

## Nest-site selection and nest depredation of semi-aquatic turtles on golf courses

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**Abstract** Urban landscapes present various challenges to semi-aquatic turtle reproduction. In developed regions, golf courses may provide some of the best remaining habitat for turtle populations. We explored nest-site selection of eastern painted turtles (*Chrysemys picta*) at a golf course pond in Davidson, North Carolina, USA, and modeled nest-site preference using Akaike Information Criterion, with the best supported model favoring nests surrounded by mulch and mowed grass. Additionally, we evaluated nest depredation rates using simulated turtle nests and found that golf course ponds did not have significantly greater nest depredation compared to urban and rural ponds. Our results suggest that golf courses may offer suitable habitat for turtle reproduction in developed areas.

**Keywords** *Chrysemys picta* · Golf courses · Nest depredation · Nesting behavior · North Carolina · Semi-aquatic turtles · Turtle reproduction

Habitat loss and degradation caused by urbanization is one of the greatest threats to animal populations (McKinney 2002). Habitat fragmentation resulting from urbanization may hinder dispersal (Doak et al. 1992), migration (Collingham and Huntley 2000), and movements associated with reproduction (Nour et al. 1993), as well disrupt predator–prey interactions (Kareiva 1987). Ultimately, urbanization can contribute to declines in species richness and reduction of population sizes (McKinney 2002; Dickman 1987). For species that rely on mobility for successful reproduction, fragmented landscapes resulting from urbanization can pose high mortality risks (Baldwin et al. 2004) and induce avoidance behavior of landscapes associated with human activity (Ryan et al. 2008).

Semi-aquatic turtles are sensitive to urbanization and associated habitat fragmentation (Steen and Gibbs 2004; Gibbs and Steen 2005; Harden et al. 2009). The persistence of semi-aquatic turtle populations is dependent on adequate reproduction and recruitment, which are directly linked to successful movements through terrestrial environments. Most semi-aquatic turtles prefer non-forested, open areas for nesting (Baldwin et al. 2004; Christens and Bider

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1987; Janzen 1994; Mitchell 1988; Rowe et al. 2005; Shepard et al. 2008). If non-forested habitat is locally unavailable, then female turtles may migrate extensive distances to find suitable nesting sites (Baldwin et al. 2004; Rowe et al. 2005). Extensive movements by female turtles put them at risk if they are forced to cross roads during migrations (i.e., Gibbs and Shriver 2002; Gibbs and Steen 2005; Haxton 2000) or if predation rates increase with time spent migrating through terrestrial habitats (Congdon and Gatten 1989). Mortality of nesting females can affect sex ratios within populations, making populations male-biased (Gibbs and Steen 2005) and ultimately leading to reduction of reproduction rates.

