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The Impact of ATVs on Survival of Softshell Turtle (*Apalone* spp.) Nests

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Abstract.—Recreational activities can be detrimental to biodiversity; for example, off-road vehicle traffic (e.g., ATV riding), which has become increasingly popular in recent decades, can threaten wildlife. Although ATV riding around wetlands may threaten the shallow nests of turtles, there are no data on the effect of ATVs on turtle nests. We studied nest site choice and nest survival in two species of softshell turtles (*Apalone mutica* and *A. spinifera*) along a river in Louisiana before (1993–1994) and after (2015–2016) ATV riding became popular at the site to determine whether ATVs were an important source of nest mortality, and whether there was an effect of nest site choice on nest survival. ATVs were the most common source of nest mortality (one-third of nests destroyed); nest mortality was significantly positively related to increased ATV traffic but was not influenced by species or nest site choice. Experiments with surrogate eggs and an ATV revealed that the most vulnerable nests to ATV mortality were those that were shallower, were driven over more slowly, and were turned upon. We recommend restricting the access of riding clubs to the river; enforcement of regulations on isolated riders from adjacent residential areas will be logistically and financially challenging.

The majority of current threats to wildlife populations are anthropogenic. Wildlife species and populations are declining as a result of habitat loss, overharvesting, invasive species, pathogens, climate change, or some combination of these factors (Barnosky et al., 2011; Primack, 2014). Some of these threatening processes are difficult to reduce or reverse; for example, habitat loss, the most pressing threat, continues unabated partly as a result of an exponentially growing human population (Cardillo et al., 2004; Laurance, 2010). However, other anthropogenic threats can be more easily reversed, removed, or reduced, such as the impacts of recreational activities.

Recreational activities can have significant negative effects on wildlife (reviewed by Larson et al., 2016). For example, birds can be negatively affected by nature-based recreation such as cycling, running, hiking, dog walking, canoeing, and even wildlife viewing (reviewed in Steven et al., 2011). Typical impacts on wildlife range from the level of individual (e.g., behavior, physiology) to population-level impacts (e.g., survival, occurrence, abundance, reproduction; Larson et al., 2016).

One growing form of recreation is off-road vehicles; these range from single-person All Terrain Vehicles (ATVs) to four-wheel drive trucks. For example, ATV use in the United States has grown dramatically in popularity and it has had severe environmental impacts (Havlick, 2002). With the use of ATVs, the lines between natural areas and suburbs have become blurred; vehicles are no longer restricted to paved roads, but now have the capability to access previously isolated areas. Impacts of ATVs on the desert Southwest in the United States were documented as early as the 1970s (Wilshire and Nakata, 1976), eventually prompting management decisions regarding this new threat, especially on public lands (Havlick, 2002). To simultaneously handle growing concerns of impacts and recreational activities, public land groups have provided trails designated specifically for ATVs in an attempt to keep enthusiasts on specific trails and out protected natural areas; however, research suggests this might not be enough to protect natural resources (Meadows et al., 2008).

