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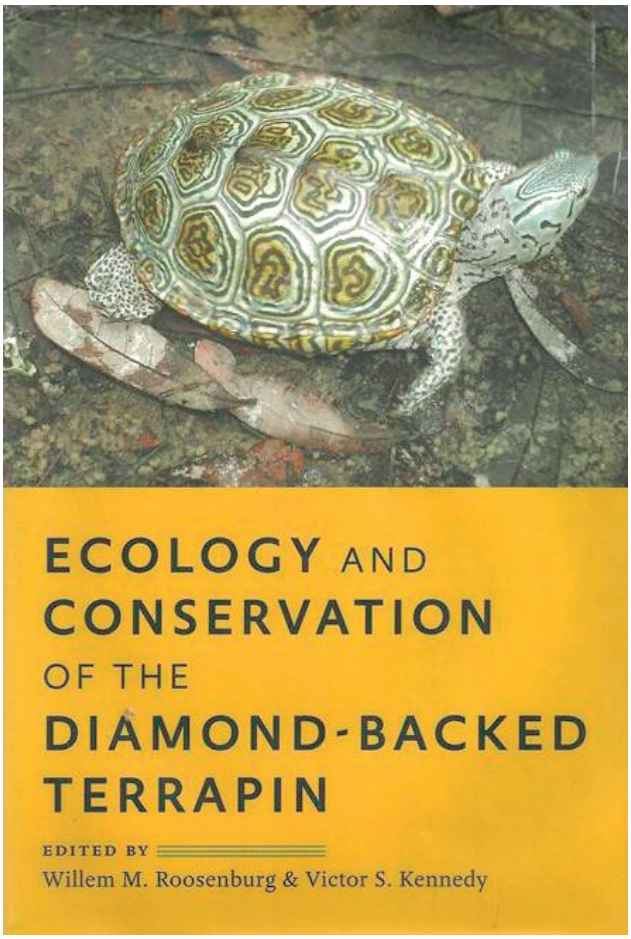

Given the numerous serious threats to its widespread populations, it is a wonder that the diamond-backed terrapin still exists in sufficient numbers to be as thoroughly studied as this book reveals. For those unfamiliar with this turtle, it is a member of the North American "pond turtle" family, Emydidae, but it is most certainly not a "pond turtle." It is the one turtle species worldwide with an entirely estuarine distribution and thus is easily argued to be unique. It is a single species in a distinctive genus (*Malaclemys*) that has a narrow, linear distribution along the eastern U.S. coast from Massachusetts to Texas. Perhaps this linear distribution, which provides ample opportunity for movement between population centers, has allowed populations to avoid extirpation in spite of very intense commercial harvest, serious bycatch issues, and intense degradation and loss of the multiple coastal habitats that it requires. The diamondback terrapin is becoming a sentinel species for the east coast of North America as we enter an era of significant sea level rise that will result in rapid changes to our coastlines. Thus, this is a timely volume that summarizes scientific understanding of the biology and conservation of this remarkable turtle.

The diamond-back terrapin is a unique evolutionary experiment. It is a member of a freshwater turtle lineage that has become very well adapted to highly productive estuarine environments. However, periodic access to freshwater is apparently essential. Although it has a lachrymal salt gland, it is not a sea turtle and cannot drink sea water. It is the only truly estuarine turtle species. Unlike sea turtles, hatchlings avoid high salinities and have remarkable behavioral adaptations to do so. In a chapter on foraging ecology, the authors describe this species as a "transboundary predator" that pursues terrestrial, intertidal, and subtidal foraging strategies in extremely productive ecosystems. In some cases, it can be argued to be a top carnivore.

This volume reveals that *Malaclemys* is a well-studied species that has been monitored by biologists at multiple sites along its linear distribution at multiple life stages. Study across the species range is uneven, with a declining gradient from NE to SW. In addition to more recent field and lab studies, there is a wealth of fisheries data and records from an era of intense commercial harvest and farming.