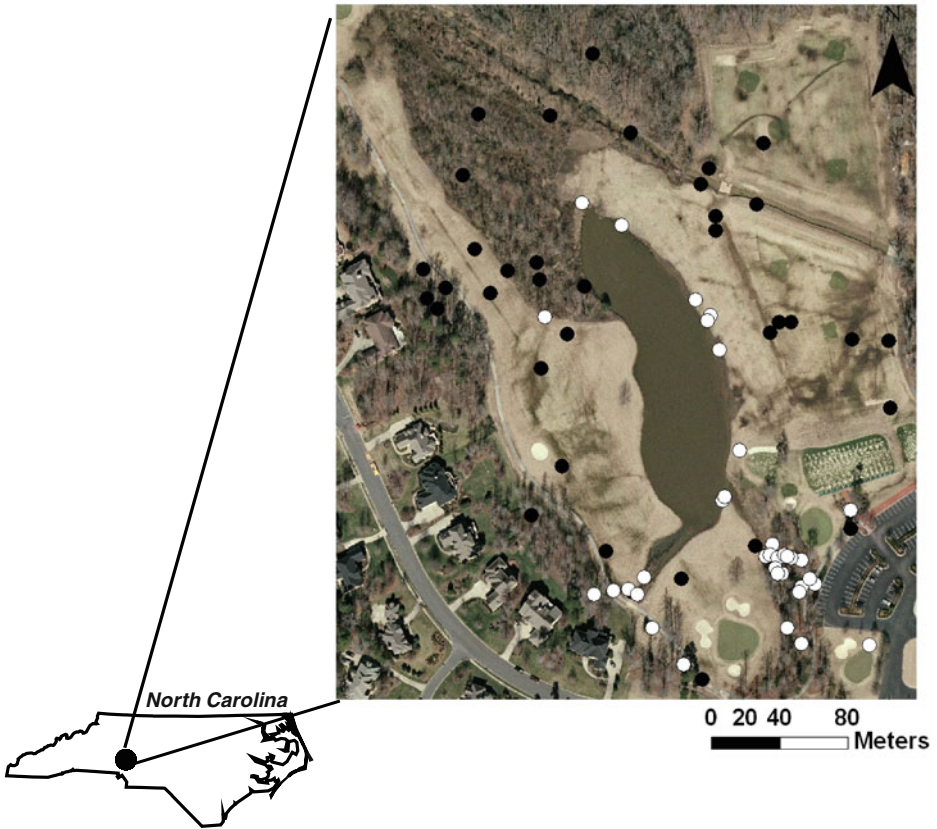
Populations of semi-aquatic turtles in urban areas may also be affected by characteristics of the nest-site and predation patterns of nests by human-subsidized predators (Cagle et al. 1993; Conner et al. 2005; Kolbe and Janzen 2002). Nest site characteristics, such as vegetation cover, moisture, and temperature can affect the sex ratios and development of hatchlings (Janzen 1994). Predation by generalist predators on semi-aquatic turtle nests can result in declines of turtle populations (Burke et al. 2005; Strickland et al. 2010), especially in urbanized areas where such predators are abundant (Prange et al. 2004; Wilcove 1985). Distance of nest from aquatic habitat may interact with predation pressure to influence turtle populations. For example, Marchand et al. (2002) found that simulated nests located farthest (i.e., 100–150 m) from the pond had decreased rates of predation and, in an additional study, Marchand and Litvaitis (2004) found the highest rates of predation within clumped nests near pond edges (i.e., within 50 m). Turtles restricted to nesting in small habitat patches, such as those often found around urban ponds, may experience significant nest predation (Marchand et al. 2002).

Within urban areas, golf course ponds represent a common type of anthropogenically modified aquatic environment that may serve as suitable turtle habitat (Colding et al. 2009; Failey et al. 2007; Harden et al. 2009; Lindsay and Dorcas 2001). Ponds on golf courses experience recurring human presence, frequent mowing, and pesticide and herbicide use (Colding et al. 2009; Rodewald et al. 2005), but tend to have large expanses of open, grassy habitat that may be appropriate for nesting. In this study, we examined nest-site selection of painted turtles (*Chrysemys picta*) inhabiting a golf course pond. We also investigated the effects of pond type and distance from pond edge on depredation rates of simulated turtle nests. Evaluating these two important aspects of the reproductive ecology of semi-aquatic turtles is critical in assessing the suitability of golf courses for turtle reproduction.

## Study area

*Description of study sites* We investigated nest-site selection at a pond (8,593 m<sup>2</sup>) at River Run Country Club (RRCC) in Davidson, North Carolina, USA (UTM E 0517853, UTM N 3924783; Fig. 1). The pond sampled at RRCC contained substantial emergent vegetation and was surrounded on three sides by open area (fairways) and on the fourth side by forested habitat. Active golfing occurred along two sides of the pond and mowing frequently took place along three sides throughout the study (May to July).

