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HIGH INCIDENCE OF ROAD-KILLED FRESHWATER TURTLES AT A LAKE IN EAST TEXAS, USA

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***Abstract.*—We describe a high incidence of road-killed freshwater turtles along a section of US 190 in eastern Texas, USA. The surveyed section spans B.A. Steinhagen Lake by means of a series of bridges and a causeway. We detected 850 road-killed turtles between 2008 and 2012 of which 40% were positively identified as female, 1% male, and the remaining 59% were too damaged to confirm the sex. We found more dead turtles during the breeding season (May to August) than other times of year. The causeway is attractive to female turtles as a nesting site, and the use of the road side causes an increased risk of road mortality. To our knowledge, this site has the highest documented rate of unmitigated turtle road mortality in North America.**

Key Words.—Eastern River Cooter; *Pseudemys concinna*; Red-eared Slider; *Trachemys scripta*; turtle conservation; wildlife road mortality

INTRODUCTION

Roads have negative effects on many species of North American freshwater turtles (Gibbs and Shriver 2002; Gibbs and Steen 2005) including direct mortality from vehicle collisions, barriers to movement, and loss and change in quality of habitat (Jaeger et al. 2005; Eigenbrod et al. 2009). The magnitude of these effects is dependent upon many factors including broad-scale landscape characteristics, adjacent land cover type (Steen and Gibbs 2004; Langen et al. 2009), and road characteristics (Aresco 2005a; Langen et al. 2012). Ecological and behavioral differences between species can also interact with landscape and road characteristics to produce responses that are often species-specific, and can be difficult to anticipate (Gibbs and Shriver 2002; Forman et al. 2003). For example, in an analysis of mortality hot spots for five species of turtle in northern Texas, Cureton and Deaton (2012) found that locations of high road mortality in Common Snapping Turtles (*Chelydra serpentina*) and Ornate Box Turtles (*Terrapene ornata*) was best explained by the distance to the nearest wetland and Red-eared Slider (*Trachemys scripta*) mortality was best explained by the distance to the nearest forest. No patterns were found for River Cooters (*Pseudemys concinna*) and Three-toed Box Turtles (*Terrapene carolina*).

Turtle populations adjacent to roads are particularly sensitive to adult road mortality because most turtles are late maturing, long-lived, and have high juvenile mortality (Brooks et al. 1991; Congdon et al. 1993; Heppell 1998). The overland movements of adult female turtles to nesting sites causes an additional, sex-specific road mortality risk (Aresco 2005b; Steen et al. 2006), which can lead to male-biased sex ratios, lower population sizes, and greater risk of extinction (Fahrig and Rytwinski 2009). Furthermore, the creation of artificial habitat conditions on roadsides can actually attract turtles and increase road mortality (Aresco 2005b) above and beyond that experienced by other overland movements. Roads may be considered an ecological trap (Schlaepfer et al. 2002) for turtles when individuals actively select roadsides as nest sites; this can increase the risk of road mortality and cause other threats to population stability (see Forman et al. 2003). There is also some evidence that some drivers will intentionally run over turtles (Ashley et al. 2007), this further increases the risk of mortality above that predicted by earlier probability models based primarily on traffic volume (Gibbs and Shriver 2002).

The identification and mitigation of hot spots of road mortality is an important goal for wildlife management and conservation biology (Langen et al. 2009). Turtles provide valuable freshwater ecosystem services and serve as trophic links between aquatic and terrestrial habitats (Moll and Moll 2004; Lindsay 2011); consequently, mitigation of road-killed turtle mortality should be a specific objective when managing freshwater resources. In addition, wildlife road mortality is a public safety issue. A 2008 report to the U.S. Congress estimated that there were 1–2 million wildlife-vehicle collisions in the U.S. each year and that the proportion of total accidents attributable to wildlife-vehicle collisions had risen between 1990 and 2004 (Huijser et al. 2008). Although the prevalence of turtle-vehicle related accidents is unknown and most likely low on average throughout the U.S., survey method guidelines (Langen et al. 2007) and examples of successful mitigation strategies (Aresco 2005a; Tom Langen, unpubl. report) can help transportation and public safety agencies identify and find solutions where hot spots occur, for the protection of both people and wildlife.

Here, we document a particularly high incidence of road-killed turtles at a lake in eastern Texas, USA. We report on the total number of dead turtles detected during surveys from 2008 to 2012, the species composition, and trends in space and time that can help inform mitigation planning and future research at this site. We briefly highlight partner mitigation plans and challenges to date.

