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THE DIAMONDBACK TERRAPIN: THE BIOLOGY, ECOLOGY, CULTURAL HISTORY, AND CONSERVATION STATUS OF AN OBLIGATE ESTUARINE TURTLE

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Abstract. Ranging from Cape Cod to nearly the Texas-Mexico border, the diamondback terrapin (*Malaclemys terrapin*) is the only species of North American turtle restricted to estuarine systems. Despite this extensive distribution, its zone of occurrence is very linear, and in places fragmented, resulting in a relatively small total area of occupancy. On a global scale, excluding marine species, few turtles even venture into brackish water on a regular basis, and only two Asian species approach the North American terrapin's dependency on estuarine habitats. Here we describe some of the biological and behavioral adaptations of terrapins that allow them to live in the rather harsh estuarine environment. In this chapter we review the natural and cultural history of this turtle, discuss conservation issues, and provide information on the types of research needed to make sound management decisions for terrapin populations in peril.

Key Words: Adaptations, conservation, genetics, *Malaclemys terrapin,* population, management, saltmarsh.

LA TORTUGA DE AGUA DULCE: ESTATUS BIOLÓGICO, ECOLÓGICO, HISTORIA CULTURAL, Y ESTATUS DE CONSERVACIÓN DE UNA TORTUGA ESTUARINA OBLIGADA

Resumen. Extendiéndose desde el Cabo de Bacalao hasta casi la frontera entre Texas y México, la tortuga de agua dulce (*Malaclemys terrapin*) es la única especie de tortuga de Norte América restringida a sistemas de estuarios. A pesar de la extensiva distribución, su zona de ocurrencia es muy linear y en lugares fragmentados, lo qual resulta en una relativamente pequeña área total de ocupación. A escala global, excluyendo especies marinas, pocas tortugas se aventuran a aguas salobres en base regular, y solo dos especies asiáticas alcanzan la dependencia de la tortuga de agua dulce de Norte América en habitats de estuario. Aquí describimos algunas de las adaptaciones biológicas y de comportamiento de las tortugas de agua dulce que les permiten vivir incluso en el ambiente de estuario más duro. En este capítulo revisamos la historia natural y cultural de esta tortuga, discutimos asuntos de conservación, y proveemos información sobre los tipos de información que se necesita para tomar decisiones de manejo adecuadas para las poblaciones de tortuga de agua dulce en peligro.

Many freshwater fishes, mammals, and a variety of birds exploit marine and estuarine habitats so it is surprising that, even on a global basis, only a few reptiles occur regularly in salt and brackish marshes (Greenberg and Maldonado, *this volume*). The dearth of saltmarsh reptiles follows a general lack of reptilian species adapted to any marine environment. Crocodiles (two species), sea turtles (two families, seven species), sea snakes (about 50 species), and marine iguanas (one species) are the only truly marine reptiles. Most of the aforementioned species are strictly marine; the diversity of reptiles with a strong association with estuarine habitats, including saltmarshes, is lower. Although populations of various snakes and freshwater turtles have taken up residence in brackish habitats, few taxa (species or subspecies) are restricted to tidal marshes (Greenberg and Maldonado, *this volume*). In contrast, the diamondback terrapin appears to have a long evolutionary association with estuaries and their saltmarshes. The degree of divergence in terrapins is reflected in its status as representing a monotypic genus with time since divergence from non-estuarine taxa estimated as being in the neighborhood of 7–10,000,000 yr (Chan et al., *this volume*). If these estimates are correct, terrapins are the taxa with the longest estimated association with tidal marshes. Interestingly, two other species of turtle (also in monotypic genera) are largely restricted to estuarine habitats, but are found in tropical systems of southeast Asia (*Callagur* and *Orlitia*). Therefore, the diamondback terrapin, which occurs along the Atlantic and Gulf coasts of North America, is the only species of turtle specialized to saltmarsh and estuarine habitats in the temperate zone. In addition to its unique ecological evolutionary status, diamondback terrapins have achieved a level of economic and cultural importance that surpasses most of the saltmarsh vertebrates. Before populations were reduced, terrapins supported a multimillion dollar industry catering to the gourmet restaurant trade. Over-harvest and habitat modification virtually eliminated them in the late 1800s and early 1900s (Lazell 1979). All of these factors justify a focused look at diamondback terrapins as a saltmarsh endemic. We focus this chapter on terrapin adaptations to the salty estuarine environment, as well as cultural history or past human use of the terrapin as a food resource. We then discuss the management and conservation future of this well-known estuarine endemic.