ATV riding creates a suite of specific ecological impacts (reviewed in Webb and Wilshire, 2012), including increased soil compaction, soil erosion, and vegetation and seed destruction, in a variety of habitats ranging from desert regions to forests (Lathrop, 1982; Webb, 1983; Hannaford and Resh, 1999; Sack and Da Luz, 2003). ATV riding in wetlands is especially damaging. Streams and rivers are susceptible to pollution from ATVs with excess oil getting washed off into the water, and sedimentation attributable to erosion in streams can negatively impact the biota of the stream by affecting water turbidity (Evans, 2002; Havlick, 2002; Taylor, 2006). ATVs have also negatively affected wild chelonian populations. A population decline in the federally threatened Desert Tortoise (*Gopherus agassizii*) in the Mojave Desert (USA) was caused by increased ATV activity (Bury, 1978). While reversing some threats to turtles (e.g., the wildlife trade, habitat loss) is difficult to achieve (Rhodin et al., 2018), other threats such as ATVs can be readily abated or reduced. For example, concerns about ATVs on coastal beaches sparked legislation and protection attributable in part to concerns for nesting and hatchling sea turtles (Mann, 1978; Hosier et al., 1981). Many of the world's ~350 spp. of turtles inhabit freshwater systems, including in rivers, streams, lakes, ponds and ditches (Moll and Moll, 2004; Rhodin et al., 2017). With one known exception, *Chelodina rugosa* (Kennett et al., 1993), freshwater turtles lay their eggs on land, and thus require terrestrial nesting habitat near their wetlands. Nesting mothers must often traverse a gauntlet of predators and vehicles when moving to and from nesting areas (Steen et al., 2012), and may find that the nesting habitat has been degraded or no longer exists (Moll, 1997). After a turtle has nested, the eggs are left alone for at least 2–3 mo, during which time they are susceptible to multiple threats, mainly flooding and predation (Ewert, 1979; Wilbur and Morin, 1988; Moll, 1997). ATV tracks on ocean beaches can slow the hatchling emergence process, which in turn can increase hatchling mortality via predation and desiccation (Hosier et al., 1981). Although sea turtle nests are often deep enough to preclude eggs being crushed by ATVs, the eggs of freshwater turtles are deposited in shallow nests, generally 10–25 cm below the surface (Ernst and Lovich, 2009), making them vulnerable to being crushed.

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Are ATVs a threat to freshwater turtle eggs? An ideal system for addressing this question is softshell turtles (*Apalone* spp.) nesting along the Comite River in Louisiana (USA). The Comite is a recreational hotspot for ATV riding. The Comite exhibits a number of sandy beaches and the banks and shallow depths make it ideal for ATV recreation (virtually all turtle nesting areas are accessible by ATVs). Nesting softshell turtles excavate shallow (12–22-cm deep) holes on exposed sandbars and banks, making them potentially vulnerable to being crushed by ATVs. However, ATVs were rare on the Comite with only the occasional motorbike and three-wheeler seen, and only on 1–2 nest sandbars (Doody, pers. obs.; Doody, 1995). In a previous study, Doody (1995) quantified nest site choice and nest mortality of softshell turtle nests (*A. mutica* and *A. spinifera*) from 1992 to 1994, citing flooding as the principal threat to eggs, with no anthropogenic mortality. In contrast, in recent years, large numbers of ATV enthusiasts have navigated the river, especially during the summer months when turtle eggs are incubating (S. Holcomb, unpubl. data.). This recreation has occurred despite the Comite being protected under the Louisiana Scenic Rivers Act since 1970 and the addition of a 2014 provision banning motor vehicle use in scenic rivers (Louisiana Scenic Rivers Act 1970; Louisiana Scenic Rivers Act 2014, Title 76, section 115). This marked temporal change in land use, and offered the rare opportunity to determine the impact of ATVs on freshwater turtle nesting success.

To study the impacts of ATVs on turtle nesting, we followed the methods of Doody (1995) on the Comite River and aimed to answer the following questions: 1) Are ATVs destroying softshell turtle nests? And if so, what is the magnitude of this mortality? 2) Is there an effect of nest site choice (location) on nest mortality attributable to ATVs? 3) Does an increase in ATV traffic decrease nest survival? Finally, we conducted field experiments with an ATV and surrogate (chicken) eggs to determine 4) what aspects of turtle nests (e.g., depth) and ATV maneuvering (e.g., turning, different speeds) are most detrimental to survival of softshell turtle nests. We use our findings to make recommendations for wildlife managers interested in reducing the impact of ATV recreation on turtle populations in Louisiana and elsewhere.

