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Ecology of Turtles Inhabiting Golf Course and Farm Ponds in the Western Piedmont of North Carolina

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Abstract: Both agricultural land and golf courses represent prevalent forms of land alteration in many areas, but may offer habitat to some animals in areas of high urbanization. Our understanding of animal ecology in such modified habitats is limited. A comparative ecology study of turtles inhabiting five golf course and five farm ponds was conducted in the western Piedmont of North Carolina. Relative species diversity, species abundance, size distribution, body condition and sex ratios were assessed between pond types. The relationship between surrounding habitat within a 500-m radius of each pond and pond size on turtle abundances was examined. Painted turtles ($N = 248$) (*Chrysemys picta*), 43 common snapping turtles (*Chelydra serpentina*), 86 yellowbelly sliders (*Trachemys scripta*) and 28 eastern mud turtles (*Kinosternon subrubrum*) were captured. Relative species abundances, size distributions for each sex and sex ratios were not distinguishable between the two pond types. More *K. subrubrum* were captured when roads were located farther from ponds ($p = 0.05$), more *C. picta* were captured in ponds with a higher percentage of surrounding unforested habitat ($p < 0.05$), and more *C. serpentina* and *C. picta* were captured in larger ponds ($p = 0.01$ and $p = 0.05$, respectively). *Chrysemys picta* from golf course ponds had higher condition indices than those from farm ponds ($p < 0.001$). In this region, both farm and golf course ponds can provide habitat for several species of semi-aquatic turtles and for some species, the characteristics of the surrounding landscape may be more influential to species abundances than specific pond type.

Key Words: Turtle ecology; Farm pond; Golf course pond; Anthropogenic habitats.

INTRODUCTION

Many animals persist and thrive in habitats directly impacted by human activities (Meffe and Carroll 1997; Lindsay and Dorcas 2001); however, landscape alterations created through urbanization and agriculture result in substantial decreases in habitat suitable for many animals. Urbanization can result in fragmentation of many animal populations into smaller less viable ones (McKinney 2002) and introduce new hazards such as roads (Forman and Heanue 2002) and railroads (Kornilev et al. 2006), which can cause direct mortality. Activities in agricultural lands, such as cattle grazing and farming in and around aquatic habitats, may alter water quality (Lindsay and Dorcas 2001; Mallin et al. 2002; Knutson et al. 2004), sometimes resulting in eutrophication (Knight and Gibbons 1968; Tesauro 2001).

Golf courses and agricultural lands represent a major form of anthropogenic habitat modification. Construction of golf courses both physically and biologically modifies landscapes (Forman and Godron 1986; Love 1999). However, properly designed and managed golf courses can provide habitat for wildlife species including birds (Stanback and Seifert 2005) and a number of amphibian species (Scott et al. 2003). Semi-aquatic turtles also frequently inhabit ponds and other water bodies on golf courses, especially when natural wetlands and ponds have been destroyed or modified. Similar to golf course ponds, farm ponds can provide habitat for various wildlife species (Davis and Mumford 1962; Hartke and Hepp 2004; Knutson et al. 2004; Nemjo 1990).

In this study, semi-aquatic turtle populations inhabiting farm and golf course ponds were compared. Specifically, (1) relative abundances of species and species richness in both habitats, (2) size distribution between sex and pond type, (3) turtle body condition between sex and pond type, (4) sex ratios of species between pond types and, (5) the effects of surrounding habitat and pond size on abundances were assessed.

MATERIALS AND METHOD

Study Sites

A mark-recapture study of semi-aquatic turtles was conducted at 10 ponds in Mecklenburg, Iredell and Cabarrus Counties, North Carolina from 17 April to 28 July 2005. Five ponds were sampled on golf courses surrounded predominantly by residential neighborhoods, mixed hardwood forests, and golf course fairways. In addition, five man-made farm ponds surrounded mostly by open pasture, forest and/or residential neighborhoods were sampled. Ponds ranged in size from 0.03 to 1.02 ha and all were constructed at least 10 yr before our study.

Capturing and Processing Turtles

Turtles were captured using hoop-net traps (model MHNIA, 2.54 cm mesh, Memphis Net and Twine, Memphis, TN) baited with sardines. Ten baited traps were set in shallow water at standard intervals around the perimeter of each pond. Bait (one can of sardines per trap) was replaced every 4 or 5 days. Each time traps were checked, all turtles were removed and returned to the laboratory for measurements and marking. Recaptured turtles were recorded and released. All turtles held in the lab were returned to their resident pond within two days of capture. Traps were checked every two days for a total of 20 days at which point the number of new turtles captured in the traps of each pond approached zero (Lindsay and Dorcas 2001).

