fyke nets, which are permanently submerged. Dead, apparently drowned, terrapins have been found in the vicinity of fyke nets. Roosenburg (1993) has found that placement of a float in the back of the cod end can avoid this type of terrapin loss.

STATUS:

Conflicting information exists regarding the status of the terrapin in various parts of its range. Populations are reported to be stable (or slowly increasing) in Massachusetts and the Florida Keys. Terrapins in Long Island South, New York, were specifically investigated recently due to fears that large numbers were being taken for food by the local Asian community. However, a healthy population appears to be present, with terrapins found at over 70 percent of study sites and within a variety of habitats (Steve Morreale, unpub. data).

However, a two-year study of terrapins in a Delaware salt marsh suggested a population decline and lack of recruitment of new individuals (Hurd et al. 1979). Capture effort in 1975 indicated a reduction in population size through the active season, from a June mean of 1655 (density of 1.8 terrapins per linear meter) to an August mean of 378. The decline primarily occurred in late-July, and was assumed to be due to late-season dispersal. However, 1976 data indicated a continued decline of population and no significant immigration of new individuals. The reduction in numbers was disproportionate between the sexes, with 30 percent fewer males, but 57 percent fewer females, and a specific decline in females of less than 15.5 cm carapace length. Size-class frequency data revealed a lack of juveniles; specimens 3.0-9.0 cm in length could not be located anywhere in the marsh, although newly hatched specimens had been observed near nesting sites, and various capture techniques were used. Studies elsewhere have also noted an absence of hatchling and very young terrapins during capture efforts (Coker 1906, Lovich and Gibbons 1990, Seigel 1984).

In Maryland waters, over 3500 terrapins have been captured and marked as part of a long-term mark-recapture study within the lower Patuxent River of Chesapeake Bay (Roosenburg 1990). The findings indicate low recruitment of young; over 50 percent of the population is comprised of individuals over 10 years of age. Moreover, the number of successful nests declined from 3.6

percent in 1987 to 2.4 percent in 1990. Despite an apparent decrease in nest predation, the number of hatchlings produced from each successful nest decreased from a mean of 10.75 to 3.4. He has found the species to be localized in distribution, limited in the number of dispersal sites, and extremely vulnerable to mortality factors. Identified management needs include greater protection of reproducing females and of nesting sites.

During the progress of one study in South Carolina, captures of terrapins ceased within one drainage, apparently due to loss of the resident population. Members of that population were not captured elsewhere, indicating they had not simply moved from the area into another. A distinct lack of young turtles was apparent. Incidental take by crab-trappers was considered a possible cause of the loss (Lovich and Gibbons, unpub. data).

On the Florida east coast, population estimates for two study areas in the early 1980's were 404.7 and 212.5 (densities 178.3 and 131.1 per acre) (Seigel 1984). In 1992 and 1993, these two Florida study sites were re-sampled, with timing, locations, and sampling procedures identical to those used in the earlier study (Seigel 1993). The 1992 search revealed only one terrapin, and, in 1993, 4-6 terrapins. Local observers indicated the last large terrapin aggregation had occurred in 1986, with terrapins only being seen rarely since then. No obvious cause for the decline was apparent. Primary habitat changes since 1979 were loss of mangrove vegetation along one dike due to two winter freezes, and some erosion and siltation of a canal. Population losses may have been due to these alterations, or to direct mortality from the winter freezes. Other possibilities included long-term raccoon predation, incidental capture of terrapins in crab-traps, which were common in two of the area's lagoons, and the placement of dredge-spoil onto terrapin foraging areas (Seigel 1993).

Although relatively substantial work has been conducted on terrapin populations along the Atlantic Coast, very little work has been done in coastal areas of the Gulf of Mexico. An accurate determination of terrapin status is an essential need for this region. Populations in Mississippi appear to be low and may be experiencing continued severe declines (Tom Mann, unpub. data).

