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Habitat Selection and Movements of Diamondback Terrapins, *Malaclemys terrapin*, in a Maryland Estuary

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ABSTRACT. – Habitat selection and movements of diamondback terrapins, *Malaclemys terrapin*, were studied in a brackish water estuary of the Chesapeake Bay in Maryland. Adult male, adult female, juvenile male, and juvenile female turtles were tagged using a fishing bobber and followed by boat for 3-hr periods. Location was determined using GPS at 15-min intervals. Water temperature, depth, and distance from shore were measured and compared among the groups. Adult females moved more often and were further from shore than adult males, juvenile males, and juvenile females. Adult females were observed more frequently in deeper water than juvenile males and females. Water temperature did not differ between the groups. Our findings suggest that larger adult female terrapins move further and spend more time in deeper water while smaller males and all juveniles remain nearer shore in shallower water. Movement differences are probably the consequences of differences in foraging behavior. Differences in habitat use can affect terrapin management and conservation strategies both locally and throughout the species' range.

KEY WORDS. – Reptilia; Testudines; Emydidae; *Malaclemys terrapin*; turtle; terrapin; movement; critical habitats; habitat partitioning; crab pots; conservation; management; Maryland; USA

Understanding differences in habitat use among age, size, and sex classes is critical to developing effective conservation strategies that will protect all members of a population. Ontogenetic shifts in habitat may be associated with a variety of causes including intraspecific competition, diet changes, behavioral changes associated with mating, and predator avoidance. Whatever the adaptive value of the change in habitats used, loss of one or more of the frequently used habitat types can negatively impact both reproductive success and survivorship. This can be particularly problematic for long-lived iteroparous organisms such as turtles, for which small decreases in adult or juvenile survivorship can have dramatic effects on population viability (Congdon et al., 1993, 1994; Spotila et al., 1996). In this study we compared habitat use and movement patterns of different sex, age, and size classes of the estuarine diamondback terrapin, *Malaclemys terrapin*, in Maryland.

Throughout their range, terrapins overlap in habitat with the blue crab, *Callinectes sapidus*, and several studies have indicated that terrapin populations are decreasing primarily due to drowning in crab pots (Bishop, 1983; Burger, 1989; Roosenburg, 1991; Seigel and Gibbons, 1995; Roosenburg et al., 1997; Wood, 1997). One reason for the increase in terrapin mortality may be the crabbing pressure in near-shore areas that results from lucrative crab prices and a more competitive fishery. Thus, areas previously considered cost-ineffective for crabbing may now be economically viable targets. Additionally, the persistent increase in shoreline development has increased the recreational use of crab pots in near-shore areas, resulting in further increases in terrapin mortality in addition to the loss of estuarine habitat.

Our goal was to determine the extent that near-shore areas are used by terrapins. If crab pot use overlaps with critical terrapin habitat then measures should be taken to reduce the use of crab pots in these areas or require excluder devices that prevent terrapins from entering crab pots (Wood, 1997; Roosenburg and Green, in press). Previous studies have demonstrated that hatchling terrapins move into heavily vegetated near-shore areas, frequently burrowing under debris accumulated at the high tide line (Lovich et al., 1991). The extent these habitats are used by other age, sex, and size classes is currently unknown. Other terrapin habitat and resource partitioning studies have been done in salt marshes and tidal flats that are characterized by large expanses of marsh cord grass, *Spartina* spp., where the primary prey organisms are snails, *Littorina* spp. (Tucker et al., 1995). The inland tidal habitats where our study was conducted do not have salt marsh snails and the physical relief confines the marsh habitat to a narrow band that grades quickly to open water seaward and into agricultural or forested regions landward. Thus, terrapin habitat use may differ considerably among the available microhabitats in their range.

MATERIALS AND METHODS

We studied a population of diamondback terrapins in the Patuxent River, an estuarine tributary of Chesapeake Bay in Maryland. The study site lies on the western shore of the river approximately 5 km south of Benedict where the river is approximately 3 km wide and has several large creeks (> 300 m across the mouth) entering it. The creeks are usually shallow (1–2 m), while the river is typically deeper, with large sand and mud flats 2–5 m in depth and a channel > 10 m in depth. The river and adjoining creeks experience a tidal amplitude of approximately 0.5 m and the shoreline is comprised of salt marshes interspersed with narrow sand beaches that are used by terrapins for nesting (Roosenburg, 1994). Unlike more coastal estuaries utilized by other terrapin populations, characterized by vast expanses of *Spartina* marshes, the Patuxent system has limited *Spartina* marshes. Most of these marshy areas are restricted to a narrow band along the shoreline approximately 3–10 m wide. Some small marshes exist (< 2 ha), but we have rarely encountered terrapins in these areas.