All captured turtles were permanently marked by filing a unique three-letter code in the marginal scutes (Sexton 1959). Digital calipers were used to measure the straight-line carapace and plastron lengths (CL and PL, respectively), and the maximum shell width and depth (to the nearest 0.1 mm) for all newly captured turtles. Shell dimensions exceeding 150 mm were recorded with larger calipers to the nearest 1 mm. The sex of adult painted turtles (*Chrysemys picta*), yellowbelly sliders (*Trachemys scripta*) and river cooters (*Pseudemys concinna*) was determined by examining the foreclaw length, shell shape, and tail length and thickness (Ernst et al. 1994). The sex of adult eastern mud turtles (*Kinosternon subrubrum*) and stinkpots

(*Sternotherus odoratus*) was determined using tail length and plastron size and shape (Ernst et al. 1994). The formula described by Mosimann and Bider (1960) was used to determine sex of snapping turtles (*Chelydra serpentina*). If a turtle was too young to exhibit sufficient secondary sexual characteristics for gender determination (e.g., juveniles), it was categorized as ‘‘unable to sex.’’

A top loading balance was used to weigh all turtles (to the nearest 0.1 g; except adult *C. serpentina*). Adult *C. serpentina* were weighed using a spring scale (to the nearest 0.1 kg). Each turtle was examined for any distinguishing features such as shell damage or missing limbs. Such abnormalities were recorded to assist in future identification. A digital camera was used to photograph the carapace and plastron to help identify the individual in the future.

Data and Habitat Analyses

To assess differences in species abundance between farm ponds and golf course ponds, a measure of similarity was used (Bray and Curtis 1957). A chi-square test was used to determine the effects of pond type on relative species abundance. *Chrysemys picta*, *C. serpentina* and *T. scripta* were grouped into size categories (PL for *C. picta* and *T. scripta* and CL for *C. serpentina*; Lindsay and Dorcas 2001) and tested for effects of pond type on male and female size distributions using chi-square tests. Size groupings were also used to determine the modal size in both habitat types. Insufficient data were collected to perform a statistical analysis for male *T. scripta* size distributions.

To assess turtle body condition, the residuals of a linear regression with mass as the dependent variable and the straight-line PL as the independent variable were calculated for *C. picta* and *T. scripta* (Budischak et al. 2006). Straight-line CL was used as the independent variable for *C. serpentina* because plastron length varies more with body size (Lindsay and Dorcas 2001). These residuals were then used as the dependent variables in a two-way ANOVA to analyze the effects of sex and pond type on body condition (SAS ver 9.1, SAS, Cary, NC USA). A contingency analysis was performed using JMP (ver 5.1, SAS, Cary, NC USA) to examine the effects of pond type on sex ratios for *C. picta*, *C. serpentina* and *T. scripta*.

A geographical information system (GIS; ArcGIS 9.0, ESRI, Redlands, California USA) was used to quantify the habitat within a 500-m radius buffer surrounding each pond (Baldwin et al. 2004). Surrounding habitat was classified as either open pasture, forest (areas where trees occupy a minimum of 1 ha), residential, golf course (the fairway and rough), or powerline right-of-way using color aerial photographs (0.5 m resolution; taken during 2002). Distance to the nearest road was measured (to the nearest 1 m) within a 500-m radius using the aerial photograph. Linear regression analysis was used to examine the relationship between distance to the nearest road and *C. picta, C. serpentina* and *T. scripta* sex ratios. Linear regression analysis was also used to examine the effects of distance to nearest road on turtle abundances of *C. picta, C. serpentina, T. scripta* and *K. subrubrum*.

Linear regressions were used to assess the effects of unforested areas (combined values of pasture, powerline right-of-way and golf course) on the number of *C. picta, C. serpentina, T. scripta* and *K. subrubrum* captured because these species prefer to nest in open, unforested areas near the water (Ernst et al. 1994) and because *K. subrubrum* typically overwinter in terrestrial, forested environments (Gibbons 1983).