Materials and Methods

Study Area and Species.—The Comite River is a sandy-bottomed river flowing 90 km south from Centreville, Mississippi to the Amite River near Denham Springs, Louisiana. The study site encompassed ~14.5 km of the Comite River in East Baton Rouge, Louisiana (from 30.700956N, −91.051624W to 30.525834N, −91.091305W; Doody, 1995). In 2015 we used the same river section from the previous study. In 2016 we added an ~2.85-km section of river in an attempt to provide a control site (no ATVs) that increased the total surveyed area to ~17.35 km. The ~17.35-km river stretch was divided into five sections to accommodate sampling. Average depth of water was <0.5 m, with deeper pools up to ~2.0 m. The banks were vegetated, but there were large sandbars (typically 100–200 m long), mainly where the river bends, that typically remain free from vegetation. In 2015 and 2016, 44 possible nesting beaches were identified on the ~17.35-km stretch. Although the river is generally shallow, it experiences significant flooding following heavy rainfall in the catchment.

The softshell turtles *A. mutica* and *A. spinifera* are medium-sized species specialized for aquatic life. Their distributions are similar, roughly centering around the Mississippi River catchment (Ernst and Lovich, 2009). Both species prefer to nest close to water, typically in sandy areas with little shading vegetation, where they lay ~6–20 eggs in a shallow back-filled nest; eggs are laid at depths ranging from 7 to 20 cm below the surface (Doody, 1995). Eggs incubate for ~60–80 d depending on temperature (Doody, 1995).

Nest Surveys.—We conducted nest surveys 5–6 d/wk during the nesting season (mid-May to early August) in 1993, 1994, 2015, and 2016 with one of the five sections being traversed by foot each day. Nests were located by following crawls in the sand made by nesting females and by noting slight depressions in the sand. A probe consisting of a wooden dowel and a steel rod was used to detect eggs via density differences between softer sand in the (back-filled) nest chamber and harder sand surrounding the nest chamber (Doody, 1995).

For each nest we measured the crawl width, slope (with a clinometer), aspect (with a compass), height above water, distance from water, and distance from nearest vegetation. We carefully excavated each nest, ensuring egg orientation was maintained, to measure depth to the top egg, chamber depth, clutch size, and the number of infertile eggs and broken eggs. Rough age was estimated using the size of the chalk spot (where the vitelline membranes adhere to the inner shell membrane; Ewert, 1979, 1985). Eggs were carefully returned to the nest chamber and the nest reburied.

To identify nests to species, in 1993–1994 we installed wire cages on most nests; cages were 6-mm hardware wire and were hidden below the surface just above the top egg. Nests were checked for hatching every 1–2 d beginning at day 50 (hatching begins at around day 55 at the earliest). To identify nests to species in 2015–2016 we brought one egg from each nest into the laboratory at Southeastern Louisiana University and incubated the eggs at a constant temperature of 30°C in one of two incubator types (Hovabator 1602n™ incubator or an R-com 50™ incubator). Hatchlings were released at their nest sites within 2 wk of hatching.

Monitoring Nest Survival and ATV Traffic.—To facilitate monitoring nest survival, nests were marked with small bamboo stakes; in 2015–2016 Global Positioning System waypoints and photographs were also taken for each nest. Nests were inspected 2–5 times/wk for signs of predation, flooding, or ATV mortality (ATV tracks directly over the nest), but were only excavated if there were obvious signs of mortality (i.e., eggshells, nest below a flood mark, ATV tracks over the nest). Eggs in excavated nests were examined to determine how many were preyed upon, rotten as a result of flooding, infertile, or exhibited early mortality caused by intrinsic reasons, or crushed by ATVs.

To estimate ATV traffic on each sandbar in 2015–2016, each week one of us walked from the tree line to the shoreline (perpendicular to the river), at the approximate middle of each sandbar during our nests surveys; ATV tracks were recorded if they crossed our path. To avoid double-counting, only recent tracks (tracks exhibiting visible tire tread and depression with limited weathering) were counted. We then calculated an average traffic per season (number of counted tracks/how many times the beach was surveyed) for each beach. Nests laid on that beach now had an average traffic value. Although we could not accurately assess how many ATVs created the tracks, our estimates were indicative of the total (recent) use of the sandbars by ATVs. In the 2015 and 2016 sampling season, 44 beaches were identified in our sampling stretch, and 33 beaches had nests.

