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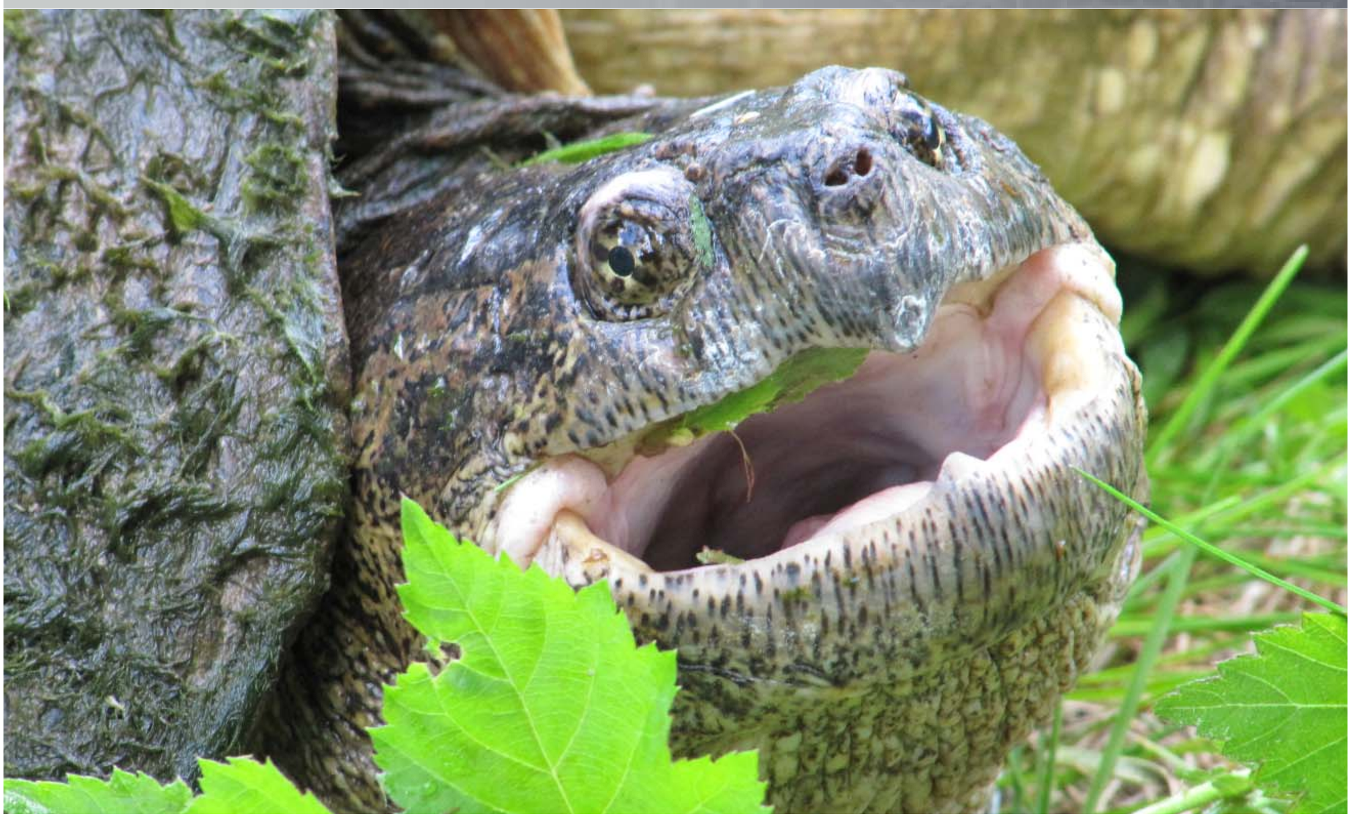

Nearly half of all turtle species are threatened or endangered (current assessments estimate 56% of freshwater turtle species), making them one of the most imperiled groups of vertebrates. Detailed assessment of turtle populations in golf course wetlands would improve our understanding of the potential conservation value of these wetlands for freshwater turtles and of turtle-habitat relationships that would permit development of guidelines to improve the quality of habitat that golf courses could provide. Researchers from Columbia University and the State University of New York contrasted populations of snapping turtles (*Chelydra serpentina,* shown above) and painted turtles (*Chrysemys picta*) among wetland habitats typical of urban areas, golf courses, and wildlife refuges over two years. Researchers concluded that wetlands of appropriate quality may act as refuges in disturbed landscapes, and golf courses may be especially appropriate for this function due to their low road densities and restricted access.