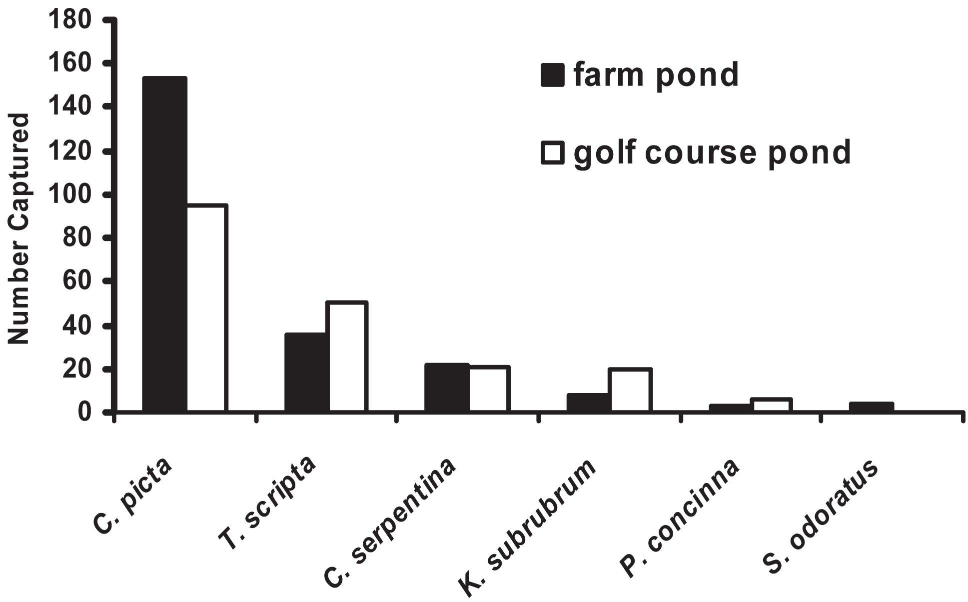

FIG. 1. Relative abundances of *C. picta*, *C. serpentina, T. scripta*, *K. subrubrum*, *P. concinna* and *S. odoratus* in ten ponds located in the Piedmont of North Carolina captured from 17 April to 28 July 2005. Both habitat types had similar species composition (Bray Curtis = 0.04). Species abundances for *C. picta, C. serpentina, T. scripta* and *K. subrubrum* differed between habitats ($X^2 = 18.44$, df = 3, $p < 0.001$).

Each pond's area was calculated (to the nearest 0.01 ha) and analyzed to determine the relationship between pond area and abundance of *C. picta, C. serpentina, T. scripta* and *K. subrubrum* using linear regression. An alpha of 0.05 was used for all analyses.

RESULTS

Relative Abundances

A total of 418 individual turtles, representing six species, were captured and processed during the study period (Fig. 1). *Chrysemys picta* was the most commonly captured species (n = 248), followed by *T. scripta* (n = 86), *C. serpentina* (n = 43) and *K. subrubrum* (n = 28). *Pseudemys concinna* was captured in low abundances at three ponds, and *S. odoratus* was only captured at one of the farm ponds; thus, these two species were not used in any statistical analyses. Golf course and farm ponds were similar in species composition (Bray Curtis p = 0.04); however, the relative abundances of *C. picta, C. serpentina, T. scripta* and *K. subrubrum* were different in farm and golf course ponds ($X^2 = 18.44$, df = 3, $p < 0.001$). *Chrysemys picta* comprised a higher proportion of total captures in farm ponds (67.7%) than in golf course ponds (49.5%). *Chelydra serpentina* composed 9.7% of total turtle captures in farm ponds and 10.9% in golf course ponds. *Trachemys scripta* and *K. subrubrum* were found in greater abundances in golf course ponds than in farm ponds (*T. scripta* 26.0% and 15.9%; *K. subrubrum* 10.4% and 3.5% respectively).