We collected terrapins from Washington and Persimmon creeks and areas of the Patuxent River adjoining these creeks. Turtles were caught using peeler bank traps, fyke nets, or modified crab pots (Roosenburg et al., 1997) from 26 June until 5 August 1996. The age, sex, and reproductive condition were determined as a part of an on-going mark-

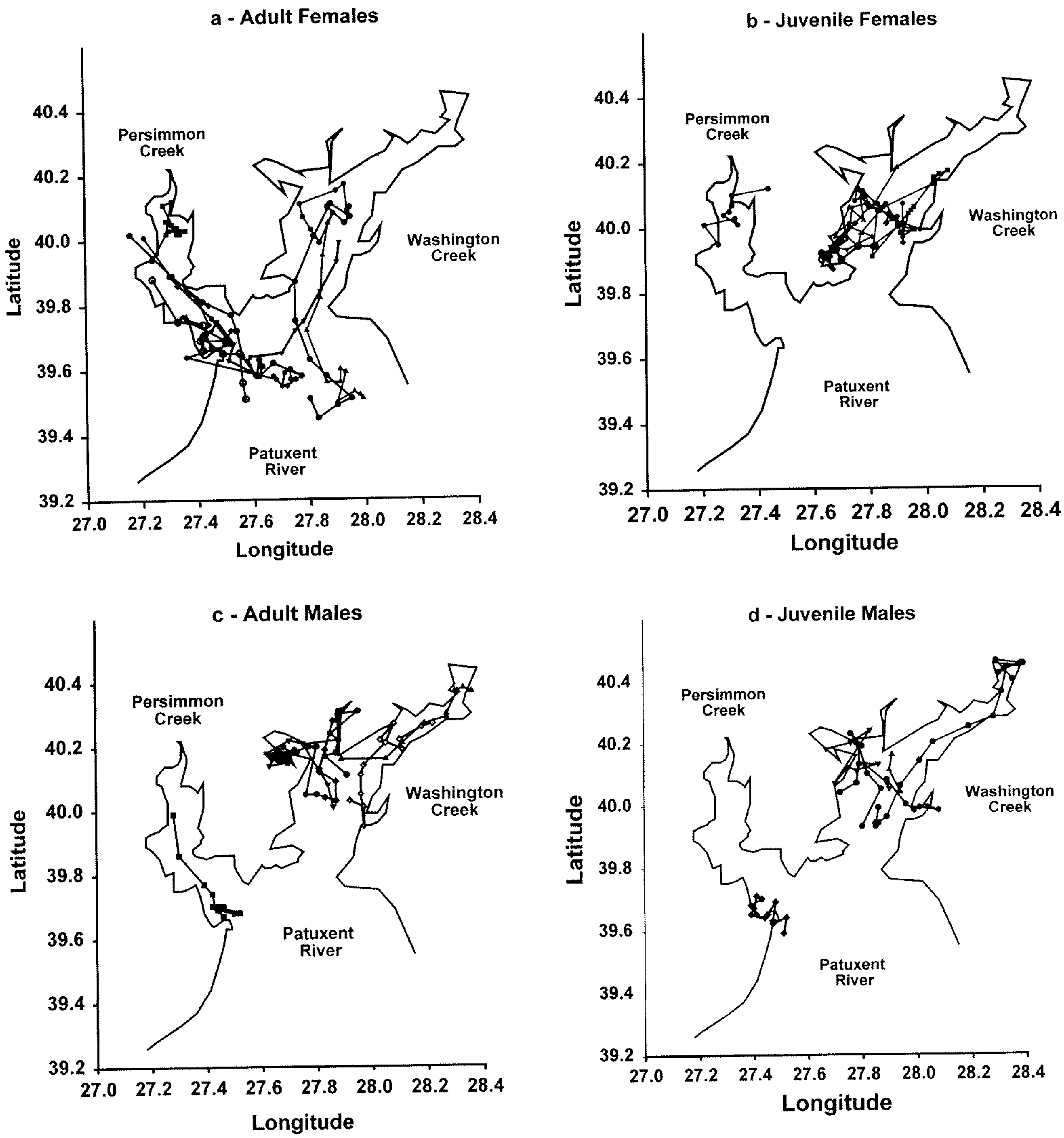

Figure 1. Maps of movement and habitat use of the four age and sex classes of terrapins (**a** - 11 adult females, **b** - 7 juvenile females, **c** - 7 adult males, **d** - juvenile females). All tracks were obtained over a 3-hr period with locations taken at 15-min intervals using GPS. Tracks resulting in terrapins appearing to be on land are the result of inaccuracies in the GPS system. At no point in our study did terrapins leave the water.

Table 1. Mean and standard errors of water temperature (°C), water depth (m), and distance from shore (m) for the four groups of turtles evaluated. Superscript letters (a–c) identify pair-wise comparisons that were significantly different from one another based on studentized maximum modulus test. Adult females ventured further from shore than the other three classes, which could not be distinguished from each other. Adult females were found in deeper water than adult and juvenile males but could not be distinguished from juvenile females. No differences in temperature were observed among the four classes.

	Adult Females	Juvenile Females	Adult Males	Juvenile Males
Temperature	27.8 ±0.48	27.5 ±0.44	26.6 ±0.50	26.9 ±0.66
Water Depth	1.9 ±0.19^{a,b}	1.4 ±0.13	1.2 ±0.10^{a}	1.1 ±0.11^{b}
Distance from Shore	84.5 ±2.46^{a,b,c}	50.5 ±9.86^{a}	50.0 ±8.13^{b}	36.5 ±7.53^{c}

recapture study (Roosenburg, 1996; Roosenburg and Dunham, 1997). We only used previously marked terrapins in our study, identified by drill holes or notches in the marginal scutes. We tied 4 m of 20 lb test monofilament fishing line to one of these holes and attached a bobber to the line. Turtles were released for observation within 50 m of the capture location. We followed the turtles at a distance of at least 10 m by boat. Terrapins were observed for 3 hrs each and their location, water temperature, water depth, and distance from shore were recorded at 15 