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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1921, the USGA has funded more than $40 million for research at universities. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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Golf Courses as Refuges for Freshwater Turtles in Urban Landscapes

Kristin M. Winchell and James P. Gibbs

SUMMARY

Freshwater turtles are declining worldwide, threatened mainly by habitat loss and degradation. Habitat loss is particularly acute in urban areas where golf courses might provide valuable habitat as some of the only remaining semi-natural habitats available to turtles. We captured 249 snapping turtles (*Chelydra serpentina*) and 164 painted turtles (*Chrysemys picta*) and measured their habitats at 88 wetlands that occurred among urban areas, on golf courses, and at wildlife refuges near Syracuse, New York in 2009 and 2010. Our research indicates that:

- Wetlands on golf courses had the smallest area, the most circular shapes, predominantly inorganic substrates, and the greatest extent of rooted vegetation.
- Uplands surrounding the golf course wetlands had relatively little forest and grassland and much lower road densities.
- Probability of occurrence and fraction of turtles captured that were females for both species did not vary among golf courses, urban areas, and wildlife refuges, whereas capture success for both species was lowest in golf course wetlands and relative mass of individuals was greater in golf course wetlands than in wildlife refuges.
- We conclude that golf course wetlands provide major protections to turtles from road mortality and over-harvest but can be enhanced by increasing wetland area, varying wetland shape, promoting the growth of emergent and rooted vascular vegetation, and increasing the proportion of forest and native grassland nearby while continuing to limit access and maintain minimal automobile traffic near wetlands.

Nearly half of all turtle species are threatened or endangered (current assessments estimate 56% of freshwater turtle species), making them one of the most imperiled groups of vertebrates (15, 29). Habitat loss and fragmentation pose the greatest threat (28). As urban areas are expanding worldwide (18), we need new approaches to provide adequate habitat for viable freshwater turtle populations despite inexorable urban expansion.

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Urban wetlands, such as retention basins and constructed wetlands in community parks and golf courses, could provide valuable habitat in urban zones. Golf courses are often the only large semi-natural spaces in urban areas, and they occupy a large and expanding portion of the urban landscape (27). As such, they may provide virtually the only habitat for aquatic species in urban areas (7, 14, 19, 23), although we currently know little about the relative quality of these wetlands as freshwater turtle habitat.

The highly altered state of golf course habitats due to land leveling, forest clearing, and golf course infrastructure (16) may compromise the value of golf course wetlands as turtle habitat. Golf courses could provide refuge from harvest pressures by strictly controlling access to those who would capture turtles and from road mortality by reducing the traffic volume and speed near wetlands (12). Moreover, although often substantially altered from their original state, golf courses still provide a mosaic of potentially favorable habitat types including turfgrass, fairways, forest, streams, shrubs, and residential lawns (14).

As urban areas are expanding worldwide, new approaches are needed to provide adequate habitat for viable freshwater turtle populations despite inexorable urban expansion.

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Only two species were captured in the 88 wetlands studied: painted turtles (left) and snapping turtles (right). Both species were found in golf course wetlands.

Detailed assessment of turtle populations in golf course wetlands would improve our understanding of the potential conservation value of these wetlands for freshwater turtles and of turtle-habitat relationships that would permit development of guidelines to improve the quality of habitat that golf courses could provide. To this end, we contrasted populations of snapping turtles (*Chelydra serpentina*) and painted turtles (*Chrysemys picta*) among wetland habitats typical of urban areas, golf courses, and wildlife refuges over two years. We considered (1) how golf course-associated wetlands compare to urban and wildlife refuge habitats, (2) whether turtle populations in golf course wetlands differ in key population parameters, and (3) which habitat characteristics should be the target of management of urban freshwater turtle habitats on golf courses.

Materials and Methods

We considered wetlands within three major landscape types found in the vicinity of Syracuse, New York (Figures 1 and 2): urban zones (n=26), golf courses (n=41), and wildlife refuges (n=21). Over two years (2009-2010), we sampled turtle populations and measured salient habitat features at 88 wetlands.