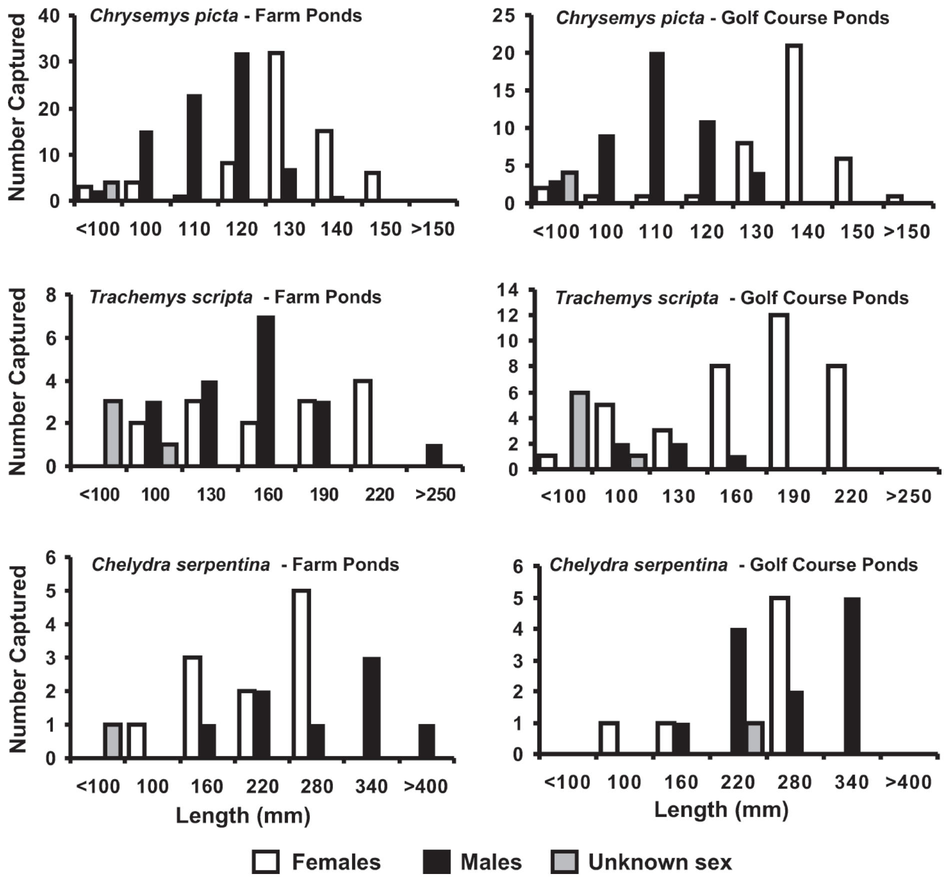

FIG. 2. Size distributions of *C. picta* and *T. scripta* (plastron length) and *C. serpentina* (carapace length). The sub-adult category includes unsexed juveniles. More large *C. picta* females were found in golf course ponds than in farm ponds ($X^2 = 15.09$, df = 3, $p < 0.001$).

Size Distributions

More large (modal PL = 140.0 mm) *C. picta* females were captured in golf course than in farm ponds (modal PL = 130.0 mm; $X^2 = 15.09$, df = 3, $p < 0.001$; Fig. 2). No significant differences were found in size distributions between pond types for male *C. picta* ($X^2 = 4.38$, df = 3, p = 0.22), although we found the modal PL for males in farm ponds (120.0 mm) was greater than in golf course ponds (110.0 mm; Fig. 2). There was no difference in size distributions between pond types for *C. serpentina* males ($X^2 = 0.14$, df = 1, p = 0.71) or females ($X^2 = 0.12$, df = 1, p = 0.73; Fig. 2). *Chelydra serpentina* from both farm and golf course ponds had the same modal PL values for females (280-340 mm) and males (340-400 mm). The modal PL for female *T. scripta* inhabiting farm ponds (220-250 mm) was greater than in golf course ponds (190-220 mm). Overall, a similar size distribution was noted in both habitats for female *T. scripta* ($X^2 = 0.84$, df = 2, p = 0.66; Fig. 2); however, we found more females with PL values > 190 mm in golf course ponds (20 individuals compared to 7 in farm ponds). Although sufficient data were lacking to conduct a chi-square analysis, more large male *T. scripta* were captured in farm

Table 1. Percent composition of habitat within a 500-m buffered radius of all 10 ponds. The first five ponds listed are farm ponds and the last five are golf course ponds. Open area analysis combined pasture, golf course and power line values to assess the affect on turtle abundances. Asterisks (*) indicate the nearest road was located within a housing subdivision because no state road passed within a 500-m radius of the pond.

Pond	Pond (ha)	Forest (%)	Residential (%)	Pasture (%)	Golf Course (%)	Power Line (%)	Total Road Length (m)
RP 1	0.52	17.85	30.58	51.58	0	2.51	127
RP 2	0.32	24.03	33.95	42.02	0	1.97	213
CH	0.39	59.96	3.30	36.74	0	0	467
GR	0.03	18.03	22.00	59.97	0	1.53	196
GG	1.02	0	28.34	71.66	0	0	195
MH 1	0.23	15.40	45.51	26.56	12.52	0	194
MH 2	0.87	24.28	35.46	16.12	24.14	0	446
NS	0.74	0	57.36	8.75	33.90	0	250
RR 1	0.13	28.16	21.33	22.06	28.45	1.38	32 *
RR 2	0.27	47.85	27.85	5.51	18.80	0	57 *

ponds (modal PL size = 160 – 190 mm) than in golf course ponds where all male *T. scripta* PL values were < 190 mm.

