Road occurrence and mortality of the northern diamondback terrapin

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Abstract. We examined road occurrence and mortality of the northern diamondback terrapin, *Malaclemys terrapin terrapin*, in the Jacques Cousteau National Estuarine Research Reserve during the 2004 nesting season (May-July). Traffic volume estimates were obtained using measuring devices stationed on sections of Great Bay Boulevard, an access road through a salt marsh habitat in Tuckerton, New Jersey. Six hundred adult female terrapin occurrences were recorded, 53 of those being road mortalities (8.83%). A significantly greater proportion of road kills was found in the section of the road with the highest traffic volume. There was also a positive correlation between road kills and increasing traffic volume throughout the day. Approximately half of the road mortalities were discovered in the first survey hour, suggesting that some nesting terrapins were being killed during the night or in the early morning hours. The information gathered suggests that terrapins are attracted to the roadside as it meets the requirements for a suitable nesting habitat.

Key words: Access road; diamondback terrapin; *Malaclemys terrapin terrapin*; nesting; road mortality; traffic.

Introduction

Of all the organisms encountering roads, amphibians and reptiles seem to be affected the most. This may be because they are much slower (Rosen and Lowe, 1994; Ashley and Robinson, 1996; Hels and Buchwald, 2001), may not be aware of the potential danger of automobiles (Ashley and Robinson, 1996), or because their activity throughout the day may coincide with greater traffic loads in certain areas (Rosen and Lowe, 1994; Hels and Buchwald, 2001). Reptiles encounter roads while searching for food, water, breeding or nesting sites (Ashley and Robinson, 1996). Snakes have been shown to use roads for temperature regulation and during migration to water (Bernardino Jr. and Dalrymple, 1992), and roadsides are utilized by turtles for nesting (Wood and Herlands, 1997; Haxton, 2000; Aresco, 2005). Turtles may also encounter roads while simply moving through their environment in search of terrestrial habitat (Buhlmann and Gibbons, 2001) or when emerging from hibernacula (Hoden, pers. comm).

The effect of road mortality on turtle populations (Haxton, 2000; Gibbs and Shriver, 2002; Steen and Gibbs, 2004; Gibbs and Steen, 2005) is becoming an ever increasing problem and may be associated with factors such as traffic density, nesting behavior, or ecological features surrounding the roadway. Road mortality may contribute to skewed sex ratios in aquatic species as females are lost while nesting (Steen and Gibbs, 2004; Aresco, 2005; Gibbs and Steen, 2005) or act as a major source of local extirpation (Rosen and Lowe, 1994). Road mortalities of adult turtles could lead to rapid population decrease since they are unable to be replaced quickly (see Brooks et al., 1991).

Increased vehicular traffic has increased road morality of many herpetofauna (Fahrig et al., 1995; Forman et al., 2003), including turtles of terrestrial, semi aquatic and aquatic species (Gibbs and Shriver, 2002) and may also impact the northern diamondback terrapin, *Malaclemys terrapin terrapin*. Because terrapins are a "Species of Special Concern" in New Jersey (New Jersey Department of Environmental Protection, Division of Fish and Wildlife, NJ Endangered and Non-Game Species Program, website 2005), an understanding of the impact of road mortality is critical (Forman et al., 2003).

While some studies have documented road kills, few traffic related mortality studies have been conducted on the terrapin. In southern New Jersey, a study on the Cape May Peninsula from 1989-1995 obtained 4,020 road kills on roadways adjacent to salt marsh habitat (Wood and Herlands, 1997). Wood and Herlands (1997) suggested that increased weekend traffic did not correlate with daily changes in mortality, but it is unclear as to how traffic and road kills were analyzed or if increased monthly or daily traffic affected mortality as well. Previous studies at the Jacques Cousteau National Estuarine Research Reserve (JCNERR) reported that between 1999 and 2002, 71% of the 634 terrapins recovered on Great Bay Boulevard died because of automobile traffic (Hoden and Able, 2003). Approximately half of the adult females observed were victims of road mortality (N total = 208; N dead = 98). In that study however, transect surveys were only made once in the morning and afternoon and no estimates of traffic activity were made.

Accordingly, this more detailed and rigorous study was performed to acquire accurate estimates of traffic volume, road occurrence of terrapins, and road mortality rates. The objective of this study was to describe relationships that exist between the road mortality of the northern diamondback terrapin and the traffic they encounter on Great Bay Boulevard in Tuckerton, New Jersey.