Terrapin numbers in Alabama may be declining, and populations are facing a growing series of pressures (Marion 1986). The major threat may be reduction of coastal marsh habitat due to dredging and filling operations associated with residential and industrial development. Crab-trapping may be another major threat. Although extensive hunting of terrapins for food is now restricted, some take for food purposes (and possibly the pet trade) continues. More important, however, is the growing number of crab-traps placed close to marsh areas which incidentally capture and drown terrapins. Large females are now uncommon in many areas that otherwise support suitable habitat. In order to prevent further decline of terrapin populations, Marion (1986) has identified the need to better ascertain the status of the species along the Alabama coast, particularly extent of mortality due to crab-trap activities. The protection of important marsh habitats is of extreme importance.

1994 Diamondback Terrapin Workshop:

On August 2, 1994, 35 experts from 13 states gathered at the Savannah River Ecology Laboratory in South Carolina to discuss the ecology, status, and conservation of the diamondback terrapin. This Workshop, sponsored and hosted by Richard A. Seigel (Southeastern Louisiana University) and J. Whitfield Gibbons (Savannah River Ecology Laboratory), was prompted by reports of potential declines of terrapin populations in several locations in its range. In addition to sharing data on terrapin ecology and status, the Workshop was designed to produce specific recommendations for action by local, state, and federal management agencies.

Based on the Workshop proceedings and on the results of a questionnaire distributed at the Workshop, Seigel and Gibbons have summarized the major findings and recommendations of the Workshop as follows:

1) There is evidence for stable or increasing populations in five states, declining populations in seven states, and insufficient data for remaining areas (see below). Broad-scale data, however, are lacking for most states within the range of the species.

Stable:	Massachusetts (slowly increasing) Rhode Island New York Florida (Keys)
Declining/Stable:	Maryland
Declining:	New Jersey (declining rapidly) North Carolina South Carolina Florida (Atlantic Coast) Mississippi Louisiana
Unknown:	Delaware Virginia Georgia (anecdotal evidence of decline) Alabama Texas

2) There is insufficient evidence at this time to warrant listing the species under the auspices of the Endangered Species Act. However, there is sufficient evidence to consider designating all subspecies Category 2 candidates for listing (the northern, Mississippi, and Texas subspecies are currently Category 2 candidates).

3) Most participants believed that terrapins merited protection by State legislation where such protection was not already provided.

4) There is an urgent need for better survey data throughout the range. Surveys should use multiple methods to insure reasonable sampling representation of sexes, size classes, etc. The exact methods used may need to vary from region to region. Surveys should be repeated at appropriate intervals (i.e. a single year is not considered sufficient).

Workshop discussions on threats to the species were summarized as follows:

1) One of the major threats to populations of terrapins appears to be incidental drowning in crab traps. Immediate efforts should be made to reduce incidental killing in crab traps by the use of newly-developed excluder devices. In addition, efforts should be made to determine the extent of mortality in crab traps by determining the number of operational traps in optimal habitats of terrapins, and extrapolating from known mortality rates. Better data are also needed on mortality rates from other portions of the terrapin's range.

2) Habitat loss continues to be a major concern. Examples include drainage and impoundment of saltmarshes, human disturbance of nesting sites, and altered flow of freshwater into estuarine systems. GIS technology should be used to determine the loss of nesting and feeding habitat.

3) Other potential threats include (but are not limited to) commercial harvesting for the meat and pet trade, incidental kills by motorboats, road mortality, and predation on adults and eggs by raccoons and other predators. These threats require additional study.

Research Needs:

All participants of the August terrapin Workshop identified a critical need to resolve data gaps. Although some aspects of terrapin ecology are well-known in at least some parts of its range, many areas remain poorly studied. Workshop discussions resulted in a list of critical research needs. These areas warrant special consideration for funding by state and federal agencies:

- demography
- behavioral ecology
- habitat requirements (nesting, foraging, wintering)
- juvenile ecology
- genetic and taxonomic analysis of subspecies
- movement ecology and home range size (using telemetry, sonic tags)
- mortality factors

SUMMARY:

The life history and demographic structure of terrapins make them a species that is extremely vulnerable to changes in its habitat and mortality pressures. Their prolonged generation time renders them unable to adapt to rapidly changing environmental pressures while enduring losses of reproductive individuals. Terrapin demography of the terrapin may normally involve low survivorship and recruitment of young individuals. Therefore, the best assurance for the success of this species may lie in protection of the reproductively mature segment of the population, as well as insuring that sufficient numbers of young survive to sustain a healthy population.