Body Condition

Chrysemys picta captured in golf course ponds had higher condition indices than *C. picta* in farm ponds ($F = 11.22$, $df = 3$, $p < 0.001$). Male and female *C. picta* had similar body condition ($F = 0.05$, $df = 3$, $p = 0.82$). Neither pond type ($F = 0.33$, $df = 3$, $p = 0.57$) nor sex ($F = 0.01$, $df = 3$, $p = 0.91$) affected *C. serpentina* body condition. Similar *T. scripta* body condition values were found in both farm and golf course ponds ($F = 1.19$, $df = 3$, $p = 0.28$). *Trachemys scripta* body condition did not vary between sexes ($F = 0.34$, $df = 3$, $p = 0.562$).

Sex Ratio

The male:female sex ratio for *C. picta* in farm ponds and golf course ponds was 1.16:1 and 0.90:1, respectively. A sex ratio of 0.8:1 was found for *C. serpentina* in farm ponds and a 1.71:1 male:female sex ratio in golf course ponds. Statistical assessment of *C. picta* and *C. serpentina* sex ratios revealed no differences between pond types ($X^2 = 0.80$, $df = 1$, $p = 0.37$ and $X^2 = 1.30$, $df = 1$, $p = 0.25$, respectively). Fewer male *T. scripta* were captured in proportion to females in golf course ponds (0.13:1) compared to farm ponds where we found a 1.29:1 male to female sex ratio. Contingency analysis of *T. scripta* revealed a significant effect of pond type on the sex ratio ($X^2 = 17.18$, $df = 1$, $p < 0.001$).

Habitat Analysis

Land-use composition within a 500-m radius of our study ponds was variable, however all ponds had significant portions of surrounding landscape in anthropogenic land-use (Table 1). The distance to the nearest road did not significantly affect capture numbers for *C. picta* (linear regression; $R^2 = 0.02$, $p = 0.73$), *C. serpentina* ($R^2 = 0.13$, $p = 0.31$), or

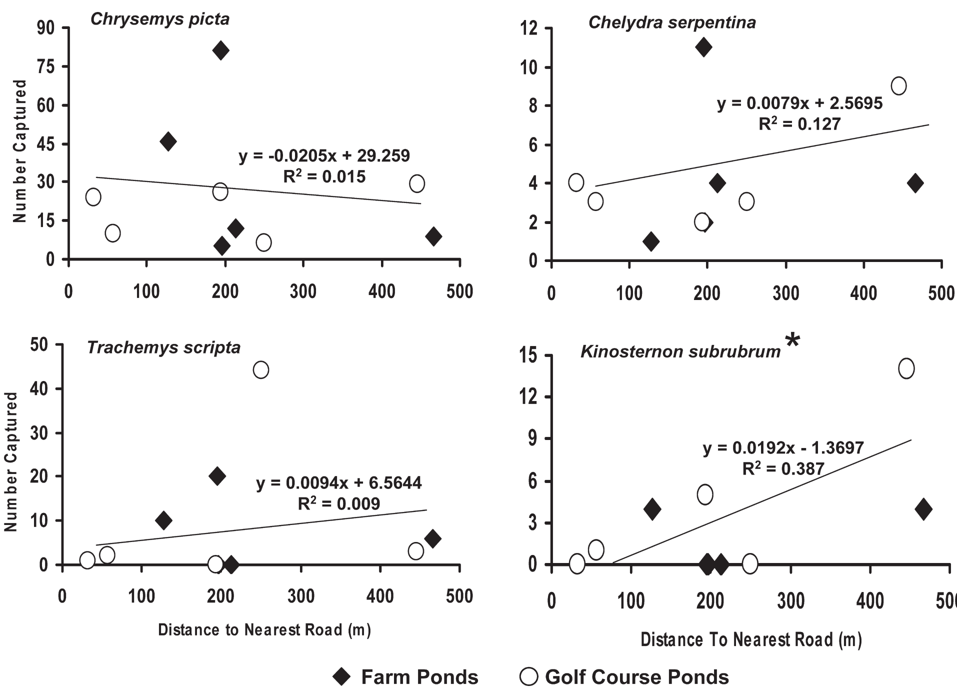

FIG. 3. Number of *C. picta, C. serpentina, T. scripta* and *K. subrubrum* captured with varying distances (m) to the nearest road. Distance to nearest road was positively related to *K. subrubrum* abundances (R^2 = 0.39, p = 0.05). Asterisk (*) indicates significance.