RANGE OF THE DIAMONDBACK TERRAPIN

The diamondback terrapin has a range consisting of small, linearly distributed, and isolated populations in US coastal waters from Cape Cod, Massachusetts, to the Texas-Mexico border. Seven subspecies (Fig. 1) have been described, based primarily on differences in carapace morphology and skin coloring. Some of these smaller, regional subpopulations are extremely vulnerable to extinction.

CULTURAL HISTORY

Diamondback terrapins played an important role in the cultural history of colonial America. These turtles were an important food item of the Continental Army in the 1700s, and in later years were a major source of protein for

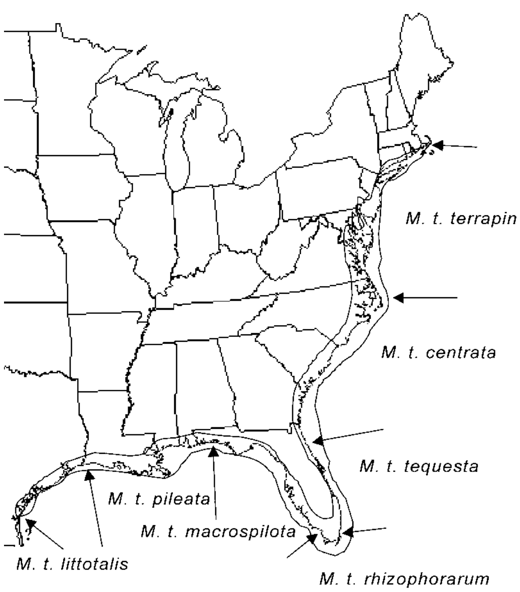

FIGURE 1. Current range and subspecies designations for the diamondback terrapin (modified from Carr 1952).

slaves on tidewater plantations. In the late 1800s through the Great Depression terrapins were a highly sought-after item in exclusive restaurants as well as an important food source for families living in remote coastal settings. This high demand for terrapins resulted in a population crash and a major effort of the U.S. Federal Bureau of Fisheries to raise terrapins for restocking and commercial use. Because of their previous cultural and economic importance terrapins are arguably one of the most celebrated reptiles in North America.

At one time, slaves in tidewater plantations consumed a diet heavy in turtle meat, with terrapins reportedly served about two times a week. Then, for reasons difficult to explain terrapin meat became regarded as a gourmet item. Virtually overnight terrapins were sought with enthusiasm by the privileged. As early as 1830 the Prince of Canino tried to transplant terrapins to Italy. Later, the species was successfully established in Bermuda (D. Lee, pers. obs.) and at least two unsuccessful attempts were made to establish them in San Francisco Bay (Taft 1944, Hildebrand and Prytherch 1947). Eating terrapin became fashionable, in fact special terrapin bowls and terrapin forks became part of the flat and silverware of the affluent. Diamondbacks brought top dollar in markets and had the fashion continued, this turtle would likely be extinct today.