The work of 36 contributors is split up into 19 chapters that cover topics ranging from evolutionary history and fossil record to habitat restoration and headstarting. It's too bad that the

phylogenetics chapter is missing a cladogram; that would have been very useful. The chapter explains that *Malaclemys* is the sister group to *Graptemys* (a speciose genus of mostly river dwellers) and in a clade with *Trachemys* (the red-eared slider and relatives). The only fossils of *Malaclemys* are from the Rancholabrean, but the genus is thought to have diverged from *Graptemys* in the Miocene. This chapter also misses the opportunity to point out that *Malaclemys* is a member of the subfamily Deirochelyinae in which all genera show sexual size dimorphism where females are larger than males. This is not just a feature shared with *Graptemys*.

The taxonomy of this species has long been in need of revision, but this issue remains unresolved. Capturing the pattern of variation along its 1,600 km coastal distribution has been attempted by the use of subspecies. Clearly, it is all one species which is not surprising given the evidence cited in this volume for strong gene flow even at regional scales. Male-mediated gene flow apparently results from this species' remarkable vagility. There is, however, obvious morphological variation along the extensive linear distribution, and seven subspecies have been recognized in an attempt to document this variation. But work summarized in this volume indicates that the subspecies are not confirmed by molecular data and instead suggests limited phylogenetic structure (four genetic clusters). This may be the result of high rates of gene flow, but *Malaclemys* was also subjected to a great deal of artificial mixing of populations. This was caused by many translocations of terrapins that started during the era of commercialization and was continued by well-meaning conservationists. This volume documents transport of terrapins between North and South Carolina and from the Gulf of Mexico to the east coast. They were moved primarily to support farms which then released their stocks when the demand for terrapin subsided. At present, terrapins on the Atlantic coast are genetically more similar to Texas populations than to Florida populations, which is consistent with translocations for farms but could alternatively reflect gene flow during the Pleistocene, when Florida was isolated. It seems that open water and developed landscapes are the most important impediments to gene flow. Distributional work reviewed in the volume leaves open the issue of terrapins in Bermuda; are they native or not? Had a Floridian genotype been discovered, the case for overwater dispersal by the Gulf Stream might be more convincing.

The life history of *Malaclemys* and geographic variation in those traits are covered in several chapters. Because this is a very well-studied species, data extracted from literally dozens of local studies can be summarized. Life history data are considered in a geographic context, particularly with respect to latitude. This summary shows that males can mature in as few as three years and females in just six years, although there is geographic variation. Latitude was found to be an important factor in clutch size and egg size, and in egg mass and hatchling mass, but not in adult body size or hatchling size. Survivorship has been quite difficult to study since it is so strongly affected by anthropogenic mortality factors. Crab traps, road mortality, and boat strikes are all reported to impact large percentages of individuals in study populations, and both crab trap and road mortality appear to be size and gender selective. Included reports of loss to crab traps are particularly appalling: in one case, more dead terrapins were found in one crab trap than were thought to exist in that entire local study population. At least one study has suggested that crab trap mortality may be shaping population structure in Chesapeake Bay.

As is the case with sea turtles, this volume shows that nesting females are the most accessible life history stage and most easily studied. But there are also conspicuous courtship and mating aggregations known at several different sites. Males do stroke the female's head but do not have long claws as in most members of their subfamily. Nesting occurs from April to August with aggregations of females off of

nesting beaches observed at many sites. Nesting females are reported to make use of high tides to get to the best nest sites, and there is good evidence for strong site fixity at some sites. Nest construction is typical for emydids with clearing with forelimbs followed by excavation of the egg chamber with the hind limbs. Some hatchlings overwinter, with hatchlings from the same nest emerging both in fall and the following spring. This "asynchrony" of emergence seems to be a regular feature of *Malaclemys* nests and may increase with a decrease in temperature. Hatching and emergence success can be quite high where predators are absent, but predation is a major deterrent to success, with 100% predation reported from some sites.