min intervals. Location was determined using Global Positioning System (GPS), Magellan 2000, to ascertain latitude and longitude. Water temperature was taken using a thermometer suspended 20 cm from the surface of the water. Water depth was measured using a weighted line marked at 0.5 m intervals. Distance from shore was estimated by the observers to the nearest 5 m up to 100 m. Distances beyond this range were recorded as "greater than 100 m." We also used the GPS to generate a map of the study area.

Maps of the movement of terrapins were generated using the longitude and latitude readings from the GPS. Averages of water temperature, water depth, and distance from shore were analyzed using PC SAS Version 6.12, PROC GLM, and PROC CORR (SAS Institute, 1990). Unplanned comparisons of means for water temperature, water depth, and distance from shore were made using studentized maximum modulus test (Day and Quinn, 1989).

RESULTS

We tracked 34 individuals: 11 adult females (Fig. 1a), 7 juvenile females (Fig. 1b), 11 adult males (Fig. 1c), and 5 juvenile males (Fig. 1d). Several of the adult females used larger areas than members of the other age and sex classes (Fig. 1). In one case an adult female moved from one creek to the other. Adult females also tended to stay in the open waters of the river and the mouths of creeks (Fig. 1a). Adult females ventured further from shore (ANOVA, $F_{3,30} = 8.43$, $p = 0.0003$; Table 1) than the three other classes and were found in deeper water (ANOVA, $F_{3,30} = 6.42$, $p = 0.0017$) than juvenile and adult males (Table 1). Additionally, distance from shore correlated positively with female plastron length and age (Table 2; Fig. 2). In contrast, the juvenile females, juvenile males, and adult males were found at similar distances from shore and similar water depth (Table 1), although male plastron length was positively correlated with distance from shore (Table 2; Fig. 2). There appeared to be a change in the typical distance from shore beyond about 120 mm plastron length of both males and females (Fig. 2) suggesting that the habitat shift that may be related to size. We found no average difference in water temperature among the four classes of terrapins (ANOVA, $F_{4,30} = 1.25$, $p = 0.3124$; Table 1).