It is as difficult to explain the decline of the popularity of terrapin as it is to understand the appetite that developed for it; by the 1920s the species had been exploited to the extent that the industry could not sustain itself. Rather than conservation and economic concerns being responsible for the decline of terrapin harvest, it was Prohibition that made it difficult to obtain the various liquors in which the turtle meat was prepared. By the time of the Great Depression restaurants were no longer serving high-priced entrees and terrapin meat simply became just another seafood. The near collapse of terrapin populations in the wild kept the turtle meat market from rebounding, and the last restaurant to have terrapin on its menu closed its doors in Baltimore in the 1990s. The last possibility of the terrapin reclaiming its fame as a gourmet food item was in the Nixon presidency; once a year President Nixon threw a large formal affair in which diamondbacks were the main entree. For weeks before the event waterman throughout the Chesapeake Bay saved all the terrapins they could gather and every one was bought at top dollar for the affair. The increasing effort necessary to obtain enough terrapins for this annual dinner gave testament as to how uncommon the species had become. As an economic commodity these turtles were a paradox, demanding top dollar in New York, Philadelphia, and Baltimore, and yet a staple food of the residents of remote places like Ocrocoke Island at least through the early 1940s.

In the early 1900s, considerable effort went into attempting to culture the species. The U.S. Bureau of Fisheries set up a number of terrapin pounds to study the feasibility of rearing and breeding captive diamondback terrapins. The bureau even made some unsuccessful attempts to improve the stocks by breeding the better tasting northern turtles with the larger ones found in Texas. The most prominent of these terrapin pounds was operated in Beaufort, North Carolina, between 1902 and 1948. The staff of the Beaufort lab published a number of studies centering on the propagation of terrapins and it is because of these studies that we have baseline information on the reproductive biology and growth of terrapins (Hildebrand and Hatsel 1926; Hildebrand 1929, 1932). The captive-breeding effort was extremely efficient and tens of thousands of hatchlings of various experimental stocks were released into the marshes and sounds of North Carolina, and other Atlantic and Gulf coast states when demand for the terrapin declined.

TERRAPIN BIOLOGY AND ECOLOGY

Life History

Although terrapins were raised in captivity and well studied in the early 1900s, relatively little is known about wild populations of terrapins. These medium-sized turtles (adults are 10–23 cm long) exhibit considerable sexual dimorphism, with females being three–four times larger by weight than males (Ernst et al. 1994). Diamondbacks are strong-jawed with a particular affinity for small mollusks and crustaceans. One of the major benefits to living in brackish water is the availability of a rich food supply—major food items include saltmarsh periwinkles (*Littorina irrorita*), small clams including blue and horse mussels (*Mytilus* and *Modiolus*), fiddler crabs (*Uca*), mud crabs (*Panopeus, Neopanopes*, and *Eurypanopeus*), and blue crabs (*Callinectes sapidus*). Less important foods include carrion, fish, and, on occasion, plant material (Tucker et al.1995). Although variations occur with latitude, male terrapins first reproduce after their fourth year whereas females reach sexual maturity after their seventh year (Hildebrand 1932, Montevecchi and Burger 1975, Auger 1989, Roosenburg 1990, Lovich and Gibbons 1990, Seigel 1994). Female terrapins lay one to several clutches of eggs, and this also varies from north to south throughout the range (Zimmerman 1992, Roosenburg and Dunham 1997).

Making a Living in the Marine Environment

Although diamondbacks are seldom found in any of the freshwater habitats that adjoin the marshes and sounds in which they live, they can survive well in fresh water in captivity. Apparently it is the ability of terrapins to regulate osmotic pressures of brackish water that allows this turtle, one derived from freshwater ancestors, to survive in salty water. Species living in a marine environment must contend with maintaining osmotic balance. For the terrapin, a shell and scaled skin help to control dehydration, but other challenges exist with living in this environment. The turtle's total body weight decreases significantly (up to 0.32% per day) when exposed to pure (salinities of 34 ppt) seawater (Robinson and Dunson 1976). Whereas, most freshwater turtles have no tolerance for even brackish water, diamondback terrapins live in estuarine environments throughout their lives and survive through an interesting combination of physiological and behavioral adaptations.