Materials and Methods

Study area

We conducted field work near the Rutgers University Marine Field Station in the Jacques Cousteau National Estuarine Research Reserve in Tuckerton, New Jersey. Within the reserve, the Great Bay Wildlife Management Area is a 2,168 ha peninsula consisting of relatively pristine salt marsh wetlands. Great Bay Boulevard, an access road, is a two-way, 8.1 km paved road that runs through the salt marshes of the management area between the town of Tuckerton and the field station. Five bridges along the road cross over the subtidal creeks that flow through the salt marshes and divide the road into six transect sections (fig. 1). The lengths of each transect section range from 0.8-2.0 km with coarse sand and gravel prevalent along the side of the road in each of the sections.

Overall data collection

We conducted surveys of Great Bay Boulevard during the terrapin nesting season from 25 May to 31 July 2004. Eight to ten surveys were completed each day, approximately five to six days per week for a total of 299 samples. Sampling by car or bike began when terrapins were first sited in May, and lasted until two weeks after the last terrapin was seen in July. Surveys were conducted consistently from 0800-1600 h, with one beginning at 0745 h and some ending after 1700 h. A total of 12 random night transects were made during 5 nights of the season from 2100-0100 h, generally 2-4 surveys on each occasion. Volunteers also reported terrapins on or along the roadside while surveying by car during the day. Typically there was one volunteer working per day of sampling. Survey data included; date, time of day a terrapin was sited, location of terrapin(s) (transect section and telephone pole number), and the condition of the individual (alive or dead).

For each terrapin we measured and recorded sex, stage of development (hatchling, juvenile, or adult), and size; midline carapace length (CL) and plastron length (PL) were measured using a digital 300 mm caliper (Fowler Company, Model # S54-100-112) and were double-checked by eye using the manual metric ruler on the caliper. The sex of adults was determined by the overall length of the individual, head size, and tail characteristics (size of the tail and location of the cloaca differ between males and females). Stage of development was determined based on the midline carapace length. Adult females were considered to range from 150-230 mm and males from 100-140 mm (Ernst et al., 1994), juveniles (not sexed) $\geqslant$ 35 to $\leqslant$ 100 mm, and hatchlings (not sexed) $\leqslant$ 35 mm carapace length (Hoden and Able, 2003). During this survey only adult females and one juvenile were observed.

After measurements were taken, living terrapins were released at the side of the road, and positioned in the direction they appeared to be heading prior to collection. We moved terrapin carcasses several meters off the road in the marsh to prevent duplicate counting.