TABLE 1. Annual sources of mortality for *Apalone* nests during the two study periods. Numbers of nests per annum are in parentheses after years. Percent of the year's mortality associated with the source is represented in parentheses after number of nests associated with a mortality source.

Source	1993 (105)	1994 (104)	2015 (40)	2016 (59)	Means %
ATV	0 (0%)	0 (0%)	14 (35%)	18 (31%)	16.5%
Flooding	0 (0%)	43 (41%)	0 (0%)	18 (31%)	18.0%
Predation	12 (11%)	1 (1%)	5 (12.5%)	1 (2%)	6.6%
Erosion	0 (0%)	0 (0%)	5 (12.5%)	0 (0%)	3.1%
Totals	12 (11%)	44 (42%)	24 (60%)	37 (63%)	44.2%

Experiments Investigating ATV Impacts on Eggs.—To investigate what modulates the crushing mortality (an egg exhibiting a cracked shell exposing membrane and egg contents) of ATVs on turtle eggs, we needed a surrogate egg (to preclude killing viable turtle eggs). We used chicken eggs. An apparatus to test the crush resistance of eggs was built with the guidance of the Southeastern Louisiana University Physics Department, and using the design from a poultry egg crushing device (Tyler and Coundon, 1965), which consisted of a scale and crushing platform. Copper BBs were slowly added to the cup above the soon-to-be crushed egg. When the egg collapsed, the BBs were removed and weighed to the nearest gram. Nine softshell turtle eggs were sacrificed to determine the crushing resistance for comparison with the chicken eggs.

Artificial nests consisted of two chicken eggs placed on top of each other lengthwise and buried to the designated heights. Artificial nests were tested using a utility ATV (2011 Honda Foreman 450^{TM}) on a privately owned sandy beach on the Tangipahoa River near Hammond, Louisiana. Treatments included vehicle speed (slow = 5 km/h vs. fast = 16 km/h) and nest depth (shallow = 7 cm below the surface, intermediate = 11.5 cm, and deep = 16 cm). These depths were chosen to cover the range of depths in the two softshell turtle species based on previous data (Doody, 1995). The previously mentioned tests had the rider drive in a straight line over the nest. Frequent "doughnut tracks" were seen on the Comite River, with substantive amounts of sand displaced from "doughnuts," so we tested whether hard turns affected nest survival using the same three nest depths. All treatments had five replicates. A cracked or crushed egg was the indicator of nest mortality.

Statistical Analysis.—Nest density was calculated by dividing the total number of nests detected in a season by the entire river stretch surveyed. During the 1992, 1993, and 2015 sampling year the river stretch was ~14.5 km long. In 2016, the sampling stretch was ~17.35 km. In 2016, an attempt was made to have a control site (a stretch of river that did not have ATV activity), thus adding to the overall area surveyed and additional detected nests. A chi-squared test was performed on a contingency table of nest mortality year and sources to test for significant variation between sampling periods. Binary logistic regression was used to test whether nest placement characteristics (slope, distance from water, distance form vegetation, and height above water) were associated with ATV mortality or survivorship. Binary logistic regression also was used to determine whether ATV traffic was associated with ATV mortality or survivorship. A chi-squared test was performed on a contingency table of mortality to determine what nest depths and riding characteristics are associated with experimental surrogate nest mortality.

RESULTS

Of the 209 nests found in 1993–1994, 69 (33%) were *A. mutica*, 68 (32.5%) were *A. spinifera*, and 72 (34.5%) were unidentified *Apalone* nests. Of the 99 nests found in 2015–2016, 38 (38%) were *A. mutica*, 35 (35%) were *A. spinifera*, and 24 (24%) were unidentified *Apalone* nests. We found 99 nests during the more recent study period (2015: 40 nests, 2016: 59 nests). These numbers were roughly half those found in the previous study period, in which we found 209 nests (1993: 105 nests, 1994: 104 nests). Nest density was 7.2 nests/km in 1993, 7.2 in 1994, 2.75 in 2015, and 3.4 in 2016. This represents a >50% decline in the number of nests found between the two study periods.