Physiological adaptations

The saline environment presents a major adaptive challenge to life in a saltmarsh. Physiological regulation within blood, intercellular fluids, and various tissues plays a key role in maintaining osmotic balance. Red blood cells increase in number when terrapins are in water with high salt concentration, apparently in response to the need to remove ammonia and urea from the muscles where waste byproducts accumulate. The bladder and colon accumulate high concentrations of various compounds associated with exposure to seawater and much of it is excreted directly back into the water (Gilles-Baillien 1973). Like marine turtles and crocodiles, terrapins expel sodium through orbital glands near their eyes. Studies by Cowan (1969, 1971) showed the structure of these glands to be similar to other freshwater turtles. Although terrapins use these glands to secrete organic compounds, they are not specialized for increased salinity. Instead the lachrymal gland that is associated with the eye may have a more important role in maintaining salt balance—terrapins acclimatized to seawater show a 2.4-fold increase in sodium concentrations in the eye (Cowan 1969, 1971). Although this gland is adapted to minimize water loss as would be expected in an estuarine animal, it is clear that the gland is not dedicated to salt excretion, nor is it its primary purpose. Thus, modifications of the anatomy of terrapins contribute only in minor ways to terrapins' ability to exploit brackish water habitats.

Behavioral adaptations

The behavioral adaptations of terrapins to the harsh environment of the saltmarsh are perhaps the most interesting. Terrapins can discriminate between different salinities and much of their ability to cope with brackish water is the result of behavior (i.e., movements between salinity gradients and drinking freshwater from the surface after rains). Experimental animals retained in seawater for a week were able to rehydrate in less than 15 min when given access to freshwater (Davenport and Macedo 1990). When water is high in salt concentration (above 27.7 ppt) terrapins seem to avoid drinking it. At moderate salinities (13.6–20.0 ppt) terrapins drink small amounts of seawater, and when the salinity is low (<10 ppt) they drink large amounts (Robinson and Dunson 1976). When it rains, terrapins swim to the surface and drink from films of fresh water (D. Lee, unpubl. data). During rain they will stretch their necks above the surface and catch water in their open mouths. They also leave the water and drink rainwater that collects on the margins of their shells, and from their limb sockets, or from the sockets of other terrapins. While these observations were made on captive animals (Davenport and Macedo 1990), we have no reason to assume that captive turtles behaved differently from those in the wild. Nonetheless, although much seawater is taken orally when the turtles are feeding, even in extreme cases the turtles can quickly reverse osmotic imbalance (Davenport and Macedo 1990). Under normal conditions, of course, these turtles would only rarely be exposed to extremely low or high salinities.

Seasonal Movements

Terrapins are highly mobile, moving between water of different salinities in order to feed, mate, and brumate (brumation is a reptilian state analogous to hibernation), as well as to maintain proper osmotic balance. The pattern of these movements differs between age and gender classes of terrapins. In Maryland, Roosenburg et al. (1999) found that adult females in the Patuxent River moved more often and were found further from shore than adult males, juvenile males, and juvenile females. Their findings suggest that larger adult females move further and spend more time in deeper water while smaller males and all juveniles remain near the shore in shallower water. In South Carolina, Tucker et al. (1995) found that large females spent more time in shallow portions of saltmarshes feeding on larger snails during tidal flooding and retreating with the ebbing tide or burying themselves in the mud. They also found juveniles and smaller males near the edges of marshes and channels where they foraged on smaller prey items.

During winter brumation, terrapins move into deep, fairly small creeks, select just the right bottom type and burrow into muddy substrate where the water is deepest. Brumation sites are far enough up creeks that salinities remain modest but tidal action keeps the water circulating. Terrapins brumate in the mud for several winter months and gradually increase their cellular osmotic pressure as sea water builds in their systems. Osmotic pressure also increases in their urea suggesting that they regulate salt to some degree through excretion (Gilles-Baillien 1973). Brumation locations are likely to be positioned so that during periods of heavy winter rain the saline nature of the water is periodically diluted. Precise locations of brumation sites is largely unknown, but it is generally thought that by late November terrapins settle in for the winter and many hundreds are often concentrated in a very small area. During the rest of the year the terrapins are more widely dispersed in creeks and sounds.