T. scripta (R^2 = 0.01, p = 0.79; Fig. 3). *Kinosternon subrubrum* captures declined as the distance from the pond to the nearest road decreased (R^2 = 0.39, p = 0.05; Fig. 3). More *C. picta* were found as the amount of open space within a 500-m buffer radius increased (R^2 = 0.40, p = 0.05; Fig. 4). We found no relationship between the amount of unforested area surrounding a pond on the abundances of *C. serpentina* (R^2 = 0.12, p = 0.34), *T. scripta* (R^2 = 0.03, p = 0.64), or *K. subrubrum* (R^2 = 0.09, p = 0.41; Fig. 4).

The fewest turtles (7 individuals and 2 species) were captured in our smallest pond (0.03 ha) and the most turtles and turtle species (119 individuals and 5 species) in our largest pond (1.02 ha; Fig. 5). A positive relationship was found between pond area and the numbers of *C. picta* (R^2 = 0.39, p = 0.05; Fig. 5) and *T. scripta* captured (R^2 = 0.37, p = 0.06). A greater number of *C. serpentina* were trapped in larger ponds (R^2 = 0.55, p = 0.01; Fig. 5), but no relationship was found between *K. subrubrum* abundance and pond area (R^2 = 0.12, p = 0.32).

DISCUSSION

Many turtles inhabit water bodies in human-modified landscapes, including farm ponds and golf course ponds, which now serve as the primary habitats for semi-aquatic turtles in most of the Piedmont of North Carolina (Lindsay and Dorcas 2001. This study confirms that both farm ponds and golf course ponds appear to provide suitable habitat for several turtle species in this region.

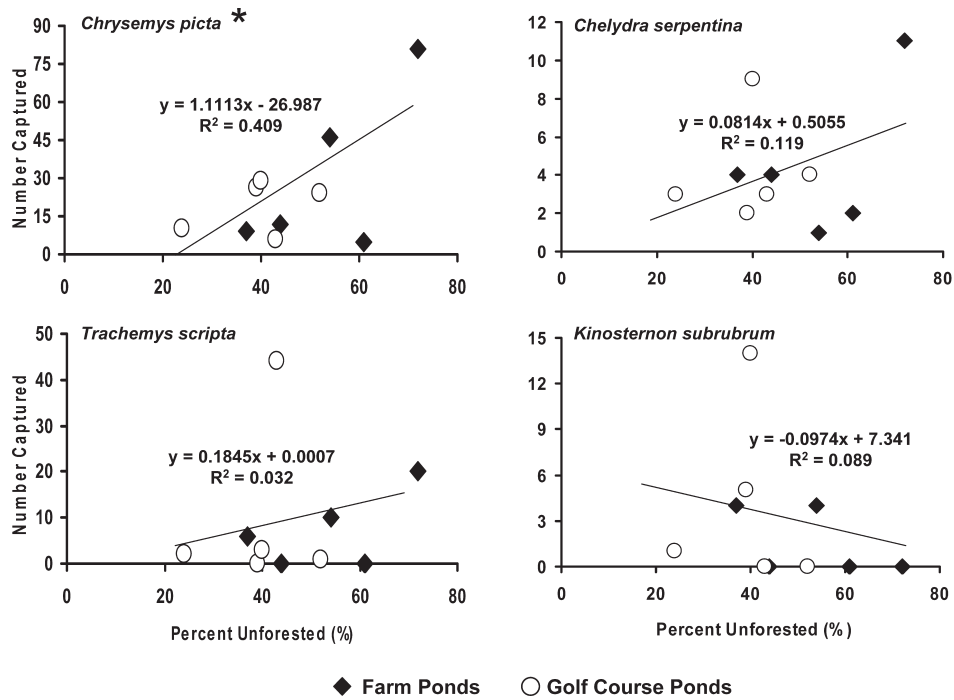

FIG. 4. Effects of unforested area within a 500-m radius of each pond on the number of *C. picta, C. serpentina, T. scripta* and *K. subrubrum* captured. *Chrysemys picta* were found in greatest abundance in ponds surrounded by large amounts of unforested area (R^2 = 0.40, p = 0.05). Asterisk (*) indicates significance.