More than 100 years of work summarized in this volume suggests that hatchlings delay their entry into aquatic environments significantly. They prefer terrestrial habitats, seeking cover in vegetation and tidal wrack. Hatchlings that emerge in fall may spend their first winter buried on shore; they are apparently freeze-tolerant, which improves overwintering on land as an option. This early terrestrial behavior in *Malaclemys* is unique and merits its own chapter. How long this terrestrial stage lasts is a bit of a mystery. But it is not just the hatchlings that are rare in aquatic settings. Early age classes, up to three years, seem to be missing from many population studies based on in-water captures.

The physiology of osmoregulation has been well investigated in this unique lineage. Periodic access to freshwater is apparently essential. Unlike sea turtles, *Malaclemys* does not drink sea water. The evolution of the lachrymal into a salt-secreting gland in *Malaclemys* has been argued to have evolved to deal with the high salinity of prey. But osmoregulation in this species is reported to be the product of a suite of strategies beyond having the lachrymal modified for salt excretion. These include a particularly impervious integument, the use of organic osmolytes, and behavioral aspects such as selective drinking, burial in non-desiccating substrates, and hypophaghy when freshwater is not available (this may decrease energy available for growth). The earliest years of life for terrapins appear to be particularly challenging given the osmotic issues associated with small size, which may help explain the increasingly apparent pattern of terrestriality during the first year(s) of life.

The volume includes an extremely useful general account of temperature dependent sex determination (TSD) with a valuable consideration of the impact of climate change. Work on terrapins has experimentally identified the temperature sensitive period (TSP) as the fifth week of incubation. But cited studies suggest that fluctuation in temperatures have a significant effect on gender. This chapter considers the latest models for both physiological and genetic bases for TSD. It reviews relevant hypotheses and considers the physiological cascades thought to function in TSD. It also reviews the knowledge of a series of genes with sex specific expression during development and evolutionary implications of their function. These authors go well beyond a contribution to the understanding of *Malaclemys* and provide a thorough assessment of the current state of understanding of TSD in turtles.

The toxicology chapter provides an excellent summary of the reproductive cycle in both genders and the role played by testosterone. This provides background for a discussion of endocrine disruptors. The chapter reviews the state of understanding of disruption of a series of major endocrine cascades. It reiterates a recurring theme in this volume that terrapins are long-lived inhabitants of estuaries which have long industrial histories making them an excellent candidate for a sentinel species. This chapter also considers how best to do this work without impacting populations that already have a precarious future.

It is quite remarkable that *Malaclemys* has survived commercial harvest, crab traps, subsidized predators, habitat loss, road mortality, an increasing number of boat strikes, and industrial development of many of the estuaries

that are its preferred habitat. But now as sea levels rise, *Malaclemys* populations face the growing challenges of additional shoreline hardening and flooding of important terrestrial and estuarine habitats. Resource managers and biologists should pay attention to this volume as it provides an invaluable resource in the efforts to improve the prospects for this species.

Long-term, comprehensive studies, like those drawn on so heavily for this volume, require substantial investment of time, energy, and funding, and the authors of the many studies cited in this volume are to be applauded for their efforts. The authors and editors have done an admirable job of molding all of this work into a single volume that summarizes the biology of an imperiled species so thoroughly. As biologists have understood for decades (Ehrenfeld, 1981), conservation efforts must be based on an accurate and complete understanding of the biology of the taxon to be conserved, and this is now summarized for this unique species. But conservation also requires a willingness to act. Too frequently we fail to do what we know needs doing to conserve a species. There is no more obvious and frustrating example than the bycatch reduction devices (BRDs) that have been shown to greatly reduce fatalities of *Malaclemys* in crab traps. BRDs are cheap and effective but need to be implemented the way that TEDs were implemented to protect sea turtles beginning in the 1970s. This could be the best way to keep *Malaclemys* off endangered species lists.

This volume should be required reading for the many federal, state, and local resource managers whose jobs include understanding the impact of human activities on coastlines and their fauna and flora. Beyond its interest to biologists and ecologists, this volume will be an excellent resource for decision-makers who will need to make active management decisions for the populations of diamond-backed terrapins in their care, especially as coastlines change and become further impacted by human responses to rising sea levels.

Reference

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