Other Aspects of Terrapin Life History

Nesting ecology

Female terrapins require sandy upland substrate for egg laying. Narrow, sandy strips of land between the open estuarine water and marsh habitat provide ideal nesting habitat, and female terrapins congregate at such places in the summer to deposit one to several clutches per season. In many areas terrapins are forced to travel through a bay or marsh system each season—the prime feeding areas are not necessarily near their brumating quarters, and neither is likely to be in the proximity of nesting beaches. Studies on nest survivorship show that the turtles have a rather narrow spectrum of beaches on which a high percentage of the nests survive (M. Whilden, pers. comm.). Those nests isolated from terrestrial predators like skunks (*Mephitis* and *Spilogale*) and raccoons (*Procyon lotor*) do best. Terrapins, like many turtles, have temperature-dependent sex determination (TSD) whereby the sex of the turtle is determined as the embryo grows and develops within the egg in the nest chamber. Early July temperatures are the most influential on the gender of the developing embryo (Auger 1989), but specific characteristics of the nest and beach microhabitat cause different sex ratios in hatchlings—cooler, shady beaches produce mostly males and warmer, open sandy beaches produce mostly females. As a result of TSD it is important to have a number of nesting beaches available in any given area to ensure that enough turtles of each sex are produced each year.

Basking behavior

Terrapins are poikilothermic and, like other turtles, bask in the sun to elevate their internal temperature above that of the water. This elevated temperature accelerates the digestion of food and other metabolic processes. Terrapins generally bask on tidally exposed mud flats or while floating at the surface on calm days. By filling their lungs with air and extending their heads, necks, and hind limbs out of the water, they can absorb heat, a process facilitated by their dark integument, and quickly elevate their body temperatures.

TERRAPIN CONSERVATION

To date no range-wide evaluation of the population status of this turtle has been made, nor is much historical information available for comparison. Sites where long-term data are available, primarily small and isolated populations, suggest the species to be in peril (i.e., Florida, Seigel 1993; South Carolina, Gibbons 2001). This is consistent with the increasing combinations of factors that threaten terrapins. The USDI Fish and Wildlife Service listed this turtle as a status review species for decades and in the last few years various groups have initiated regional population assessments.

Threats to Terrapins

Despite limited protected status in some regions, populations of this long-lived turtle species generally have not recovered from past episodes of direct harvest (Seigel and Gibbons 1995). Only recently have scientists and policymakers recognized that the main threats to terrapin populations are linked to humans. Such threats include, but are not limited to, drowning in crab pots and entanglement in fishing gear (Bishop 1983, Roosenburg et al. 1997, Hoyle and Gibbons 2000), commercial harvest (Bishop 1983, Roosenburg et al. 1997), loss of critical nesting and basking habitat with accompanying effects on sex ratios (Lazell and Auger 1981), and incidental mortality by motorized vehicles (Lazell 1979, Roosenburg 1990, Wood and Herlands 1997). Turtle nests are depredated by raccoons (Seigel 1980, Feinberg 2003), Bald Eagles (*Haliaeetus leucocephalus*), and other predators whose populations have been enhanced by human activity. Nests are also disturbed by the rhizomes of grass roots (Lazell and Auger 1981) and nesting turtles suffer from competition for access to shoreline with developers and private property owners.