Workshop participants concluded that diamondback terrapins do not appear to be in immediate jeopardy of extinction, although there is sufficient evidence indicating that populations in some areas are declining as a result of factors described above. Rather than initiate an Endangered Species listing at this time, the Workshop attendees concluded that, if taken now, proactive steps would help to improve conditions for the species and avoid the restrictions imposed by such a listing. However, these proactive steps require sufficient funding by state and federal agencies to allow detailed surveys and research, as well as cooperation from research biologists. Failure to conduct the needed studies will likely result in continued population declines and, eventually, a need for Federal protection and restriction. Thus, action must be taken now, before the species declines to the point where only dramatic intervention will be possible.

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1995

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APPENDIX B.

CAPTURE METHODS

The following capture methods have been used in various terrapin studies:

MASSACHUSETTS: Auger (1989) conducted work on the northern-most known terrapin population, located at Wellfleet Harbor in Cape Cod, Massachusetts, which has a tidal amplitude of up to 10 feet. Several capture techniques were utilized, including modified Auger trawls, dip-nets, and capture by hand. This last technique was the most effective and produced a 1:1 male:female capture ratio.

NEW YORK: Each selected study site was sampled for 36-72 hours before moving on to the next. Capture techniques were of many different types, including a series of trawls pulled from the back of a small boat, trammel nets, seining, and baited traps. Hand-capture by snorkelers was found to be the most successful technique, accounting for over 57 percent of all captures. Terrapins do not seem to be as deterred by a small profile above the water (such as a snorkeler's head) as they are by a boat. Less successful techniques included seining, hand-capture of terrapins by scuba-divers, and trammel nets. Baited traps and trawls were the least effective (Steve Morreale, unpub. data).

NEW JERSEY: Yearicks et al. (1981) used otter trawls and baited traps to capture terrapins in the creeks, sounds, and main channels. They found hibernating terrapins by probing the soft banks and creek bottoms with rods or poles, and excavating all hard objects. A total of 311 hibernating terrapins were located, ranging 9.7-18.6 cm in carapace length. Adults of both sexes were discovered, but no juveniles, but the method used may not have been able to detect very small terrapins.

DELAWARE: Studies done on turtle species have indicated that any single sampling method may bias estimates of population size and sex ratio. Hurd et al. (1979) chose the trawl method because it allowed capture of relatively large numbers of individuals in a single day, which was necessary to population size estimates based on the Lincoln Index. Seining, baited traps, and fyke nets yielded low sample sizes in the marsh system, and were not considered reliable techniques due to current velocities and hydrography of the marsh. Further, none of these alternative techniques captured larger or smaller individuals than those obtained in trawl samples. Sampling further upstream was prohibited by abrupt narrowing and meandering of the creek channel. Attempts at sampling during high tides yielded poor capture results.

Terrapins were taken at low slack water along the lower creek of a salt marsh by trawling repeatedly (usually four times) until increasing flood currents became prohibitive. A 6-m otter trawl, 3m x 1m at the mouth, with 5.0 cm mesh at the collecting bag, was used. Trawl speed was approximately 2.4 kph, but was adjusted to keep the trawl on or near the bottom at all times. Captured terrapins were marked with numbered plastic pennant tags by drilling a hole through a postcentral marginal scute at the rear of the carapace and fixing the tag with brass wire. Terrapins were sexed and the mid-carapace length measured before release back into the creek.

MARYLAND: Roosenburg (1993) recommends the following trapping techniques: fyke nets, crab-pots, peeler bank traps, and capture of females by hand that are coming ashore to nest. Traps were checked daily May 11-June 24. Gill nets were also used. Identification of terrapins was done by counting annuli on the plastron, possibly a better method than use of the carapace.