We sampled wetlands with a standardized effort of nine trap-nights per wetland (3 traps per wetland for 3 nights) using baited hoop nets. We checked traps daily and released turtles at the point of capture within 30 minutes after marking them with a single notch in a posterior marginal scute to identify the wetland of capture. We identified captured turtles to species, sexed them using external secondary sexual characteristics (10), and measured several physical characteristics. Individuals too young to exhibit distinct secondary sexual characteristics were considered juveniles.

We also conducted habitat analyses for each sampled wetland (Table 1). This was done by annotating aerial photographs and refining maps of habitat types during field inspections in addition to on-the-ground measurements. We analyzed landscape composition of the surrounding uplands (using ArcMap 9.3, ESRI 2008) to determine relative proportions of different land cover

Variable	Description or Definition	Range of Values
Wetland Area	Area (ha) of the wetland basin	1.01 to 3.68
Surface Water Irregularity Index	An index of irregularity of the surface water perimeter of the surface water to the perimeter of a circle with an equal area (Gibbs et. al, 1991)	1.07 to 3.88
Emergent Vegetation	Percentage of wetland basis in emergent vegetation (cattails, phragmites, etc.)	0 to 87.2
Rooted Vascular Vegetation	Percentage of surface water containing rooted vascular aquatic bed vegetation	0 to 100
Floating Vascular Vegetation	Percentage of surface water containing floating vascular vegetation (mainly duckweed)	0 to 100
Alder-willow Vegetation	Percentage of wetland basin in alder-willow vegetation	0 to 65.25
Mean Conductivity	Mean conductivity of the open water	12.1 to 2667.1
Mean Temperature	Mean temperature (^{O} C) of the open water	18.6 to 35.0
Substrate	Dominant substrate of the weland: O (organic), I (inorganic), M (mixed organic and inorganic)	O, I, M
Road Proximity	Distance (m) to nearest public road	5 to 1,253
Wetland Density	Percentage of landscape within 500 m that is wetland or open water according to the NLCD classification	0 to92.26
Grassland	Percentage of landscape within 100 m that is agricultural or grassland land cover types according to the NLCD classification	0 to 97.78
Developed Land	Percentage of landscape within 100 m that is developed according to the NLCD classification	0 to 100
Forest	Percentage of landscape within 100 m that is forested according to the NLCD classification	0 to 84.1
Urban Land	Percentage of landscape within 100 m that is urban according to the NLCD classification	0 to 44.95
Road Density Low-Intensity	Density (km/km^2) of low intensity roads within 500 m	0 to 11.14
Road Density High-Intensity	Density (km/km^2) of high intensity roads within 500 m	0 to 6.72

Table 1. Variables measured for wetlands included in the study for golf courses, urban zones, and wildlife refuges in central New York State, 2009-2010.

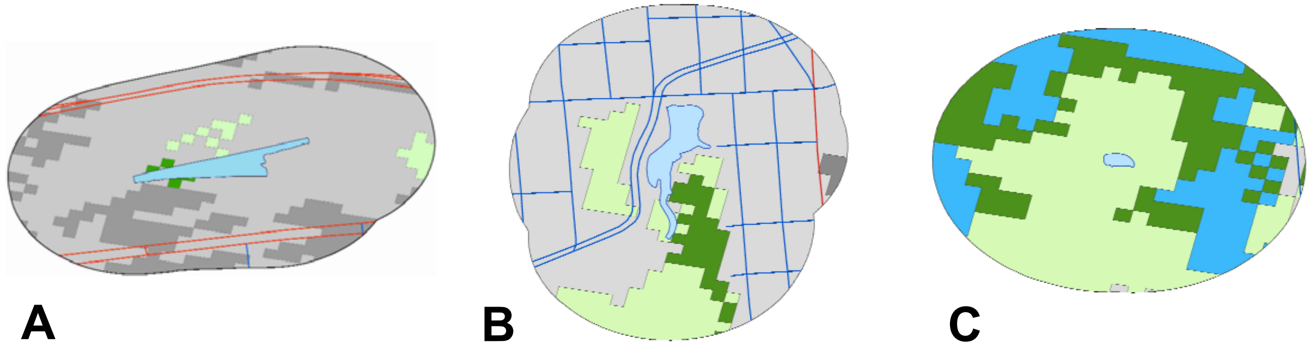


Figure 1. Examples of landscape analyses for wetlands. Urban land: dark gray, developed: light gray, blue: wetland, light green: agriculture and grassland, dark green: forest. Blue roads are "low-intensity" and red roads are "high-intensity." These are typical examples of (a) urban, (b) suburban, and (c) wildlife refuge wetlands.

types (derived from the National Land Cover Database, U.S. Geological Survey 2001) and road extent (derived from U.S. and Canada Detailed Streets map, Tele Atlas North America, Inc.). We then integrated several turtle population parameters (e.g., occurrence, abundance, sex structure, and age structure) and parameters of individual turtles (e.g., body length and relative mass index) with characteristics of wetlands sampled among landscape contexts.