We evaluated nest depredation using simulated nests at nine different ponds near Davidson, North Carolina. Three of these ponds were located in urban areas, three on golf courses, and three on farms or properties in rural areas. We defined urban ponds as ponds surrounded by houses, businesses, or other developed land. Golf course ponds were located on active golf courses and generally experienced frequent human activity. Farm ponds were located in or near pastures or agricultural grounds, some of which contained cattle and/or other livestock. Surface area at urban ponds ranged from 11,124 m<sup>2</sup> to 81,311 m<sup>2</sup>; at golf course ponds from 7,583 m<sup>2</sup> to 8,903 m<sup>2</sup>; and at rural ponds from 3,285 m<sup>2</sup> to 15,356 m<sup>2</sup>.



**Fig. 1** Study site location in Davidson, North Carolina, USA with aerial image depicting nesting sites (*light circles*) chosen by female eastern painted turtles at River Run Country Club Golf Course. Random points (*dark circles*) were generated within an 85 m buffer zone of the edge of the pond and were compared to actual nest-site points using paired logistic regression

## Methods

**Study species** To investigate turtle nesting behavior, we focused on semi-aquatic *C. picta*. The nesting period for *C. picta* generally begins in late May and concludes in July (Baldwin et al. 2004; Ernst 1971; Gibbons and Greene 1990; Trauth et al. 2004) and nesting activity tends to take place in early morning, late afternoon, or early evening (Congdon and Gatten 1989; Ernst and Lovich 2009; Rowe et al. 2005).

**Collection methods** We used ten hoop-net traps (model MHNIA, 2.54 cm mesh, Memphis Net and Twine, Memphis, TN) baited with sardines to capture female turtles at RRCC (Fig. 1). Traps were checked every other day for 10 days (24 May through 3 June 2010), and re-baited every 4 days, using the methods described in Failey et al. (2007). We scanned captured female *C. picta* with digital X-ray to determine egg presence. Fourteen gravid females were assigned individual radiotransmitters (model BD-2; Holohil Ltd., Carp, Ontario, Canada); transmitters were encased in plastic tool-dip prior to application of epoxy to ensure they were waterproof (Grayson and Dorcas 2004).

*Determining nest-site selection* Gravid females were returned to the pond with transmitters attached on 24 May 2010, at which time intensive radio-tracking began and continued twice daily through 30 June 2010. Morning and evening tracking occurred between 0700 and 0900 and 1800 and 2000, respectively. Initial turtle observations during tracking included location, either within the pond or surrounding terrestrial habitat. If a female was in the surrounding terrestrial areas, she was immediately followed to her location, and if nesting behaviors were in progress (i.e., release of water from the cloaca, digging, oviposition), the location was considered a nesting site. Turtles were approached slowly and quietly to minimize disturbance to nesting behavior. For each nesting site, we recorded location (Universal Transverse Mercator [UTM] coordinates) using a handheld global positioning system (GPS, approx. 5 m accuracy) and visually determined percentages of vegetation cover types within a 0.5 m radius of the nest (see Kolbe and Janzen 2002). Vegetation cover types included percentages of 1) mulched cover, 2) mowed rough grass (grassy areas of the golf course that were maintained weekly), 3) wetland vegetation (emergent vegetation from the pond), 4) natural vegetation (unmowed grass, weedy and/or leafy cover), 5) bare ground (such as sidewalks, sandpits, and pavement), and 6) green (short, heavily-mowed—daily or every other day—turf that is in-play). If present, canopy cover was measured using a spherical densiometer. We supplemented our radiotelemetry data by conducting intensive visual searches of the open areas around the pond at the beginning and end of the tracking periods each day. We recorded locations and habitat information of all non-radio telemetered females found performing nesting behaviors.

To determine nest-site selection, we compared percentages of vegetation cover types of turtle nesting locations with characteristics of 37 random points located within an 85-m buffer zone of the pond edge (representing the mean nesting distance of *C. picta*, see Ernst and Lovich 2009). Random points were generated with a geographic information system (GIS; ArcGIS, version 9.2, ESRI, Redlands, California).