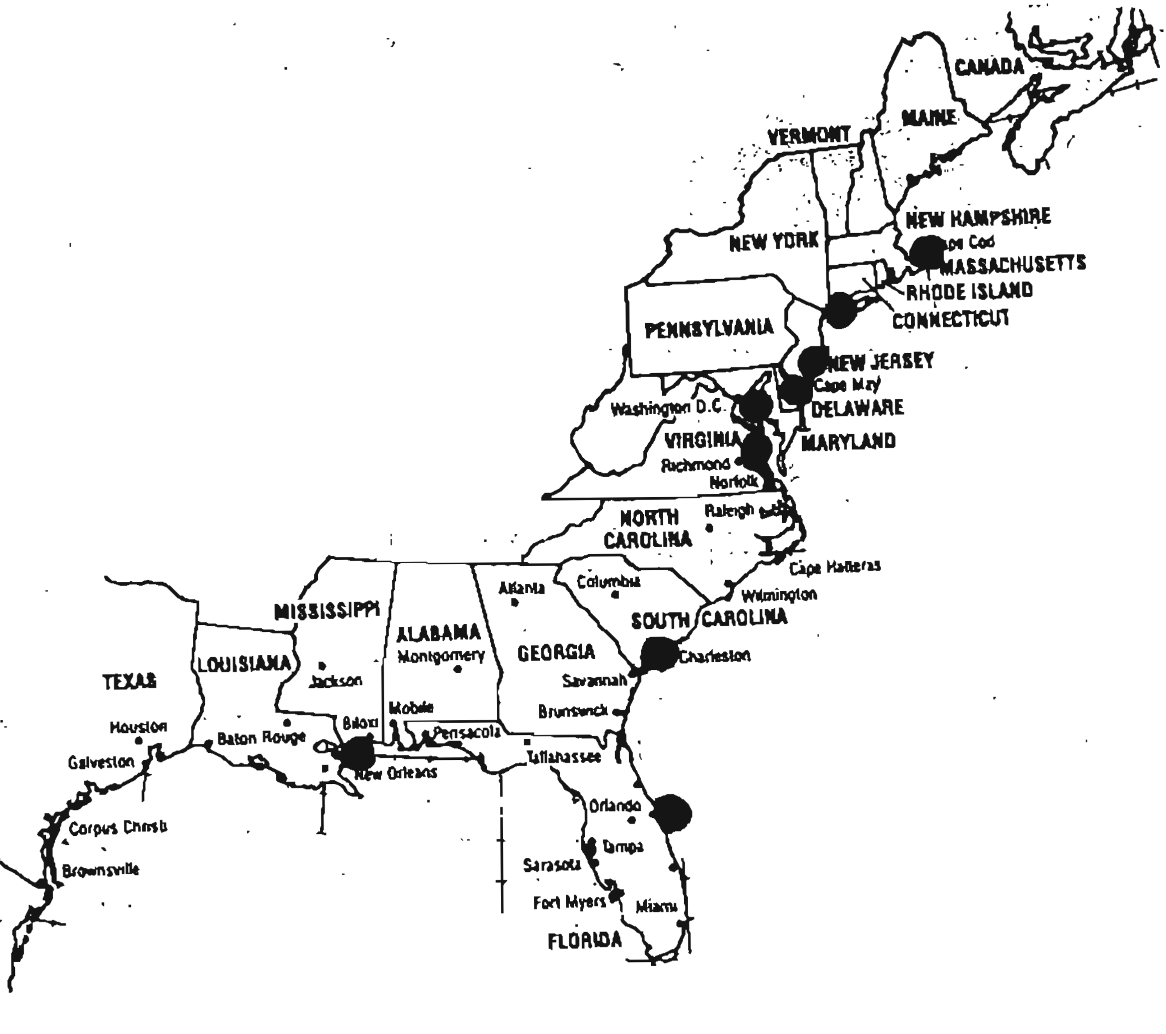
SOUTH CAROLINA: Lovich and Gibbons (1990) used a variety of techniques (dip-netting, hand capture, seining, trammel nets, and trawling) to capture a total of 414 turtles (265 males and 149 females) on Kiawah Island, South Carolina. All captures were male-biased.

GEORGIA: Captures of terrapins were most successful with placement of stop nets across the deeper parts of tidal creeks 150-600 feet (45-180 m) wide over shell bottoms and near oyster banks (Carr 1952).