Sources of Mortality.—Total mortality of nests in the recent study period was 62% ($n = 99$ nests), compared with 26.8% in the previous study period (Table 1; Fig. 1). Source of mortality was dependent on year (Contingency analysis: $C^2_1 = 16.9$, $P < 0.0001$). Mortality attributable to ATVs was 32% in the recent study period; no mortality attributable to ATVs occurred in the previous study period (Table 1; Fig. 1). Flood mortality was high in both study periods, but was absent in 1 of 2 y for each (Table 1). Predation was similarly low during both study periods (Table 1). Considering only the recent study period, ATVs resulted in the highest percentage of mortality (33%), followed by flooding (16%), predation (7%), and erosion (6%; Table 1).

ATV Mortality between Species and Effects of Nest Site Choice and ATV Traffic.—All nests that were run over by ATVs in our study suffered 100% egg mortality. Mortality attributable to ATVs was similar between species: *A. mutica* = 32%, *A. spinifera* = 31%, unidentified *Apalone* = 32%. The number of eggs destroyed by ATVs was higher for *A. spinifera* ($n = 134$) than for *A. mutica* ($n = 94$) because of larger mean clutch sizes in *A. spinifera* (*A. mutica* average 6.7 ± 1.93/clutch and *A. spinifera* 11.7 ± 4.14/clutch; Doody, 1995; Godwin, 2017). Nest site attributes did not differ

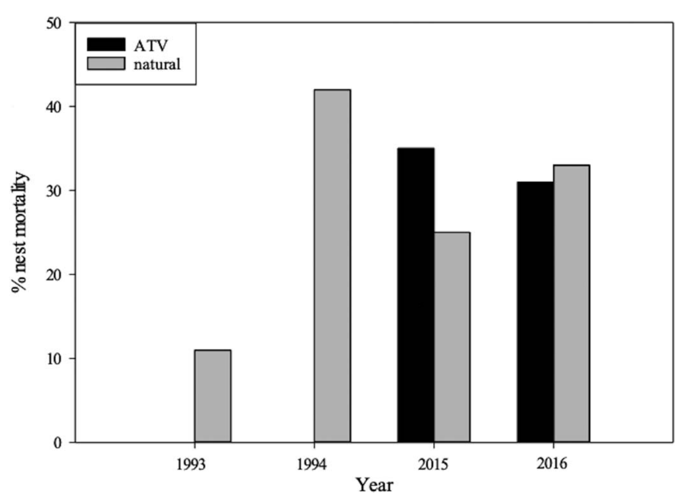

FIG. 1. Sources of nest mortality in Spiny and Smooth Softshell turtles (*Apalone spinifera* and *A. mutica*) in the earlier study (1993–1994) and the later study 22 y later (2015–2016). Natural mortality was mainly flooding but also predation and erosion, while ATV-induced mortality was crushed eggs in nests.

TABLE 2. Effect of nest site attributes on mortality between surviving nests and those destroyed by ATVs. Results are from a binary logistic regression (Nagelkerke's R^2).

Nest site attribute	n	R^2	P
Slope	98	0.014	0.319
Distance from water	98	0.036	0.102
Distance from vegetation	97	0.003	0.660
Height above water	97	0.024	0.192

between surviving nests and those destroyed by ATVs (Table 2). Nests on beaches with more ATV traffic experienced higher mortality than those on beaches with lower ATV traffic (Fig. 2; Binary logistic regression: Nagelkerke's $R^2 = 0.16$, $P = 0.003$). When broken down by year, this effect was only significant in 2016 (Fig. 2; 2015: $R^2 = 0.08$, $P = 0.124$; 2016: $R^2 = 0.29$, $P = 0.002$). The relationship in 2015, however, was influenced by an outlier: one beach with the highest numbers of ATV tracks included a nest that survived. On a few occasions, hatchling softshell turtles' tracks were detected in the ATV tracks; this could slow the emergence process to water and possibly increase predation of hatchlings.