How do turtle habitats on golf courses compare to those in urban areas and wildlife refuges?

Our study region, Onondaga County, New York (Figure 3), contained 28,700 ha of wetlands, 24.9% of which were in urban areas. Urban areas had the greatest densities of both high- and low-intensity roads, and roads were closer to wetlands. Wildlife refuges contained the greatest percentage of wetlands within 500 meters, and golf course and urban contexts had comparable amounts. The percentage of forest and herbaceous land cover, such as grasslands and agricultural pastures, surrounding wetlands was greatest in wildlife refuges and least in golf courses (manicured grasses typical of golf courses are considered developed land in the National Land Cover Data set).

Golf course wetlands were smallest in size and most circular in shape. Open water extent was least in urban wetlands and comparable in golf course and wildlife refuge wetlands. Three of four vegetation types were least extensive in golf course wetlands (floating vascular, alder-willow, emergent), but extent of rooted vascular vegetation was greatest. Water conductivity and temperature were comparable in wildlife refuges and golf courses and greatest in urban areas. Golf course wetlands were dominated by inorganic substrates (70.7% of wetlands), whereas wildlife refuges had primarily organic substrates (90.5% of wetlands) and urban wetlands had both inorganic and organic substrates (53.85% inorganic, 38.5% organic).

How do turtle populations in golf course wetlands compare to those in urban areas and wildlife refuges?

Few of the turtle population parameters analyzed differed by landscape context. Of 413 turtles captured during the two-year study period (954 trap-nights), 164 were painted turtles (40% of total captures; with 46% female, 49% male, 5% juveniles), and 249 were snapping turtles (39% female, 53% male, and 8% juveniles). Species occurrence and female fraction did not vary, but abundance for both species was lowest in golf course wetlands. Body condition (RMI), which differend only for painted turtles, was least in wildlife refuges and comparable in golf course and urban contests. Sex and age structure of turtle populations were primarily influenced by roads.

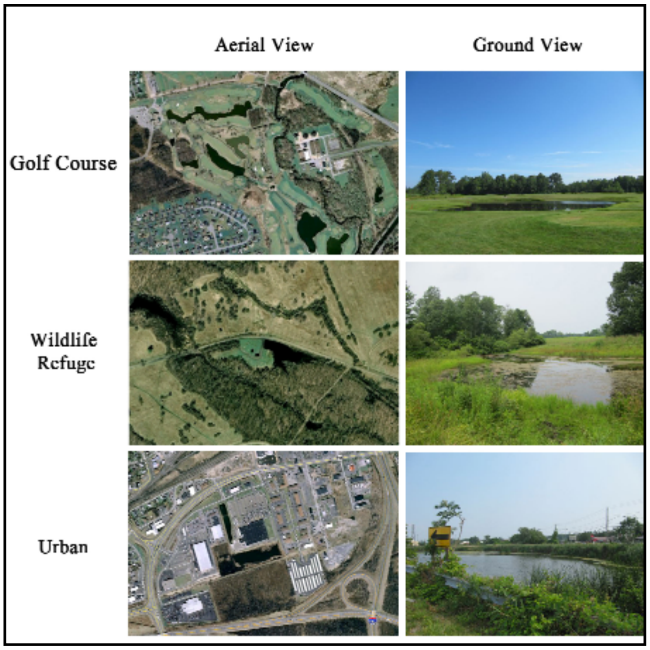


Figure 2. Examples of wetlands evaluated in 2009-2010 near Syracuse, New York to evaluate characteristics of wetlands and turtle populations among urban zones, wildlife refuges, and golf courses (aerial view left row, ground view right row, Aerial images © Google 2010; ground images © Kristin Winchell).

To what habitat features do turtle populations respond?

Occurrence and abundance for both snapping and painted turtles increased with wetland area. Snapping turtle occurrence and abundance also both increased with greater wetland shape irregularity and more emergent vegetation. Painted turtle occurrence was more influenced by the surrounding landscape: occurrence decreased with the proportion of surrounding wetlands and developed land, although abundance increased with more emergent and floating vegetation and more extensive urban land.