FLORIDA: Seigel (1984) studied terrapins at Merritt Island NWR, Florida. At one lagoon, terrapins were collected by deploying small mesh (maximum diameter 6 cm) gill nets along a narrow canal. Two nets were set perpendicular to the shoreline to block off a 100 m section of the canal. Turtles moving up and down the canal became entangled and were removed within two hours of capture. Terrapins at a second lagoon were collected purely by hand as they basked on a spoil island or swam in the surrounding waters.

MISSISSIPPI: Tom Mann's capture method for one season has involved modified crab-traps that are placed in the water for 48 continuous hours, but are checked and rebaited every 6-8 hours. He will be modifying his crab-traps further, based on results gathered to date.

APPENDIX C.
RESEARCH LOCATIONS



APPENDIX D.

TERRAPIN PROTECTION DEVICES

Crab-trapping has been shown, or is suspected, to be responsible for major losses of terrapins each year in many locations. The targeted segment is generally males and immature females; mature females are usually too large to easily enter a standard crab-trap. In an effort to reduce the impact of this activity, various devices designed to either exclude terrapins from crab traps, or enable them to avoid drowning, have been proposed to date.

TERRAPIN EXCLUDER DEVICES:

Roger Wood, of Stockton State College, New Jersey, has studied terrapins at Cape May. and believes that crab-traps represent a major problem for terrapin populations in that area. This is despite the fact that terrapins are protected from take April 1 through October, and that crab-trappers are required to check their traps daily. In an effort to reduce such losses, he has developed a simple excluder device.

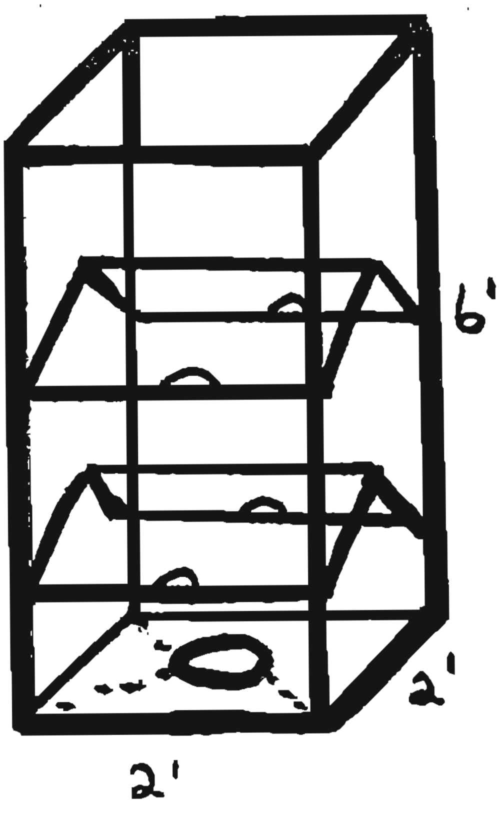
Four small rectangles are fashioned from a coat-hanger, and one is placed in each of the four entrance funnels of a crab-trap, making the entrance too small to allow most terrapins to enter the trap. Studies have indicated that the device may have reduced the number of trapped terrapins by as much as 95 percent. Equally important, however, at least to crab-trappers, is the finding that the device does not result in a reduction of crab-catch but, rather, a significant increase in the number of crabs caught, with little reduction in their overall size.

Willem Roosenburg, of Hood College, Maryland, has conducted extensive work on terrapins in Chesapeake Bay. He has found that crab-traps can be a significant cause of terrapin mortality (possibly as much as 20 percent of the population annually), and has fashioned an excluder device that appears to result in reduced losses. He has found that PVC piping, 3-1/2 inches long, placed on the sides of each of a crab-trap's "churches", can be highly effective in preventing entrance by most terrapins.

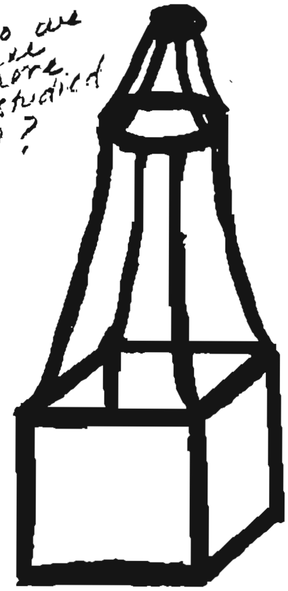
TERRAPIN-SAFE CRAB-TRAPS:

Willem Roosenburg, working in Chesapeake Bay, has developed a modified crab-trap that increases the height of the trap, allowing terrapins to retain access to air and avoid drowning. To be effective, however, the trap must be tall enough to exceed the highest tide water level. This may limit their successful use to relatively shallow areas, rendering them ineffective in very deep waters.