*Data analysis for nest-site selection* We used paired logistic regression (SAS 9.2; SAS Institute 2002) to establish that nest-site selection was non-random within the available habitat of the 85 m buffer zone. To avoid bias from individual female preference in our results, we excluded known repeated nesting events from analysis (i.e., only used one nesting event—the first recorded—per female). Based on the available cover types we determined were available at the golf course, we assessed paired logistic regression models for nest-site selection using AIC (Akaike Information Criterion; Akaike 1973) with values corrected for small sample sizes (AICc, Burnham and Anderson 1998). We standardized the covariates to reduce the bias of extreme values, such that each value was related to the mean (using z-scores, found by subtracting the average score from the raw covariate score and dividing that value by the standard deviation, see Donovan and Hines 2007). The following seven nest-site covariates were used: percentage of mulch, mowed rough grass, wetland vegetation, natural vegetation, bare ground, green, and canopy cover.

We established four candidate models to evaluate the strength of the covariates for nest-site selection based on “landscaped”, “golf”, “natural”, and “canopy” cover types. We condensed the original seven variables to evaluate selection of nest-sites by females from the modeling. Thus, the “landscaped” model consisted of mulch cover and mowed rough grass, “golf” consisted of green and bare ground, “natural” consisted of wetland and natural vegetation, and “canopy” consisted of canopy cover as measured by the spherical densiometer. Models with the highest Akaike weight ( $w$ ) best support the data, and this criterion was used to determine probable models for nest-site selection. We determined the significance of individual parameters using 95% confidence intervals.

**Nest depredation study** We investigated nest depredation using simulated turtle nests at nine study sites in the Davidson area (three each at farm, urban, and golf course ponds).

Fourteen artificial nests were constructed at two spatial scales around ponds: seven nests in a zone 0–5 m from the pond's edge, and seven nests in a zone 80–100 m from the pond's edge (Ernst and Lovich 2009). Random location points for nests within the two zones were determined using GIS. Selection for random points was limited to only open areas (i.e. not in brush patches, tall grass, or within clumps of trees), since turtles primarily choose open ground for nests (Baldwin et al. 2004; Christens and Bider 1987; Janzen 1994; Mitchell 1988; Rowe et al. 2005; Shepard et al. 2008). We used a trowel to dig a chamber for two bobwhite quail eggs (purchased from Turnbull Farms, Clear Creek, Indiana), covered the eggs with the excavated soil, and poured approximately 250 mL of scented water (from a captive *C. picta* tank) over the nest to mimic the release of bladder water by the female at the time of nesting (see Marchand and Litvaitis 2004). Nests were then marked by flagging tape placed approximately 1 m from nest to avoid predator and human association of flags with nest sites (Tuberville and Burke 1994). Simulated nests were checked every other day for fourteen days; egg removal and signs of possible nest disturbance were recorded.

**Data analysis for nest depredation** We used nest survivorship modeling in program MARK (ver 6.0, White and Burnham 1999) to assess survivorship rates and the power of contributing factors to nest survivorship. Because nests began on different days over a period of three weeks, we did not assess time dependency of nest survivorship. Rather, we analyzed the effects of pond type and distance to pond edge (and the two factors combined) on the survival of the nests and compared the models using AICc values and Akaike weights ( $w$ ). We selected models for nest survivorship based on the lowest AICc value and highest weight.

## Results

**Nesting activity** From 24 May to 30 June 2010, 13 out of 14 females with attached transmitters emerged from the pond to nest (one female's signal was lost completely, either because of transmitter error or long-distance migration from the pond site). Five of the 13 females were recorded during multiple nesting forays, for a total of 13 repeated nesting events. Additionally, we recorded 24 nesting events from non-radio telemetered turtles. In total, we recorded 37 independent nesting events, and the majority of nesting forays involved turtles crossing through emergent vegetation and rough grass into landscaped areas near the pond edge (Fig. 1). Distance traveled to a nest-site ranged from 1 to 115 m and averaged 36 m (SE=4.70); the minimum distance traveled (1 m) was seen in 6 of the 37 separate nesting events. Mulch cover represented the greatest percentage of ground cover type at nests (Table 1).