In this study, *C. picta, C. serpentina, T. scripta* and, to a lesser extent, *K. subrubrum* were ubiquitous compared to *P. concinna* and *S. odoratus*. Previous studies showed *C. picta* to be the most abundant turtle species in many parts of the North Carolina Piedmont (Lindsay and Dorcas 2001) and *C. serpentina, T. scripta* and *K. subrubrum* are prominent members of lentic turtle assemblages in the Southeastern United States (Stone et al. 1993; Lindsay and Dorcas 2001). Like Stone et al. (2005), *P. concinna* were found in relatively low abundances, which is consistent with their habitat preference for larger, lotic habitats (Ernst et al. 1994). Most of the *P. concinna* captured in this study were in ponds located closer to larger water bodies (i.e., reservoirs). Similar to this study, other turtle studies have found *S. odoratus* in low abundances (Dreslik et al. 2005; Rizkalla and Swihart 2006), but in some regions they can be ubiquitous (Ernst et al. 1994).

Larger modal PL values were noted for male *C. picta* and both male and female *T. scripta* in farm ponds than in golf course ponds; however, larger sized *C. picta* females inhabited golf course ponds. Reasons for these size differences are elusive; however Gibbons (1967) found that turtle size correlated best with food quality rather than age because higher quality food (especially in the first few years of life) promotes increased growth rates resulting in larger adult sizes. Increased nutrient levels in human-modified landscapes may provide turtles with more abundant herbaceous food sources as a result of increased aquatic plant growth, a condition under which *C. picta* are known to thrive (Knight and Gibbons 1968). Conversely,

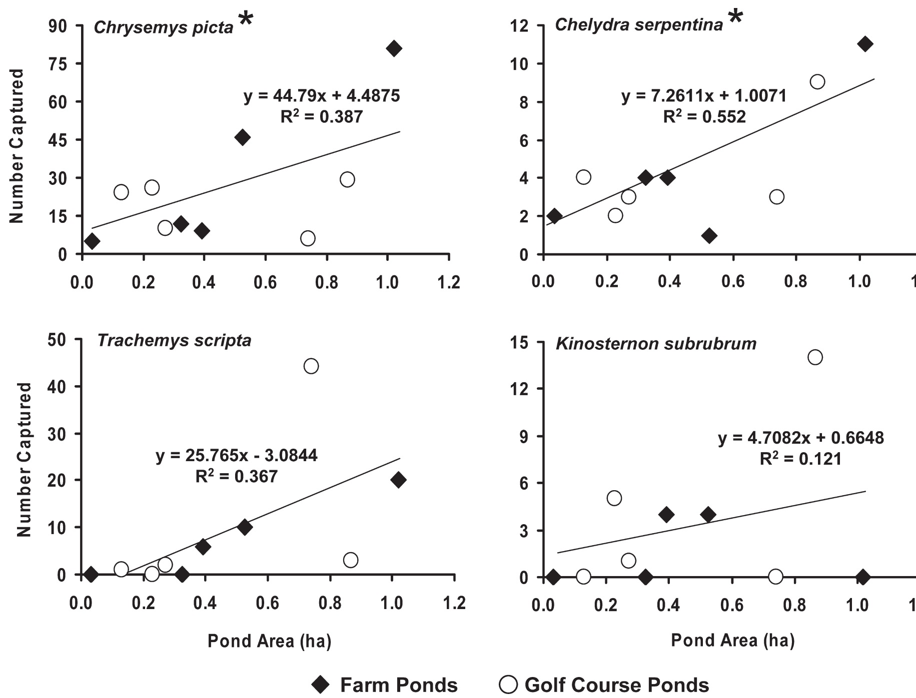

FIG. 5. The effects of pond area on capture numbers of *C. picta, C. serpentina, T. scripta* and *K. subrubrum.* Abundances of *C. picta* and *T. scripta* were marginally correlated with pond area ($R^2 = 0.39$, p = 0.05 and $R^2 = 0.37$, p = 0.06; respectively). *Chelydra serpentina* were found in greater abundances in larger ponds than in smaller ones ($R^2 = 0.55$, p = 0.01). Asterisks (*) indicates significance.

increased nutrient levels may limit food availability and type for some species (i.e., *K. subrubrum*; Lindsay and Dorcas 2001) because of the detrimental impact of decreased dissolved oxygen levels on certain aquatic invertebrate taxa (Hynes 1960). We suspect our golf course ponds had higher nutrient levels than the farm ponds we examined because of fertilization (Mallin et al. 2002); however, both pond types are likely susceptible to nutrient enrichment from agricultural fields, cattle, grass lawns and/or fairways.