Interactions with gear designed to catch blue crabs

The incidental catch and subsequent drowning of diamondback terrapins in pots designed to catch blue crabs has become a major conservation issue along both the Atlantic and Gulf of Mexico coastlines. Crab pots deployed within the range of terrapin populations may directly threaten those populations (Wood, unpubl. data; Bishop 1983, Seigel and Gibbons 1995, Roosenburg et al. 1997), because terrapins of certain sizes are trapped in the pots and drown. Considerable mortality may also stem from terrapins getting lodged inside abandoned pots. In fact evidence of a crab-pot effect may be apparent in sex ratio data from Maryland (W. Roosenburg, pers. comm.) and North Carolina (K. Hart, unpubl. data). Sex ratios are consistently female-skewed in areas with intense commercial crabbing, which may be a result of differential mortality of males versus females in crab traps. However, until we know more about baseline terrapin sex ratios, population structure, mating systems, or vital rates, we cannot interpret skewed sex ratios as more than a predominance of females in the system.

Blue crabs support valuable commercial fisheries along the southeast and gulf coasts of the US, and today the majority of the total crab harvest is taken in crab pots. In North Carolina, for example, a 1998 estimate for the fishery places 1,063,331 crab pots in North Carolina waters, nearly doubling the number of pots set just 10 yr prior (North Carolina Marine Fisheries 1998). While these numbers are only estimates based on surveys, they indicate that potential accidental terrapin catch and mortality in crab pots in North Carolina can be highly detrimental to a species like terrapins that may be already declining. Interestingly, New Jersey and Maryland now require bycatch reduction devices (BRDs) on certain crab pots. BRDs are stiff, rectangular wire devices that are affixed to the funnel entrances of crab pots, reducing the size and height of the funnel opening. Recently, North Carolina outlined a requirement for BRDs for crab pots as a potential management option in the draft North Carolina Blue Crab Management Plan. However, it is currently unclear where, and when, such devices should

TABLE 1. STATE PROTECTION CURRENTLY OFFERED FOR THE DIAMONDBACK TERRAPIN.

State	Protection
Massachusetts	Threatened.
Rhode Island	Endangered.
Connecticut	State regulated species.
New Jersey	Special concern, turtle excluder device (TED) on all crab pots.
Delaware	Species of state concern, regulated game species.
Maryland	Turtle excluder device (TED) on all noncommercial crab pots, harvest restricted to November through March, >15 cm plastron.
North Carolina	Species of special concern.
Georgia	Species of special concern.
Alabama	Species of special concern.
Mississippi	Species of special concern.
Louisiana	Species of special concern.

be required because of the lack of information on terrapin distributions and their overlap with blue crab fisheries. Furthermore, little is known about terrapin population structure and the extent or scope of terrapin mortality in crab pots. Characterizing the threat that commercial crab pots pose to terrapins, and quantifying terrapin movement and habitat use in a temperate estuarine system will help focus efforts to regulate the blue crab fishery towards the goals of continuing the valuable fishery and enhancing terrapin populations. Further, demonstrating economic benefits rather than losses from gear modifications appears to be an effective way to ensure implementation in commercial fisheries.

After conducting studies in Maryland, Roosenburg et al. (1997) concluded that between 10 and 78% of a local terrapin population might be captured annually in crab pots by recreational crabbing activity. Watermen on the Delaware Bay reported that during the warmer parts of the season a typical catch of 300 terrapins/day was normal (D. Lee, unpubl. data). Several Atlantic Coast state fisheries departments are now looking into requiring BRDs and changing harvest regulations.

Other threats

In addition to interactions with crab pots, terrapins are vulnerable to other anthropogenic disturbances at every phase of their life cycle. The list of threats to terrapins is long—from pollution to loss of wetlands, bycatch in fishing gear, loss of habitat to real estate developers, and predation by raccoons and bald eagles—and unfortunately diamondback terrapins often lose the battle against these pressures

CONSERVATION STATUS

Currently, terrapins benefit from only limited protection (Table 1) yet their populations are declining or of unknown status in three-quarters of the states they occupy (Table 2) (Seigel and Gibbons 1995). Unfortunately, our current knowledge of terrapin ecology and population genetics is limited. Although we know that this long-lived turtle is much reduced from historical numbers, we do not know the scope and scale that either individual or collective threats pose at the population level (Roosenburg et al. 1997, Hart 1999).