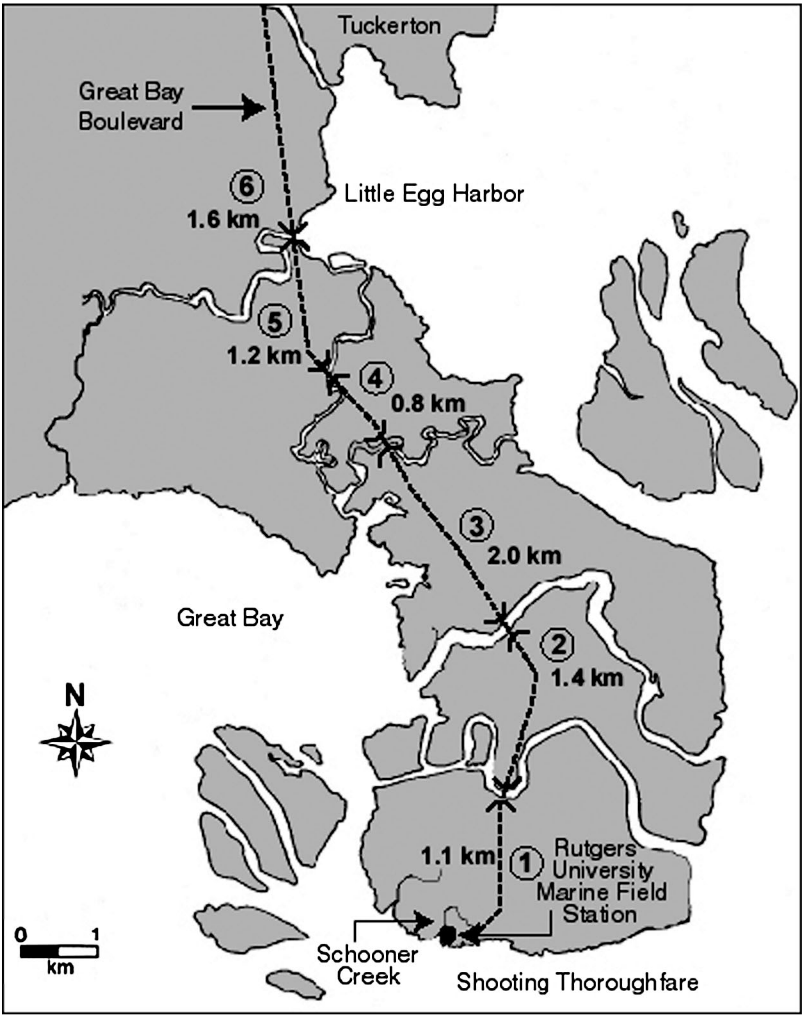

Figure 1. Detailed map of the study site, Great Bay Boulevard in the Jacques Cousteau National Estuarine Research Reserve (see Hoden and Able, 2003). Transect sections of the road are numbered 1 through 6.

Measuring traffic

We used traffic volume measuring devices (TRAX I Plus Counter/Classifiers provided by JAMAR Technologies Inc. of Horsham, PA) to attain highly accurate estimates of traffic flow. These devices allowed traffic to be monitored 24 hours a day, 7 days a week. The devices were stationed in the middle of each of the four transect sections of Great Bay Boulevard. At the start of the study, all six sections had traffic counters, but due to vandalism and theft (in sections 3 and 4), only sections 1, 2, 5, and 6 had traffic devices running the entire season. We downloaded traffic data weekly using a laptop computer. The average volume of sections 2 and

5 were added and then divided by two to estimate the volumes for sections 3 and 4. Given that Great Bay Boulevard dead ends in transect 1, and no traffic can enter the system except at section 6, the estimated volumes for sections 3 and 4 were probably comparable to their actual volumes because they had to be less than section 5 and greater than section 2.

Data analysis

The proportion of road mortality between transect sections was tested using Pearson chi-square analysis with an alpha level of 0.05, assuming equal survival status for all sections of the road. Monthly proportions of mortality were also tested in the same manner. Spearman's rank order correlation with one tailed probability, and $P = 0.05$ was used to test the relationship between road mortality rates and hourly mean traffic volume during the survey hours of 0901-1600 h because more consistent sampling was performed during these times. Mortalities by transect section between these hours were pooled ($N = 29$) because of few numbers within sections, and compared with the traffic pattern entering the Great Bay Boulevard road system. Although not all mortalities occurred in section 6, values from this section were used for comparison because traffic patterns were relatively similar across all sections.

Results

Road occurrence

We observed 600 adult female terrapins (175 ± 1 mm CL, 158 ± 1 mm PL) on the road during the nesting season with three distinct peaks of nesting activity on or near the full and new moons (fig. 2). In all six transect sections, live and dead terrapins were found during most hours of our sampling (table 1). In the first survey hour 0801-0900 h, approximately half of the road mortalities were discovered and a smaller second peak was noted between 1001-1100 h. All other road mortalities were scattered throughout the day with a few found during night sampling (table 2).

The effects of traffic volume on road mortality

We observed 53 adult female terrapin road mortalities on Great Bay Boulevard (8.83%). In transect section 6, a significantly greater percentage of mortalities by proportion was found compared to the other transects ($P < 0.001$, $x^2 = 22.44$, df $= 1$) as well as the greatest mean volume of vehicles/day (table 1). There was a decrease in traffic volume from section 6 to the end of the roadway in section 1. Many vehicles that entered Great Bay Boulevard (at transect 6), did not travel all the way to the end (transect 1), but turned around at different points on the road and returned to town. This accounted for a greater volume of traffic in transect 6. During our sampling period from 0901-1600 h, road mortality rates correlated