DISCUSSION

Larger, adult female terrapins used more open, deep water habitats further from shore while smaller males and juvenile females remained in shallow creeks nearer to shore. However, some of the adult female terrapins also used the shallow inshore waters frequented by turtles of smaller size classes. Interestingly, the two adult males that were greater than 120 mm in plastron length were comparable to adult females in their average distance from shore, suggesting that changes in habitat use may be more a function of body size than sex or age. Our correlations of body size on distance from shore (Table 2; Fig. 2) support this conclusion.

Our findings differ somewhat from those in a coastal South Carolina terrapin population where larger female terrapins spent considerable time in the upper reaches of salt marshes feeding on larger snails during tidal flooding and retreated with the ebbing tide or buried in the mud (Tucker et al., 1995). In that study juveniles and smaller males were found near the edges of marshes and channels where they foraged on smaller prey items; this is similar to the locations where we found our smaller

Table 2. Pearson's correlation matrix of the relationship between plaston length, age, water temperature, water depth, and distance from shore. Female values are above the principal diagonal and male values are below the principal diagonal. Values presented are the Pearson correlation coefficients and the sample sizes (in parentheses). Statistically significant corellations are indicated (* = $p < 0.05$, ** = $p < 0.001$).

	Plastron Length	Age	Water Temperature	Water Depth	Distance from Shore
Plastron Length		0.872 ** (15)	0.213 (18)	0.373 (18)	0.775 ** (18)
Age	0.614 * (13)		0.201 (15)	0.201 (15)	0.541 * (15)
Water Temperature	-0.013 (13)	-0.107 (12)		0.031 (18)	0.033 (18)
Water Depth	0.490 (16)	0.412 (13)	-0.085 (13)		0.513 * (18)
Distance from Shore	0.600 * (16)	0.341 (13)	0.136 (13)	0.808 ** (16)	

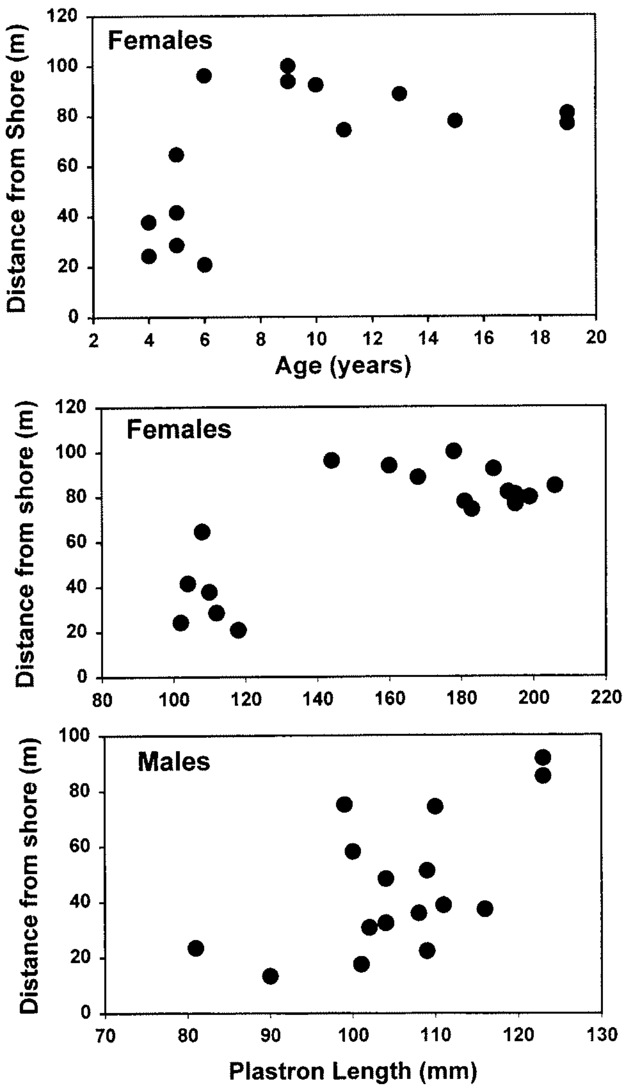

Figure 2. Three significant correlations that pertain to habitat use of terrapins. The correlations between distance from shore and female age (**top**), female plastron length (**middle**), and male plastron length (**bottom**).

turtles. Tucker et al. (1995) and our study suggest that prey availability plays a major role in habitat use by terrapins and the differences result in dramatically different habitat use by adult female terrapins in the South Carolina and the Maryland populations.