MATERIALS AND METHODS

Study site.—We monitored a section of US 190 that spans the border of Jasper and Tyler counties in eastern Texas, USA, as it crosses B.A. Steinhagen Lake south of the confluence of the Neches and Angelina rivers (30°51'11.89"N, 94°11'52.95"W). The lake was formed by the Town Bluff Dam on the Neches River in 1951 and the current bridges were built in 1943 in anticipation of the construction of the dam (Floyd Boyet and Keith Horn, pers. comm.). The lake and surrounding land is managed by the U.S. Army Corps of Engineers, with parts leased by the Texas Parks and Wildlife Department (TPWD). The TPWD manages Angelina-Neches/Dam B Wildlife Management Area and Martin Dies Jr. State Park; however, the primary purpose of the lake is to store water and generate hydroelectric power. A 3.5 km, two-lane road comprised of a series of causeways connected by four bridges spans the lake. Annual Average Daily Traffic (AADT) ranges between 4,972 and 5,297 vehicles/day. We surveyed 2.7 km of the road and divided the surveyed area into three sections each separated by a bridge; the west (0.6 km in length), middle (0.2 km) and east (1.9 km). It was not feasible to survey three of the four bridges.

Survey methods.—We conducted 24 surveys for road-killed turtles on the causeway over a five year period from 2008 to 2012 (range 3–8/y; Table 1). We conducted surveys from January to October and, although we focused on the spring/summer months of April to September, we tried to perform at least one survey prior to the start of the nesting season (see Table 1 for dates). We conducted surveys between 0800 and 1800 and usually completed them in approximately 3 h. Two people walked each side of the road (a total of 5.4 km) and recorded all turtles found alive and dead on the road, and on the vegetated right-of-way alongside the road. We identified all live turtles to species and determined their sex by comparing the length of the tail relative to the carapace (Ernst and Lovich 2009). We also identified road-killed turtles to species and sexed where possible. For all turtles that we could not confirm the species or sex, we recorded the individual as unknown. In cases where multiple individual turtle remains had been obliterated and potentially mixed, we attempted to determine the number of individuals by counting only unique body parts (e.g., heads, tails).

We also recorded any turtle nests observed. We took GPS coordinates of each nest and individual turtle found dead or alive for all years except 2008, and in two surveys in 2011 when the equipment failed. We recorded GPS coordinates to examine spatial patterns in mortality locations to identify any potential hot spots and better inform mitigation measures. For the same reason, we also recorded which side of the road (north or south) we found the nests and individual turtles. We removed all dead individuals from the survey area after they were counted. For the analysis, we use correlation coefficients to examine temporal and spatial patterns and chi-squared tests to examine differences in frequencies between groups ($\alpha = 0.05$). All test statistics and P values were calculated in R (Version 3.1.3, R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Survey effort was not equal across years with three, eight, five, five, and three surveys each year, respectively. We did not find evidence that the number of surveys affected our total annual counts ($r = 0.46$, $P = 0.431$); however, the longer the average number of days between surveys within a year, the lower the total annual count of dead turtles ($r = -0.93$, $P = 0.020$). In August 2011, a guard rail was installed along the entire length of the surveyed area, which could have altered turtle behavior and/or detection probabilities for the remaining surveys (one survey in 2011 and all in 2012). The number of dead turtles found on the road decreased over the 5-y period ($r = -0.90$, $P = 0.037$), but when we removed the last year of mortalities (because of the potential influence of the guard rail) this was no longer significant ($r = -0.89$, $P = 0.106$). Overall, the estimated mortality rate was 63 turtles/km/y across all five years and 71.6 turtles/km/y when the final year was excluded.

We detected 850 road-killed turtles. These included 290 Eastern River Cooters (*Pseudemys concinna concinna*), 278 Red-eared Sliders (*Trachemys scripta elegans*), and 282 turtles of the Emydidae family that could not be identified to species (Table 1). We identified 345 (about 40%) female turtles and only five (< 1%) males ($\chi^2 = 330.3$, df = 1, $P = < 0.001$). We could not confirm the sex of 500 turtles. We found more dead turtles during the May to August breeding season

TABLE 1. The number of surveys and the number of road moralities (n) of turtles found on US 190 in East Texas, USA, 2008–2012 showing sexes by year and survey date.

Survey Date	Survey Total	n Females	n Males	n Unknown	Year Total
2008					
20 June	100	45	0	55	229
2 July	99	29	0	70	
13 August	30	24	0	6	
2009					
28 March	2	1	0	1	197
26 April	1	1	0	0	
1 June	44	29	0	15	
3 July	74	36	0	38	
31 July	32	10	1	21	
27 August	21	13	1	7	
27 September	17	10	1	6	
15 October	6	2	0	4	
2010					
18 March	4	1	0	3	170
29 April	9	4	0	5	
14 June	68	22	1	45	
29 July	30	12	0	18	
26 August	59	5	0	54	
2011					
18 January	53	0	0	53	177
23 April	9	0	0	9	
30 May	51	35	0	16	
20 July	47	26	0	21	
16 September	17	3	0	14	
2012					
24 April	16	4	0	12	77
25 July	60	33	0	27	
31 October	1	0	1	0	
Total	850	345	5	500	
Percentage		40.54	0.59	58.75	