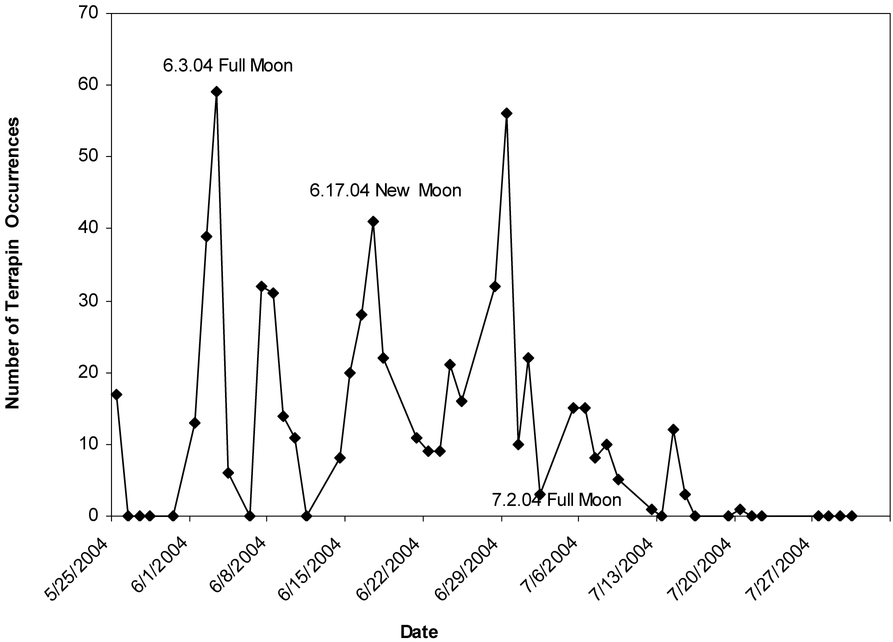

Figure 2. Northern diamondback terrapin occurrences on Great Bay Boulevard during the nesting season, 25 May-31 July 2004.

Table 1. Summary results of terrapin occurrences, mortalities, and average traffic volume by transect section on Great Bay Boulevard.

Transect Section	Live	Dead	Mean Traffic Volume (vehicles/day)
1	57	2 (3.39%)	233.7
2	101	9 (8.18%)	262.7
3	189	13 (6.44%)	363.4[a]
4	84	8 (8.70%)	363.4[a]
5	91	10 (9.90%)	464.0
6	25	11 (30.6%)*	936.4
Total	547	53 (8.83%)	

* ($P < 0.001$, $x^2 = 22.44$, df = 1).
[a] Estimated traffic volumes.

positively with increasing traffic volume ($P = 0.026$, Spearman's correlation coefficient = 0.750). Comparing results from the different months during the survey, the proportion of road mortalities was not significantly different ($P = 0.896$, $x^2 = 0.219$, df = 2) and the amount of traffic entering the system was relatively similar (mean = 826, 892, 987 vehicles/day by month, respectively).

Table 2. Summary results of terrapin mortality discoveries and average traffic volume by hour (traffic entering the Great Bay Boulevard road system).

Hour	Live	Dead	Mean Traffic Volume (vehicles/hr)
2401-0100	1	0	7.1
0101-0200	–	–	4.5
0201-0300	–	–	3.2
0301-0400	–	–	2.6
0401-0500	–	–	3.2
0501-0600	–	–	16.4
0601-0700	–	–	34.0
0701-0800	1	0	37.2
0801-0900	51	24[a]	49.4
0901-1000	71	2 (2.74%)	47.0
1001-1100	167	12 (6.70%)	54.3
1101-1200	129	4 (3.01%)	64.7
1201-1300	46	0 (0.00%)	71.0
1301-1400	31	3 (8.82%)	71.8
1401-1500	21	3 (12.5%)	79.7
1501-1600	16	2 (11.1%)	75.0
1601-1700	4	0	71.3
1701-1800	3	0	56.6
1801-1900	1	1	49.0
1901-2000	0	0	50.6
2001-2100	0	0	41.7
2101-2200	2	2	25.6
2201-2300	3	0	14.2
2301-2400	0	0	9.7
Total	547	53	

[a] Reflects deaths of unknown times (overnight and early the following morning).

Discussion

Terrapin nesting

During the 2004 nesting season, three peaks of terrapin occurrences were observed on Great Bay Boulevard, on or around the full and new moon when the tides were highest. By nesting during the spring tides, female terrapins may decrease the walking distance to the nesting locations (Burger and Montevecchi, 1975). Females were known to utilize roadside areas for nesting because newly made nests, abandoned nests, and eggs that were preyed upon were observed. Many eggs were also found on the road near the killed terrapins.

It is generally thought that terrapins prefer higher elevations, usually above the high tide line, with sandier soils and little vegetation, as nesting sites (Burger and Montevecchi, 1975; Butler et al., 2004). Consequently, the sides of access roads, such as Great Bay Boulevard, which run through coastal wetlands, provide conditions that are suitable as nesting sites. A lack of sand dunes or isolated sandy beaches, as in our study area and other developed coastal communities, may encourage terrapins to nest along the edges of roads. Furthermore, loss of habitat due to human disturbance and activities such as bulk heading and development may force terrapins to nest in alternative sites like roads (Roosenburg, 1994). In fact some terrapins may even prefer roads. Seigel (1980) observed terrapins nesting only on dike roads even though sand dunes and other possible sites were available. Other species of turtles such as the snapping turtle also utilize roadsides during the nesting season (Haxton, 2000).