The Patuxent terrapin population is different from the South Carolina population in several regards. First, the estuarine physiography is very different (see above). Second, *Littorina* and other salt marsh snails are not present or are so scarce that they are not the primary food source in the Patuxent population. Instead, terrapins feed primarily on soft-shelled clams (*Mya arenaria*), razor clams (*Tagelus* spp.), and other smaller clams (*Macoma* spp. and *Gemma*) (WMR, *pers. obs.*). These clams are more abundant on open sandy flats in deeper water. The shorelines along many of the creeks of the Patuxent River are teeming with small crustaceans including amphipods, isopods, and juvenile molting decapods that all are likely to be a suitable food resource for the smaller terrapin size classes. One of the possible reasons for the differences in habitat use between the size classes is the pressure required to crush the shells of the larger clams found in deeper water, whereas most of the prey organisms found in near-shore areas are soft-bodied. The size-related crushing ability of female terrapins contributed to their ability to exploit larger prey items in South Carolina (Tucker et al., 1995).

There are several limitations to our study that result from the methods we used and the time period of our study. First, we did not want to leave animals unattended with bobbers tied to their carapace, so we restricted our observation intervals to 3-hr periods during the daylight hours, although we did vary the hours of tracking to minimize effects that could be due to different times of the day. Furthermore, we cannot comment on the long-term movements of individuals. Second, our study was limited to only the mid-summer period. Our findings cannot be generalized to other times of the year when terrapins are active. For example, in the fall and spring it is likely that temperatures differ among the habitats resulting in either temperature differences between the age classes or habitat shifts as a result of behavioral thermoregulation. However, we chose mid-summer because it is the time of year when human recreation, crabbing, fishing, and boating are most likely to interact with the terrapin life cycle.

Our results are important for three aspects of the conservation and management of terrapin populations. First, one of the major threats to terrapins throughout their range is the mortality caused by drowning in crab pots (Bishop, 1983; Burger, 1989; Roosenburg, 1991; Seigel and Gibbons, 1995; Roosenburg et al., 1997; Wood, 1997). Commercial use of crab pots is not permitted in the Patuxent River, but waterfront property owners are allowed to place up to two pots in the shallow water area adjacent to their land. As our results suggest, this coincides with the habitat used primarily by smaller terrapins that are most vulnerable to entrapment in crab pots (Roosenburg et al., 1997). The placement of crab pots in shallow water is likely to contribute significantly to the effect crab pots can have on terrapin populations. Effective management strategies may be to eliminate the use of crab pots in shallower water or require the use of crab pots that maintain a permanent air space (Roosenburg et al., 1997) or are equipped with a bycatch reduction apparatus (Wood, 1997).

A second factor that threatens terrapin populations is habitat loss. Our study indicates the importance of near-shore shallow areas for terrapins, but these habitats are rapidly being lost through rip-rapping, bulkheading, and other shoreline stabilizing practices (Roosenburg, 1991). Perhaps the most dangerous outcome of the combined threat of crabbing and shoreline development is that terrapin populations are first extirpated by crabbing and then development of near-shore areas fails to consider terrapins because of their reduced abundance or absence. This may foil future conservation efforts to restore terrapin populations because habitats have become too severely degraded.

The third interaction between humans and terrapins is the increase in vulnerability of adult females to motor boat impacts (Roosenburg, 1991) because they use habitats that are in open, deeper water where they are more likely to encounter high speed boats. Motor boat impacts are the primary source of mortality of adult female terrapins in the Patuxent population (Roosenburg, 1991).

Perhaps the most important outcome of this study is that it identifies the difficulty in adopting standardized management strategies for a wide-ranging species. The differences in habitats available between the South Carolina (Tucker et al., 1995) and Patuxent populations illustrate the location-specific needs of terrapins. They use a variety of habitats for nesting, feeding, and hibernation throughout their range, and effective terrapin conservation and management requires that all of these factors be taken into consideration.

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