**Nest-site selection** The candidate model with the highest Akaike weight (Table 2) consisted of “landscaped” cover type ( $w=0.97$ ), and its parameters had positive estimates of  $\beta=0.0475$  for mulch (95% CI 0.0228–0.0722) and  $\beta=0.0171$  for mowed grass (95% CI 0.0035–0.0307). We found little support for the “golf” ( $w=0.03$ ; green parameter estimate  $\beta=-0.1375$ , 95% CI -4.3027–4.0277; bare parameter estimate  $\beta=-0.0216$ , 95% CI -0.0490–0.0058), “natural” ( $w=2.95E-05$ ; natural vegetation parameter estimate  $\beta=-0.0149$ , 95% CI -0.0313–0.0015; wetland vegetation parameter estimate  $\beta=0.023$ , 95% CI -0.0070–0.0530) or “canopy cover” ( $w=1.07E-05$ ;  $\beta=0.0107$ , 95% CI -0.0002–0.0216) models.

**Table 1** Average percentages of cover type in 0.50 m radius of nest-site

Cover type	Average%	Min%	Max%	Standard deviation
Mulch	40.95	0.00	100.00	17.03
Natural vegetation	7.70	0.00	100.00	40.32
Mowed rough	35.41	0.00	100.00	43.32
Green	0.00	0.00	0.00	47.46
Wetland vegetation	12.16	0.00	75.00	16.44
Bare ground	3.78	0.00	80.00	22.05
Canopy	54.29	0.00	98.96	45.58

**Nest depredation** Of the 126 nests we placed at the nine ponds, 46 were depredated (~37%) within the 2-week observation period. We found equal support for the simulated nest survival candidate models, evidenced by their AICc values (Table 3); the best supported model incorporated only pond type (golf course, urban, or rural;  $w=0.31$ ) and the next best incorporated constant survival ( $w=0.27$ ). The daily survival rate of the simulated nests did not vary greatly among pond types (Table 3); at golf courses survivorship was 92.72% (SE=0.017), and at urban and rural ponds survivorship was 96.39% (SE=0.011) and 93.02% (SE=0.016), respectively. Constant survivorship was estimated at 94.12% (SE=0.008). We found less support for models that included pond type plus distance, or distance alone, on predation rates (Table 3). The average depredation across all pond types was 2.32 (SE=0.259) nests for those placed within 0–5 m from the pond edge and 1.49 (SE=0.194) nests for those placed within 80–100 m of the edge. Survival of nests placed within 0–5 m of the pond's edge was 93.10% (SE=0.013) whereas survival of nests 80–100 m from the edge was estimated at 95.06% (SE=0.011).

## Discussion

Our results showed that painted turtles at RRCC selected mulched or rough locations to nest, and that other habitats such as greens, sidewalks, fairways, and sandpits associated with heavy anthropogenic use were avoided. Mulch is commonly used as a landscaping element to increase soil temperature and conserve soil moisture (Ramakrishna et al. 2006), and these properties may have influenced female turtles to select mulched locations for nesting. Previous studies have shown that nesting females tend to choose nest-sites that are warm enough to ensure nest success (Schwarzkopf and Brooks 1987) and that have sufficient drainage of the nest (Ernst and Lovich 2009). Additionally, nests placed in soils that are too

**Table 2** Nest-site selection of female eastern painted turtles using paired logistic regression and AICc values. Models with the lowest AICc values and highest Akaike weights ( $w$ ) were selected as the best-supported models

MODEL	# Parameters	AICc	$\Delta$ AICc	Akaike weight
Landscape (mulch/mowed grass)	3	80.11	0.00	0.97
Golf (green/bare)	3	87.26	7.15	0.03
Natural (natural vegetation/wetland)	3	100.91	20.81	2.95E-05
Canopy	2	102.94	22.84	1.07E-05