These patterns support the findings of Bowne et al. (2) who concluded that wetland quality is the most important factor for inter-wetland movement. Moreover, Patrick and Gibbs (20) contended that landscape factors such as urban land extent substantially impact overland movement. Results suggest that painted turtles and snapping turtles are responding differently to landscape- and wetland-specific habitat characteristics.

The association between abundance and occurrence and wetland size is notable. Larger wetlands may decrease aggressive interactions in territorial and aggressive species such as snapping turtles (8). Failey et al. (7) also found a positive relationship between wetland area and abundance of these two species, although this relationship may not hold true in all circumstances, particularly if larger man-made wetlands lack necessary microhabitat characteristics (21). Our results also found a positive association of wetland shape irregularity and abundance of snapping turtles. Other studies have found correlations between abundance and habitat shape complexity for a variety of taxa in both terrestrial and aquatic habitats (6).

Sex Ratios

In this study, snapping turtle captures were male-biased (average 39% females), but painted turtle captures approximated the expected ratio (average 55% females). Female fraction in both species was strongly influenced by roads: more female snapping turtles were captured when wetlands were farther from roads and surrounded by higher densities of low-intensity roads and more female painted turtles were captured when there were lower densities of high-intensity roads. The influence of roads on female fraction supports recent literature stating that male-biased populations are often associated with road proximity (26 and with higher road densities (1, 11, 12, 17, 21).

Female fraction of snapping turtle populations was also positively related to the extent of surrounding urban land and mixed substrates and negatively related to wetland area and water conductivity. Female fraction in painted turtles was negatively related to the proportion of rooted and floating vascular vegetation and positively related to water temperature.

The surprising pattern in our data was that increased female fraction in snapping turtles was associated with greater urban land extent. Road mortality of freshwater turtles depends on both road density and traffic volume; low traffic volumes are associated with less road mortality even

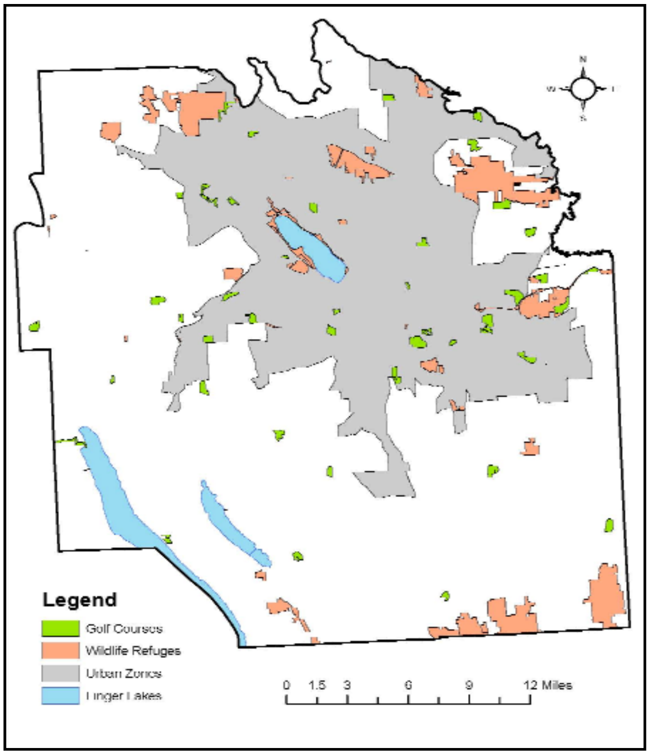


Figure 3. Land use contexts in Onondaga County. White areas are "rural" areas.

in areas of high road density (12). Suburban and residential areas tend to have lower speed limits and cautious suburban drivers, which may lead to lower road mortality even though there are a large number of roads (5).

Age Ratios

A turtle's approximate age can be approximated based on carapace (shell) length due to the indeterminate growth of the turtle species in this study. Populations with more large-bodied turtles therefore tend to have more adults. Snapping turtles reach maturity at a carapace length of approximately 200 mm, and painted turtles between 70-95 mm (10). In our study, snapping turtle size ranged from 91-375 mm (mean of 265 mm) and painted turtles ranged from 71–182 mm (mean of 141 mm).