The modified design has been analyzed in regard to the effect on crab-catch, and has been found to be more effective in trapping crabs, resulting in a slight increase in total captures. The cost of the modified trap design is nominal and, hopefully, will not inflict an economic hardship on crab-trappers; total cost of the modified trap is generally about $30.



Tom Mann of the Museum of Natural Science, in Jackson, Mississippi, has been studying terrapins along that state's coastline, and has noted a severe decline in terrapin numbers from historic records. He has modified a conventional crab-trap for capture of terrapins, which allows them access to air until they can be checked and released. He has found that Mississippi terrapins, captured in a conventional crab-trap, can drown in as little as three hours, a much shorter period of time than that considered safe in more northern climates. The current trap design may be modified still further by Mann, based on information acquired during his studies.



IMPLEMENTATION:

All workers recommend the introduction and implementation of trap modifications and terrapin excluders, by both commercial and recreational crab-trappers, as soon as possible in order to reduce current mortality rates to terrapins due to crab-trapping activities. However, it is also recommended that these protective measures be incorporated by crab fishermen on a voluntary basis rather than as a new requirement forced upon the fishery. Information regarding the need for change might be initially introduced through sportsmen's conservation organizations, with a request that they further disseminate the information to crab fishermen. Programs to underwrite the cost of the recommended changes might also be explored in order to avoid economic hardship of crabbers. However, terrapin populations are declining in at least seven states, and their status in five more are unknown. Crab-trapping is considered to be one of the major mortality factors. It should be noted that, if voluntary efforts and current regulations are not found to be sufficiently protecting terrapin populations, more restrictive measures may eventually require implementation.

APPENDIX E.

SUMMARY OF TERRAPIN WORKSHOP

WORKSHOP ON THE ECOLOGY, STATUS, AND MANAGEMENT OF THE DIAMONDBACK TERRAPIN

ORGANIZED BY RICHARD A. SEIGEL AND J. WHITFIELD GIBBONS

SAVANNAH RIVER ECOLOGY LABORATORY

2 AUGUST 1994

FINAL RESULTS AND RECOMMENDATIONS

Introduction

On 2 August, 1994, 35 experts from 13 states gathered at the Savannah River Ecology Laboratory in South Carolina to discuss the ecology, status, and conservation of the diamondback terrapin (Malaclemys terrapin). The Workshop was prompted by reports of potential declines of terrapin populations in several locations in its range. In addition to sharing data on terrapin ecology and status, the Workshop was designed to produce specific recommendations for action by local, state, and federal management agencies. Below, we have summarized some of the major findings and recommendations of the Workshop. Please bring these to the attention of the appropriate individuals in your area who have responsibility for managing this unique resource. Additional questions concerning the Workshop may be addressed to either Richard A. Seigel or J. Whitfield Gibbons (addresses listed below). A list of all attendees is also attached.

Research

1) Although some aspects of terrapin ecology are well-known in at least some parts of the range, many areas remain poorly studied. What follows is an unranked list of some areas the Workshop considered critical at this time. These areas warrant special consideration for funding by state and federal agencies:

- -Demography
- -Habitat use
- -Ecology of juveniles
- -Taxonomic studies on subspecies
- -Genetic studies (e.g. DNA fingerprinting)
- -Movement patterns and home range size
- -Long-term life history studies
- -Behavioral ecology

Status

1) Based on information developed at the Workshop, there is evidence for declines of populations of diamondback terrapins in seven states, evidence for stability or increases in populations in five states, and insufficient data are available for seven states. However, broad-scale data are lacking for most states within the range of the species.

2) There is insufficient evidence at this time to warrant listing the species under the Endangered Species Act. However, there is sufficient evidence to consider placing all subspecies as Category 2 candidates for listing (two subspecies are already listed as Category 2 candidates).