ATV Mortality Experiment.—Experiments with an ATV and surrogate eggs revealed that both nest depth and speed and/or maneuver affected the fate of experimental nests (Fig. 3). Speed and/or maneuver was not independent of depth, when considering mortality of surrogate nests (Contingency Analysis; $C^2{}_1 = 1.87$, $P = 0.007$). For all speeds and maneuvers, deep nests were more likely to survive than nests at intermediate or shallow depths, and generally, nests at intermediate depth were more likely to survive than those at shallow depths (Fig. 3). However, compared with fast speeds, slow speeds resulted in greater mortality at shallow and intermediate depths, but no mortality in deep nests (Fig. 3).

DISCUSSION

We found considerable impacts of ATVs on softshell turtle nest survival in our recent study period, and data from our older study period reveal that this mortality is relatively recent. ATV riding has become increasingly popular on the Comite in

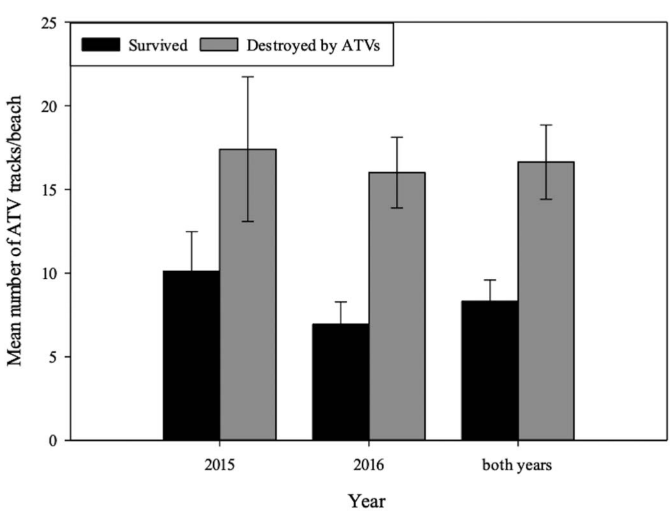

FIG. 2. Relationship between the number of ATV tracks per sandbar and whether or not nests were destroyed by, or survived ATVs, during the later study. There were no ATVs in the earlier study.

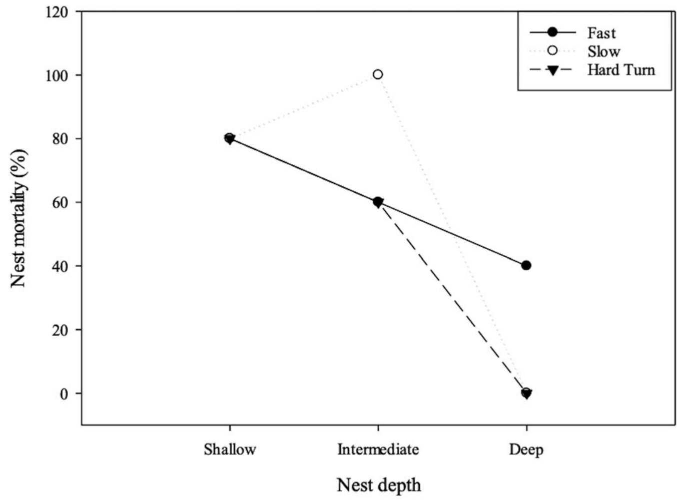

FIG. 3. Experimental results of the influence of nest depth on surrogate (chicken) egg survival, for each of three types of speed (slow, fast) or maneuvers (hard turn). Nest depths were shallow = 7 cm, intermediate = 11.5 cm, deep = 16 cm, and covered the range of nests experienced in the species at the site (Doody, 1995).