This study revealed no significant differences in sex ratios between farm and golf course ponds for *C. picta* and *C. serpentina*. However, differences in sex ratios were found between pond types for *T. scripta*, with a female-biased sex ratio in golf course ponds. Areas with diminished forest cover typically create warmer nest temperatures resulting in female-biased hatchling sex ratios (Kolbe and Janzen 2002); this has potential ecological implications, particularly in golf course habitat, because of the frequent absence of cover. However, the overall sex ratio we report for *T. scripta* may be skewed because a large number of individuals came from one golf course pond where females were prevalent; this pond had no surrounding forest cover within the 500-m buffered radius (NS; Table 1).

High road densities may also bias sex ratios and subject turtle populations to road mortality because turtle life histories are characterized by late sexual maturity, low recruitment rates, high adult survival rates and nesting in upland habitats surrounding ponds (Baldwin et al. 2004; Marchand and Litvaitis 2004; Steen and

Gibbs 2004; Ernst et al. 1994). No effects of road density on *C. picta*, *T. scripta*, and *C. serpentina* abundances were found in this study. However, the results of this study revealed a decrease in *K. subrubrum* abundance as the distance between the pond and road decreased. *Kinosternon subrubrum* may be more susceptible to overall population declines in human-altered landscapes because both sexes of this species regularly migrate in the terrestrial habitat to overwinter, thus increasing their susceptibility to road mortality (Gibbons 1983; Harden and Dorcas *in press*).

Buhlmann and Gibbons (2001) suggested that the amount of surrounding forest cover is important for *K. subrubrum* and that this species tends to abandon refugia in open habitats. However, no correlation was found between the abundance of *K. subrubrum* and the amount of unforested habitat within a 500-m buffered radius surrounding the ponds. Yet, *K. subrubrum* were notably absent from both ponds (NS, GG; Table 1) that had no surrounding forested habitat, highlighting the potential importance of appropriate winter refugia for this species.

Turtles often benefit from some landscape alterations that maintain or increase open areas (Linck et al. 1989; Baldwin et al. 2004; Marchand and Litvaitis 2004; Rizkalla and Swihart 2006). Emydid turtles require upland habitat for nesting, and *C. picta* prefer open areas with loamy soil (Ernst et al. 1994). Similar to the findings in Rizkalla and Swihart (2006), a positive correlation was found in this study between *C. picta* abundance and the amount of open area surrounding our study ponds. Golf courses as well as the residential lawns in neighborhoods associated with the golf courses may provide additional nesting habitat for turtles in human-altered, suburban landscapes (Linck et al. 1989; Kolbe and Janzen 2002).

Abundances of *C. picta, C. serpentina, T. scripta* and *K. subrubrum* were positively correlated with pond area. Larger ponds may provide turtles with more resources, such as food and basking sites; however, Gibbs (1993) emphasized that small ponds are crucial for semi-aquatic turtle persistence in a landscape. Some species, such as *C. serpentina*, may benefit from larger ponds as a larger area may decrease aggressive interactions between turtles (Galbraith et al. 1987). Other species, such as *C. picta* may increase in abundance with the presence of organic substrate and abundant shoreline vegetation (Marchand and Litvaitis 2004); features that may be correlated with pond area. Thus, we suspect that pond specific features (e.g., substrate type, amount and location of vegetation), species interactions, as well as landscape composition may be better indicators of turtle abundance than pond area alone.

Urbanization in the Southeastern United States has greatly increased over the past 20 yrs (Griffith et al. 2003) and compounds threats to wildlife such as habitat loss, pollution, roads and deforestation (Czech et al. 2000; McKinney 2002). Habitat loss and fragmentation especially threaten turtles because they rely on high adult survivorship and migrations between and within habitats (Gibbs 1993). Both man-made farm ponds and golf courses represent a significant form of habitat alteration; however, both pond types may facilitate the survival of turtle populations in these human-altered landscapes. As natural wetlands continue to be lost because of urbanization, management of these man-made ponds will likely to be important for the persistence of semi-aquatic species.

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