POPULATION ASSESSMENTS AND MODELING

Researchers agree that terrapins are not nearly abundant as they once were (Ashton and Ashton 1991, Seigel and Gibbons 1995). Populations may be rebounding from severe harvest at the turn of the century (Conant and

TABLE 2. STATUS OF REGIONAL DIAMONDBACK TERRAPIN POPULATIONS.

Declining	Stable or increasing	Insufficient data
New York	Massachusetts	Delaware.
New Jersey	Rhode Island	Virginia.
Maryland	New York	Georgia.
North Carolina	Maryland	Florida (Gulf Coast).
South Carolina	Florida (Keys)	Alabama.
Florida (Atlantic Coast)		Texas.
Louisiana		
Mississippi		

Note: Data from Seigel and Gibbons 1995.

Collins 1991), however, relatively few surveys of terrapins have been published (Mann 1995). Wood (1992) recommended further surveys to establish baseline data for populations, but presently we do not have the information we need to delineate clear population trends for the species. Perhaps this is because short-term counts have been the primary criteria for gauging the size and health of such populations (Hurd et al. 1979). Multiple years of mark-recapture data are necessary to document population trends. Mark-recapture studies generate data to allow for eventual estimation of sex ratios, survival rates, age structure, and overall population size. Despite the efforts of several researchers in different study sites (Massachusetts, Auger 1989; Maryland, Roosenburg et al. 1999; Florida, Forstner et al. 2000; South Carolina, Bishop 1983; New Jersey, Wood 1992), we currently lack most critical vital demographic rates for terrapins. However, recent efforts by Hart (1999), Tucker et al. (2003), and Mitro (2004) to analyze long-term mark-recapture data sets from various locations revealed adult survival rates of 0.83, 0.84, and 0.95 for terrapins from sites in Massachusetts, South Carolina, and Rhode Island, respectively. These estimates are within the range of published survivorship rates for other emyid turtles (Iverson 1991) with similar age and size at maturity and longevity (40 yr, Hildebrand 1932).

The work by Dunham et al. (1989) on life-history modeling and Congdon et al. (1993) on Blanding's turtles (*Emydoidea blandingii*) focused attention on the life-history and demographic constraints of long-lived organisms. Recent work by Heppell (1998), Heppell et al. (2000), and Sæther and Bakke (2000) examined relationships among age at sexual maturity, adult survivorship, and juvenile survivorship within life histories of long-lived organisms. Results from their studies indicate that all long-lived vertebrates have coevolved life-history traits that limit their ability to respond to increased mortality imposed on any age group (Congdon et al. 1993). Understanding that long-lived vertebrates have a limited ability to respond to increases in mortality is particularly important in decisions related to populations that are subject to commercial harvest or bycatch of juveniles or adults (Crouse et al. 1987, Heppell and Crowder 1998).

Enforcement and Protection

Despite these limited state listings and the application of relatively new techniques in terrapin studies, multiple threats to diamondback terrapin populations exist in all states throughout their range and enforcement of harvest regulations is all but nonexistent. Unfortunately, protected status in a few states may not suffice to ensure the survival of the species. Nonetheless, the turtle is a potential candidate for listing—it has been a species under review for candidate 2 listing with the NOAA National Marine Fisheries Service for the last several decades, but new threats to terrapin existence continue to emerge. For example, human populations of Asian descent in the US and Canada have developed a dietary fondness for turtle meat and over the last several decades the market for terrapin has responded to their demand. However, terrapin is largely unregulated as a seafood and restrictions that are in effect were made long before we fully understood the turtles' habitat needs and well before current population modeling techniques were developed. Different states have different size limits for commercially harvested terrapins, but even a 10–13 cm size limit heavily favors collection of females. Because one male can fertilize dozens of females it is unclear how these regulations may influence what is needed to maintain reproductively viable populations.