recent years (S. Holcomb, unpubl. data) and overall nest mortality is now nearly double that from ~2 decades ago, attributable to ATVs crushing eggs in nests. Our experiments revealed that ATVs can crush eggs by just riding over them, but mortality is greater with maneuvers and with decreasing nest depth. Chicken eggs were roughly twice as resistant to crushing then the softshell turtle eggs. Thus, our results from the field experiment revealing how ATVs crush eggs are conservative. The combination of natural nest mortality (e.g., flooding) and anthropogenic mortality (ATVs) may have caused, or may be causing, a population decline: nest densities in recent years were roughly half that of previous years. Nest site choice did not predict nest survival, suggesting that, evolutionarily, there is little mothers can do to reduce ATV nest mortality through the choice of a nest site (within sandbars). Although more data are needed to understand how mortality in the egg stage translates into population growth or declines, management of ATVs in the river system is recommended.

Prior to ATV use (1993–1994), our data revealed only natural nest mortality—flooding caused 0% and 43% mortality in 1993 and 1994, respectively, and a model using river stage data predicted an average of 34% mortality in the egg stage for each species (Doody, 1995). Flooding was also an issue in the recent study period (2015–2016), but ATVs resulted in the highest mortality (Table 1). Moreover, ATV mortality might be expected to be consistent because there was no notable decrease in rider presence after our 2-y study period (Doody, unpubl. data; 2020), whereas flood mortality only occurs in some years (Doody, 1995; see also Table 1).

During the previous study, vehicles were extremely rare at the site; only the occasional motorbike and three-wheeler were seen, and only on 1–2 nest sandbars (Doody, pers. obs.; Doody, 1995). However, in recent years ATV riding in the river has increased in popularity, not only with single riders, but with groups. Groups typically congregate at a privately owned ATV park that borders the Comite. As many as 50 ATVs could often be observed riding the river simultaneously. This riding is not restricted to small ATVs; larger vehicles including trucks are also involved. Riders can now traverse kilometers of river with scores of sandbars because the vehicles are able to move

FIG. 4. ATV tracks on two sandbars, showing essentially complete coverage. Some sandbars received less coverage depending on location along the river. Photographs by C. Godwin.

through moderately shallow water without stalling; the river is mostly <0.5 m deep year-round, and often mainly <0.3 m deep in the summer months (Doody, pers. obs.). Thus, typically several ATVs can be seen riding from sandbar to sandbar on a weekend day during summer. In contrast to riding in water, riders often perform maneuvers such as hard turns and doughnuts on sandbars; on some sandbars every square meter of sand is left with ATV tracks (Fig. 4). Softshell turtles nest in open areas free of vegetation, putting them at direct risk of being run over by ATVs. In some nests all eggs were crushed, in others only the top eggs; however, the smell of crushed eggs can attract predators; one nest was preyed upon after some eggs were crushed in the nest. Our experiments with chicken eggs revealed that ATVs can crush eggs by just riding over them (Fig. 3), but riding more slowly over nests incurs more egg mortality at shallow and intermediate depths (Fig. 3). Mortality was also greater with maneuvers (i.e., hard turns) and with decreasing nest depth (Fig. 3).

Although some turtles nest in vegetation, both softshell turtle species at our study site nest mainly in open areas, putting them at direct risk of being run over by ATVs. Nest site choice attributes did not influence the probability of nest mortality via ATVs. This suggests that there is little or no scope for an evolutionary response to ATV mortality in the populations, at least at the scale of nest site choice within sandbars. Mothers could avoid nesting in sandbars that have higher levels of ATV traffic, but this would require 1) the availability of other sandbars without ATV traffic or with low ATV traffic within the reach of the nesting turtles; and 2) the ability to distinguish between sandbars with low and high ATV traffic. The latter of these would require gravid turtles to visually monitor ATV traffic or to assess ATV tracks as a surrogate of ATV traffic; this ability seems unlikely. However, mothers of the Australian turtle *Emydura macquarii* were apparently able to avoid areas with high predatory fox densities, perhaps via fox scats in nesting areas (Spencer, 2002).