Size in both species was positively associated with urban and developed land extent and was influenced strongly by roads. Both species were larger when roads were farther from the wetland, and painted turtles were larger in wetlands surrounded by higher densities of high-intensity roads. Larger body size was also associated with lower levels of emergent vegetation for snapping turtles, and more grassland and forest, less floating vascular vegetation, lower water conductivity, and mixed substrates for painted turtles.

As with sex ratios, the most notable influence on body size is roads. The effect of roads is well documented with larger, adult turtles associated with lower densities and distances to roads (17, 20). In both species, a differential response of juveniles, females, and males was observed with respect to roads, suggesting increased adult mortality and reduced recruitment. The co-occurrence of reduced recruitment (indicated by increased juvenile age) and reduction in adult female turtles was observed by Garber and Burger (9) in wood turtles (*Clemmys insculpta*), eventually leading to local extirpation.

In snapping turtles, when high-intensity road density was greater, males and juveniles were larger, but females were smaller. Male and juvenile snapping turtles typically move less frequently than females and likely encounter roads less often. Thus snapping turtles are likely experiencing female road mortality and the remaining population may be male-biased and have less capacity to be self-replacing. Low recruitment rates in urban populations of snapping turtles have previously been attributed to reduced nesting success and movement restriction associated with roads (13).

In painted turtle populations, both male and female turtles were larger when roads were farther from the wetland, but male painted turtles responded more strongly than females. Recent studies have found that male painted turtles are more likely than females to leave a wetland (21, 22), although female painted turtles are likely more willing to travel further distances than males (2). Our results indicate that male painted turtles may be more susceptible to road mortality than females. Additionally, juvenile painted turtles were larger when roads were closer, indicating a decrease in recent nesting success despite stable male to female ratios among populations. Our results support previous studies suggesting that painted turtles are at greater risk of road mortality and associated isolating effects than previously thought (2).

An underrepresentation of adult turtles in a population may indicate road mortality, whereas a significant skew towards adults may indicate a lack of recruitment (25). Although freshwater turtle populations are considered stable when dominated by juveniles (3, 4), an abundance of adults is necessary for recruitment to continue. Snapping turtle populations in wildlife refuges were more dominated by large-bodied turtles compared to urban and golf course populations dominated by small-bodied turtles.

Despite this, age distribution in populations appears to be more balanced with many containing equal numbers of larger-bodied older turtles and smaller-bodied younger turtles. In contrast, painted turtle age distribution appears to be less well balanced in urban wetlands, which exhibited a major skew towards large turtles and had few balanced populations. Golf course and wildlife refuge populations were skewed towards small-bodied turtles, yet still had populations with a better mix of adults and juveniles.