Conservation Concerns

Because of the rapid marketing that has developed for seafood, terrapins captured in the field one day often arrive in the markets of another state by the next morning to be sold. This makes it nearly impossible to track marketed terrapins, to learn of their origin, to enforce regulations of other states, and to obtain any statistical information on seasonal or even annual catch rates. As well, because terrapins were not an important seafood product for much of the middle part of the twentieth century, state agencies ceased collecting reports on terrapin landings and virtually no baseline information exists from which to establish regulations for commercial harvest. At this time, only scant information exists on the amount of bycatch of terrapins in crab traps and nets. Most of the turtles captured as bycatch drown and do not become part of the reported commercial harvest. Even if terrapins did not face problems in their coastal environments, slow-growing turtles with low annual reproductive output are not programmed to respond quickly to substantial harvest (Heppell 1998, Heppell et al. 1999).

SUMMARY AND FUTURE

Many turtle species worldwide are increasingly at risk of extinction (Eckert and Sarti 1997, Heppell et al. 1999). Given the general life-history characteristics of turtles, such as delayed sexual maturity, longevity, terrestrial nesting activity, and lack of parental care, they are particularly vulnerable to human-induced threats (Crouse et al. 1987, Congdon et al. 1993, Doak et al. 1994, Heppell 1998, Heppell et al. 1999). Despite annual reproduction schedules, turtles recover slowly from population declines because their populations require high juvenile and adult survival for stability (Congdon et al. 1993, Heppell 1998, Heppell et al. 1999). As such, increased mortality in the juvenile or adult stages will generally cause populations to decline. Threats that affect these life stages in particular need to be mitigated as soon as possible.

This species seems to have fallen through the cracks of local protection and state regulation. In general, fishery agencies base regulations on catch rates and, in most states, terrapin catch is not currently reported. In a number of areas adequate studies have been done to document the local decline of terrapins in the last several decades (Seigel 1993, Gibbons et al. 2001). These populations could benefit from immediate protective measures. Existing laws need to be enforced, harvest rates need to be reported, and the extent and nature of bycatch and other mortality sources needs to be documented on a region-by-region basis. Although more research is necessary, management decisions need not be put off any longer. Concerted efforts to synthesize available data and protect the terrapin should be initiated.

Many isolated populations will be lost if we wait until the last pieces of research are analyzed and incorporated into management plans and regulations. However, terrapin conservation faces real challenges because development of coastal habitats carries on, direct exploitation of terrapins is again expanding, unregulated crabbing continues, interstate traffic of terrapins continues to be facilitated by members of the coastal seafood industry, and enforcement of existing regulations is minimal to non-existent. States that do provide various levels of protection to terrapins have different size limits and seasons, and most watermen are often not informed of these regulations and even fewer watermen report annual catch results consistently. Additionally, crabbers are likely to resist gear modifications such as BRDs, despite findings that their crab-catch rates would not likely decrease with such devices, and the general public is largely unaware of terrapins, their decline, or their modest needs.

Despite these challenges, we have hope for this resilient turtle. Practical, general measures like protecting saltmarsh habitat and specific management actions like installing temporary fences along roads where terrapin road kill is high, affixing BRDs to crab pots, and halting direct harvest would work to protect many terrapins throughout their range. While much research remains to be completed in order to make long-range decisions regarding management regulations, a number of local conservation efforts could be initiated immediately to protect declining populations. Maintaining the integrity of saltmarsh ecosystems is tantamount to ensuring the long-term protection of terrapins.

The future might be bleak for the terrapin if real protection is not afforded to the species soon. The time to address the pressing threats is upon us. Management and protection strategies can be fine-tuned as more information becomes available and the turtles, over time, respond to these efforts. But waiting for completion of long-term studies is not a viable option for a vulnerable, slow-growing species with limited reproductive output, confined to habitats that are under heavy use and continued development.

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