3) Based on results of a questionnaire distributed at the Workshop, most participants felt that terrapins merited Protected Status in most states where such protection was not already provided. The results of the questionnaire are attached.

4) There is an urgent need for better survey data throughout the range. Surveys should use multiple methods to insure reasonable sampling representation of sexes, size classes, etc.

The exact methods used will vary from region to region. Surveys should be repeated at appropriate intervals (i.e., a single year is not considered sufficient).

Threats

1) One of the major threats to populations of terrapins appears to be incidental drowning in crab traps. Immediate efforts should be made to reduce incidental killing in crab traps by the use of newly-developed excluder devices. In addition, efforts should be made to determine the extent of mortality in crab traps by determining the number of operational traps in optimal habitats of terrapins, and extrapolating from known mortality rates. Better data are also needed on mortality rates from other portions of the range.

2) Habitat loss continues to be a major concern. Examples include drainage and impoundment of salt marshes, human disturbance of nesting sites, and increased flow of fresh water into estuarine systems. Loss of habitat for both nesting and feeding areas should be estimated via GIS methods.

3) Other potential threats include (but are not limited to) commercial harvesting for the meat and pet trade, incidental kills by motor boats, road mortality, and predation on adults and eggs by raccoons and other predators. These threats require additional study.

SUMMARY

Although diamondback terrapins do not appear to be in immediate jeopardy of extinction, there is sufficient evidence that populations in some areas are declining as a result of the factors described above. Rather than call for an Endangered Species Listing at this time, the Workshop felt that proactive steps would help to both improve conditions for the species and avoid the restrictions imposed by such a listing. However, these proactive steps require sufficient funding by state and federal agencies for detailed surveys and research, as well as cooperation from research biologists. Failure to conduct the needed studies would likely result in continued population declines and eventual federal status. Thus, action needs to be taken before the species declines to the point where only dramatic interventions will help.

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State	Source	Status	Recent Survey?	Threats (in rank order)	Steps Needed	Current Research?
MA	P. Auger	Stable or Increasing	Ongoing	Motor boat impacts; nesting habitat alteration	Retain "Species of Special Concern" status	Yes
RI	C. Goodwin	Unknown/Stable	Yes-1993	Predation, habitat loss, pollution, harvesting, motor boats	State Protected Status; regulations on motor boats	Yes
NY	S. Morreale	Stable	1991	Shoreline development; channelization of marshes; pollution	Habitat protection	No
NJ	R. Wood	Declining	No	Crab traps, habitat loss, road kills	Crab trap regulations	Yes
MD	W. Roosenberg	Declining/Stable	No	Crab traps, habitat loss, motor boats, harvesting	State Protected status; crab trap regulations	Yes
VA	J. Mitchell	Unknown	No	Crab trapping, harvesting, habitat loss, predation, pollution, pet trade	State Protected status; crab trap regulations	No; not planned
NC	A. Braswell. T. Conant	Declining or Unknown	Yes	Crab traps, predation, habitat loss, road kills, pollution, predation	State Protected status; crab trap regulations	Yes
SC	J. Lovich, T. Zimmerman, K. Aifieri	Unknown (Lovich) Declining (Aifieri)	No (local only)	Crab traps, habitat loss, road kills, harvesting	State Protected status; crab trap regulations	Yes

State	Source	Status	Recent Survey?	Threats (in rank order)	Steps Needed	Current Research?
FL (Atlantic Coast)	R. Seigel	Declining	Yes (local)	Predation, habitat loss, crab traps, harvesting	State Protected species	Yes
FL (Keys)	R. Wood	Stable	No	None	None	No
AL	R. Clay	Unknown	No (planned for 1994-95)	Crab traps?, habitat loss, pet trade, harvesting	Crab trap regulations; education of enforcement officers	Yes
MS	T. Mann	Declining	Yes-1994	Crab traps; commercial harvesting; predation; habitat loss	Crab trap regulations; state protected status;	No
LA	R. Seigel	Unknown or declining	No (none planned)	Crab traps?	Unknown	No; not planned
TX	A. Price	Unknown	No (1984)	Habitat loss, crab traps, harvesting, pollution	State Protected status or game status; crab trap regulations	No; not planned