Female softshell turtles, on the Comite River, may have limited nesting success because of the expanse of ATV traffic and the inability to identify ATV tracks as a threat to nest survival within their home range. The spatial ecology of adult female softshell turtles has not been assessed on the Comite River, but studies in similar riverine systems have calculated average home ranges to be 1,288 m in *Apalone mutica* (Plummer and Shirer, 1975) and 1,400 m in *Apalone spinifera* (Plummer et al., 1997). Female softshell turtles have been known to move great distances for nesting (up to 7 km; Daigle et al., 2002), but those moves seem to be necessary because of limited nesting sites. The total length of our study site was ~17.35 km and it had 44 possible nesting beaches. Density of beaches, previously reported home ranges of female softshell turtles, and detection of nests on beaches with ATV traffic mean that it is unlikely females would feel compelled to move or would move very far from their home range to nest. It is likely that the beaches are ecological traps where they fit the criteria to deposit eggs and riding is not so frequent that females avoid the area entirely, but any riding event during the ~55-d incubation could result in nest mortality.

The egg stage of the life cycle in turtles typically incurs high mortality naturally (e.g., Ewert 1979, 1985; Congdon et al., 1983), and this is also true for populations in the current study (e.g., an average of 34% mortality attributable to flooding; Doody 1995). This natural mortality coupled with recent ATV mortality (roughly a third of nests) is likely having population-level effects on the egg stage. We do not know how a reduction in egg survival translates into population changes in general, but unabated ATV traffic at the site may result in population declines in both species. Novel threats to turtle nests have translated to population declines. On the Murray River in Australia, the invasive Red Fox (*Vulpes vulpes*) increased turtle nest predation to >93% (Thompson, 1983; Spencer, 2002). The increased nest predation led to reduced recruitment resulting in overall turtle population declines (Chessman, 2011). Indeed, greatly reduced nest density on the Comite River between 1993–1994 and 2015–2016 suggest that declines have already occurred and may be still occurring.

The riding of ATVs in the Comite River has attracted considerable attention and controversy. In particular, the stretch of the Comite River that includes our study area is designated as a 'Scenic Rivers Area' in Louisiana (Louisiana Scenic Rivers Act, 1970). As such, it is open to recreation but afforded some protection against damage to natural resources. Unpublished research from Louisiana Department of Wildlife and Fisheries in 2013 suggested that ATV riding in the river resulted in reduced diversity of benthic macroinvertebrates and fish (S. Holcomb, pers. comm.). Our study adds to those impacts by extending them to turtle nests.

Roughly, there are two classes of riders on the river: isolated riders who live nearby vs. riding clubs comprising large numbers of riders that rendezvous at certain access points. Although our data are not sufficient to provide a threshold of acceptable ATV use of sandbars to allow softshell turtle to maintain current population levels, we are confident that the large groups of riders are detrimental to softshell turtle nests and populations. It is these groups that cause widespread alteration of the sandbars across large stretches of river. The other class of riders—the isolated, resident riders—likely do less damage to turtle nests because there are rarely more than ~6 softshell turtle nests/large (~100–300-m-long) sandbar in our study area (because there are so many suitable sandbars in close proximity), and isolated riders are likely to miss some of those nests. Moreover, isolated riders may traverse fewer sandbars than large riding groups (Godwin, pers. obs.). This distinction is important with regard to enforcement. For example, disallowing riding clubs or restricting access for riding clubs is likely achievable, but enforcing isolated riders on isolated stretches of river between bridges would be logistically difficult and costly. The river is too shallow for boats in general, and so enforcement would require ATVs covering up to tens of kilometers of river.

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