Mortalities and traffic

Certain reptiles may be more vulnerable to traffic during specific times of the day depending on they way they utilize the road. For example, some species of snake are more active at night (Rosen and Lowe, 1994) and may be utilizing road heat to help regulate their body temperature. Some turtles lay their eggs at night (S. McRobert, pers. obs.) and may cross roads looking for nest sites. These types of behaviors around roads would undoubtedly increase the chances of road mortality. For terrapins, we found approximately half of the mortalities were discovered during the first survey hour. These deaths may have occurred either in the late hours of the previous evening or in the early daylight hours when traffic was beginning to increase. Wood and Herlands (1997) observed night nesting for *M. t. terrapin* and found nearly half of the mortalities noted in their study between 2130-0500 h. However, Burger and Montevecchi (1975) did not observe terrapins nesting before dawn or after sunset in New Jersey, and Seigel (1980) noted nesting only in daylight hours in Florida. In contrast, Roosenburg (1994) encountered nesting terrapins at all times, day and night in a study conducted in Maryland. If nesting primarily takes place in the morning hours, this might account for a good portion of terrapin mortalities found in the first survey hour.

Traffic volume appeared to play a large part in terrapin road mortalities within road sections and throughout the day with increased traffic intensity seeming to contribute to increased mortality rates on Great Bay Boulevard. A significantly greater proportion of road mortalities was observed in the transect section closest to the town of Tuckerton, which exhibits the highest traffic volume. These finding are similar to past studies demonstrating that there are greater road mortalities of reptiles and amphibians where there is greater traffic volume. Rosen and Lowe (1994) observed greater snake mortality during peak periods of automobile traffic. Bernardino Jr. and Dalrymple (1992) suggested a correlation between the number of vehicles and the number of snakes found dead or mortally injured. In amphibians, particularly frogs and toads, it has been calculated that the probability of being killed increases with greater traffic volume (Fahrig et al., 1995; Hels and Buchwald, 2001).

The correlation between traffic volume and mortality was also noted when comparing road mortality rates throughout the day. Even though there were more terrapins on the road before 1200 h during our sampling, the traffic volume was lower during this time and the rate of mortality was also lower. The traffic volume continued to increase up until 1500 h along with the mortality rate despite the fact that fewer terrapins were on the road.

Simply looking at individual numbers of road kills may conceal the effects of traffic on mortality of local populations. Fewer mortalities seen on the road may give the appearance that there is no real problem. However, if the number of terrapins utilizing an area is relatively small, the outcome may actually be quite detrimental. A decrease in road moralities may actually be an indication of a severely decreasing population from road mortality in combination with other mortality sources (Wood and Herlands, 1997).

With increasing traffic loads year after year (National Research Council, 1997), the number of animals killed may represent a large portion of the terrapins utilizing the roadsides, specifically mature females. This is what we suspect we observed when fewer terrapins were found nesting in the area of the highest mortality. With relatively little movement between creeks and high site fidelity to one particular creek documented for terrapins (Gibbons et al., 2001), this group within the local population may have fewer individuals because of greater numbers of road moralities over the years contributing to a decrease in abundance compared to other sections of Great Bay Boulevard. Fahrig et al. (1995) also suggest this happens for amphibian traffic related mortalities contributing to differences in total numbers observed on roads in Canada. If road mortality is not removed or reduced as a source of the adult mortality for nesting females of this particular section it may never recover as it could take at a minimum one generation to replace (Gibbons et al., 2001).

Great Bay Boulevard, like many coastal roadways, is providing nesting sites but also subjecting terrapins to the risk of road mortality. Since encounters with vehicles may eliminate reproductively active females, as well as eggs and hatchlings, traffic related mortalities may be a significant contributor to decreasing populations (Brooks et al., 1991). Comparing the numbers of live and dead animals on the road with traffic volume, as in this study, seems to provide a clear picture of the effects of traffic on morality. Road surveys at JCNERR should continue to be made to further monitor the effects of road mortality on this local population. Future studies on roads with differing traffic loads, similar to Fahrig et al. (1995) should be done to see if these trends exist for terrapins in other areas.

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