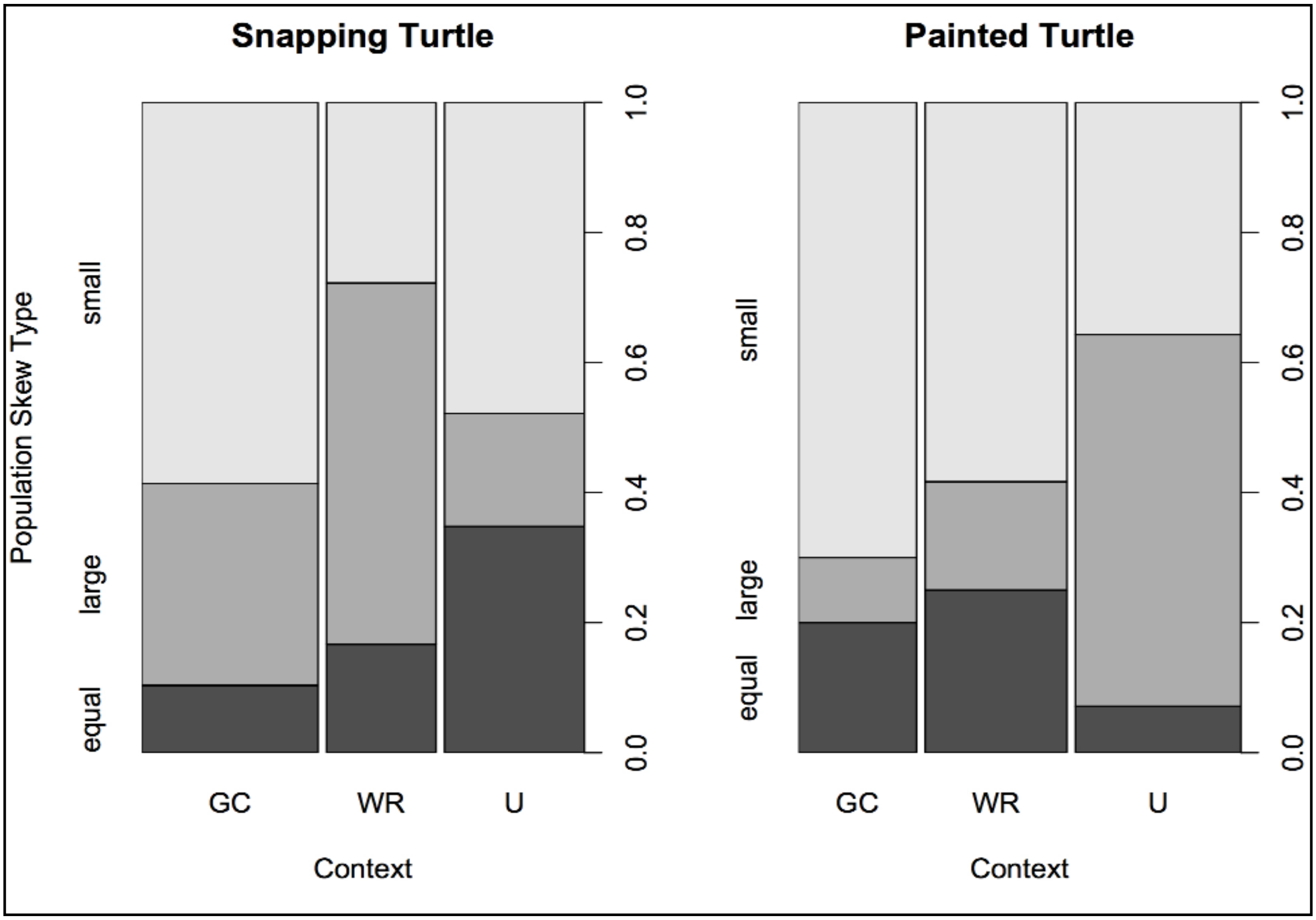
Kristin Winchell measures the carapace length of a snapping turtle. Carapace length was used to investigate size structure of populations and body condition of individual turtles.

Conclusions

With few caveats, the turtle population parameters examined in this study did not differ among wetlands in golf courses, urban areas, and wildlife refuges, suggesting that urban and golf course contexts provide habitat comparable to wildlife refuges in the region. Wetlands of appropriate quality may act as refuges in disturbed landscapes, and golf courses may be especially appropriate for this function due to their low road densities and restricted access. Enhancement of golf course wetland habitat in light of turtle-habitat relationships may further increase conservation value. Without conservation-oriented management, it is unlikely that the buffer from the threat of roads alone will increase the viability of golf course associated populations or persistence of freshwater turtles in the urban landscape.

Our study suggests several management recommendations. Wetland-level characteristics are important because these are likely easier to manipulate than landscape-level characteristics. Varying wetland shapes away from basic circular shapes, increasing wetland area, and managing vegetation types may all positively impact populations. Emergent shoreline vegetation removal (e.g. cattails, phragmites) should be limited due to strong positive associations with occurrence and abundance. Rooted submerged vegetation should be encouraged and not removed, and floating vascular vegetation, such as duckweed, should be minimized.

Where possible, managers of golf courses



Proportion of populations in each context (golf course, wildlife refuge, urban) that exhibited size-skew: “small”— more small turtles than large turtles, “large”— more large turtles than small, “equal” — equal amounts of small and large turtles. Small turtles were those that were smaller than the median size captured for the study for each species and large turtles were those greater than or equal to the median size.

should maintain a mosaic of favorable land types such as forest and grassland near wetlands. Harden et al. (14) found that although golf courses provide a mosaic of favorable habitat types such as fairways, forest, streams, shrubs, and residential lawns, they did not provide sufficient overwintering habitat, causing turtles to travel greater overland distances. An appropriate distance for many wetland-associated reptiles is up to 127-289 m from the wetland edge (24), although freshwater turtles may move considerably farther into the upland habitat (2). On golf courses, this range is often dominated by fairways and greens, which means that turtles must travel farther, perhaps exposing themselves to roads, to find appropriate habitat for nesting and overwintering.

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