(n = 715) compared to the September to April non-breeding season (n = 136), which was significant (χ^2 = 393.9, df = 1, P = < 0.001). We observed no significant difference between the number of dead turtles on the north (n = 407) and south (n = 427) sides of the road (χ^2 = 0.579, df = 1, P = 0.447) but we found more nests on the north side (n = 85) compared to the south side (n = 15) of the road (χ^2 = 49.0, df = 1, P = < 0.001). A negative correlation existed between the distance from the main river channel and the number of dead turtles on the large contiguous east section of the road (r = -0.81, P = < 0.001; Fig. 1).

DISCUSSION

The majority of identifiable turtles found dead during our study were sexually mature female turtles using the causeway during the breeding season to nest. Several studies have shown that nesting migrations place female turtles at greater risk of road mortality (Steen and Gibbs 2004; Gibbs and Steen 2005; Steen et al. 2006). Haxton (2000) surveyed roadsides in central Ontario and found an increase in the number of female Common Snapping Turtles (*Chelydra serpentina*) found both dead and alive during the nesting months with females making up 60% of all the road killed individuals. In Florida, Aresco (2005b) found 6–29% of mature female turtles in populations of four species nested along the side of the road. Turtle populations near this site were significantly male-biased when compared to ponds further away from major roads.

The life-history characteristics of large aquatic turtles can make populations especially sensitive to increases in adult mortality. Brooks et al. (1991) and Congdon et al. (1993) both concluded that for long lived turtle species with low recruitment, increases in adult mortality can quickly cause population declines. In Illinois, female River Cooters take 13–24 y to reach sexual maturity and lay 1–3 clutches of 10–20 eggs per y (Ernst and Lovich 2009). In contrast, female Red-eared Sliders can reach

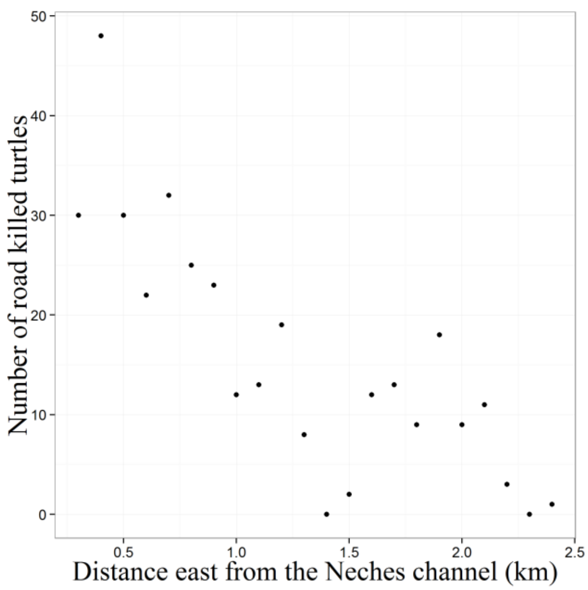

Figure 1. The number of road-killed turtles detected against distance along one of the surveyed sections of US 190, east of the main Neches River channel from 2009–2012 in East Texas, USA.

maturity within 3–4 y and lay 1–5 clutches of about 10 eggs per y (Ernst and Lovich 2009). Although specific demographic data for these two species at B.A. Steinhagen Lake is absent, it is possible that for Red-eared Sliders at least, the early age at maturity and higher annual reproductive output could make the population less susceptible to declines than the species studied by Brooks et al. (1991) and Congdon et al. (1993). A specific study of the freshwater turtle populations at this site would be required to determine if the road mortality is having an effect on the abundance and/or sex ratios of turtles in the lake.

The number of dead turtles detected on the road declined during the course of the study (but not when the final year was removed from the analysis due to the installation of the guardrail). This could indicate a reduction in the number of nesting female turtles and therefore a decline in the abundance of turtles in the lake, or the number of dead turtles detected could be unrelated to abundance in the lake. Two conflicting studies on anuran amphibians (Beckmann and Shine 2015) and mammals (Bright et al. 2015) suggest that the relationship between local abundance and road kill counts may be taxa specific and research on freshwater turtles will be required. In a similar study of road mortality in Ontario Canada, Ashley and Robinson (1996) report that, with the exception of an increase in Spotted Turtles (*Clemmys guttata*), turtle mortality remained constant between the years in their study. However, as their sample periods were separated by 12 y and traffic volume increased by 9% during this time, it is possible that fewer turtles were on the road in the latter sample period (possibly because there were fewer turtles in the surrounding population) but any individual turtle had a higher probability of mortality. The installation of the guardrail in late 2011 could have had an effect on the number of road-killed turtles detected in 2012 by making the road side less attractive to female turtles for nesting. The guard rail installation altered the substrate along a portion of the shoulder with cement footings around the posts and gravel around and underneath the rail. However, we only conducted three surveys in 2012 and these surveys had large survey intervals between them (mean 95 days), which we suspect resulted in counts biased low. Therefore, we conclude that while it is possible the guardrail had an effect on turtle mortality the low survey effort after its installation makes it impossible to separate it from the overall negative trend in the number of dead turtles detected on the road when all years are included in the analysis.