**Table 3** Nest survivorship models of simulated nests using  $AIC_c$  values. S(Pond Type) is survivorship according to pond type (golf course, urban, rural); S(Constant) is constant survivorship; S(Pond Type + Distance) is survivorship by pond type and distance of nest from pond edge; S(Distance) is survivorship according to distance of nest from pond edge. Those models with the lowest  $AIC_c$  values and highest Akaike weights ( $w$ ) garnered the greatest support

Model	# Parameters	$AIC_c$	$\Delta AIC_c$	Akaike weight
S(Pond Type)	3	213.45	0.00	0.31
S(Constant)	1	213.71	0.26	0.27
S(Pond Type + Distance)	4	214.09	0.63	0.23
S(Distance)	2	214.38	0.93	0.19

dry can desiccate and result in decreased hatching success (Cagle et al. 1993). Although we did not measure nest temperature or moisture levels in our study, moist soil, such as that found under mulch, can be easily manipulated by the turtle's hindlimbs during the construction of the nest's funnel (Ernst and Lovich 2009). On the other hand, human disturbance of mulched areas is relatively infrequent as opposed to the high disturbance of the golf course property whether from pedestrians (players and maintenance workers), golf carts traversing the green or sidewalks, or lawnmowers and other machines maintaining the turf. Thus, the infrequent disturbances to the landscaped areas of the course may have resulted in females choosing these areas to nest.

Our modeling of nest depredation through the use of artificial nests demonstrated that depredation of nests on golf courses is no greater than at other pond types. Our overall depredation rate was 38%, with 56% of depredation rates occurring during the first 48 h of artificial nest creation. Christens and Bider (1987) found that heavy predation by raccoons destroyed ~44% of natural painted turtle nests in their study, with nearly 86% of the depredation occurring on the night the eggs were laid. Tinkle et al. (1981) also found that ~20% of painted turtle nests in their study were destroyed by predation within the 48 h time frame following egg deposition. We also found that distance from pond did not significantly affect depredation rates. Conversely, both Legler (1954) and Marchand et al. (2002) found that nests close to the pond were more likely to be depredated than far nests.

Few studies have investigated nest depredation at different pond types. However, Gering and Blair (1999) suggest that predatory relaxation in urban environments (such as housing developments) may be accountable for decreased predation pressures on artificial avian nests. Gering and Blair (1999) found that natural areas (such as preserves or state parks) tended to have higher nest depredation rates, possibly due to more abundant forested land fragments which support greater predator numbers. Other studies have indicated that urban habitats may subsidize certain predators (Prange et al. 2004; Wilcove 1985). However, we found no difference in nest survivorship between pond sites, which may be attributed to similar predator densities at our locations.

Our depredation rates assume that the use of simulated nests is an accurate reflection of depredation rates on accurate nests. Several studies have indicated the utility of simulated nests for modeling nest survival (e.g. Gering and Blair 1999; Nour et al. 1993; Marchand et al. 2002). Wilhoft et al. (1979) found that even in the absence of olfactory or visual cues, predators (particularly raccoons) willingly predated decoy nests built with chicken, dove, and snapping turtle eggs, and also with ping-pong balls. Thus, simulated nests represent a realistic tool for understanding the survivorship of semi-aquatic turtle nests.

Although our small sample size provides limited inference in terms of management of specific habitats for nesting turtles on golf courses, we recommend that golf course managers incorporate mulched open areas and rough, infrequently mowed grass areas in out-of-play locations. Because our study indicates that golf courses are not necessarily high-risk depredation sites, and because evidence suggests that females prefer to nest close to the pond if abundant nesting habitat is available (Baldwin et al. 2004), offering mulched habitat close to the pond's edge may minimize predation risks to hatchlings and traveling females, and may benefit resident turtle populations. Successful nesting and hatching can contribute to juvenile recruitment and the persistence of the species, providing aesthetic benefits to golfers and ecosystem services in urban environment. Based on our findings, we feel that golf course ponds should be regarded as adequate and potentially important habitat for nesting turtles in urban environments, although studies addressing water quality, juvenile and adult survival and recruitment, and effects of herbicides and pesticides are needed to fully evaluate the suitability of golf courses as turtle habitat.

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