Our estimated mortality rates are quite likely underestimates of the true rates. Removal by scavengers, injuries that result in delayed mortality, roadside mowing, and complete obliteration by large vehicles can remove evidence of the individual mortality event and therefore bias estimates low. This probably explains the negative relationship between the average time between surveys and the number of dead turtles detected. Few studies have examined turtle carcass persistence on roads. Santos et al. (2011) report the median persistence time for road-killed freshwater turtle carcasses at a site in southern Portugal as three days (95% CI, 2–5 d), and their persistence model predicted a 0% probability of detecting a turtle carcass after about 12 d. Tom Langen (unpubl. data) calculated a persistence model based on road mortality surveys from the St. Lawrence Valley of New York state, USA, that also predicted a 0% probability of detecting a turtle at 12 d. However, Dodd (1995) determined that it could take 2–3 y for the shells of river cooter species in Florida to completely disarticulate and decompose under natural conditions away from roads. Although the site characteristics and the final location of the turtle carcass (i.e., in the road, on the road side, or off the road completely) influence both persistence and detectability, generally these studies show a reduction in carcass detection with time since death. We suggest the true mortality rate at B. A. Steinhagen Lake may be higher than we documented, and more frequent surveys could have yielded a more accurate estimate of the true mortality rate.

Langen et al. (2009) identified the same type of landscape configuration that is present at B.A. Steinhagen Lake (a causeway with wetlands on both sides) as hot spots of reptile road mortality. At their study site in New York State, they observed nine times the quantity of roadkill on causeways compared to random sites within their region. We did not evaluate turtle mortality away from the causeway; however, the spatial pattern of the mortality along the causeway suggests that some sections of the road received more turtle activity than others. We examined the longest contiguous section of the road (the eastern 1.9 km) and found a reduction in the number of carcasses as the distance from the Neches river channel increased. In 2006 and 2007, the lake was drained in an attempt to control invasive vegetation Giant Salvinia (*Salvinia molesta*). As this occurred just before the start of our monitoring, we do not know the level of road mortality or where the female turtles nested during this time. Eastern River Cooters generally nest within 30 m of the water and Red-eared Sliders within 200 m (Ernst and Lovich 2009). Consequently, it is unlikely they had access to the far eastern edge of the causeway during this time and potentially nested on the newly exposed sandbanks along the Neches River channel. The concentration of mortality along the causeway adjacent to the main Neches River channel could then be a legacy of this management action. We also detected differences between the number of nests located on the north and south sides of the roads. It is possible that access points or more favorable nesting conditions (i.e., soil temperature, moisture, or vegetation cover) exist on the north side of the road but we have no data to address this.

We are aware of only one site in North America where the number of road-killed turtles/km/y exceeded that of B. A. Steinhagen Lake at 63–71.6 dead turtles/km/year. Aresco (2005a) reported 4,343.5 dead turtles/km/y at a four-lane highway at Lake Jackson in Florida, USA. However, the road mortality at this site was successfully mitigated by installation of drift fences encouraging turtles to use an under-highway culvert. Therefore, the causeway on US 190 over B. A. Steinhagen Lake has the highest unmitigated turtle mortality documented in North America.

Mitigation effort.—At the onset of field surveys, two of the authors (PC and RRC) contacted state and federal agencies to alert resource managers to the road mortality hot spot and to begin conversations regarding possible mitigation at this site. The Texas Department of Transportation developed a design for a turtle barrier in consultation with project partners and other experts in North America. However, it was announced in March 2011 that the barrier would not be installed following opposition by local parties who, ostensibly, disagreed with the use of highway funds for a turtle fence. Instead, a guardrail was installed alongside the causeway as a safety improvement for drivers in late 2011. The stretch of highway and the bridges across the lake are due for replacement, and work is slated to begin by the Texas Department of Transportation in 2015 pending permit approval by the U.S. Army Corp of Engineers. The incorporation of wildlife road mortality mitigation measures into the design of the replacement structures should reduce both the possibility of turtle access to the road and the favorable nesting conditions on the roadside. However, post-construction monitoring would be needed to confirm the effectiveness of these mitigation measures.

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