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Notes and Discussion

Descriptive Ecology of a Turtle Assemblage in an Urban Landscape

ABSTRACT.—We studied turtle populations inhabiting a canal and a lake (both man-made) within a heavily disturbed, urban setting. Six aquatic and semi-aquatic turtle species were collected in both habitats: spiny softshell turtle (*Apolone spinifera*), painted turtle (*Chrysemys picta*), common snapping turtle (*Chelydra serpentina*), common map turtle (*Graptemys geographica*), common musk turtle (*Sternotherus odoratus*) and red-eared slider (*Trachemys scripta*). While *G. geographica* was the most common species in the canal habitat, *T. scripta* was most common in the lake habitat. We describe patterns of sexual size dimorphism and sex ratios for the three most abundant species (*G. geographica, T. scripta* and *S. odoratus*). We discuss our data in light of problems facing turtle assemblages in urban settings.

INTRODUCTION

Habitat conversion and degradation is generally recognized as the most pervasive and important of the six major threats to biodiversity (other threats being invasive species, environmental pollution, disease/parasitism, unsustainable use and global climate change; Gibbons *et al.*, 2000). The major effect of habitat conversion is the outright loss of critical habitats for essential life functions, including feeding (Vickery *et al.*, 2001), courting and nesting (Heckert *et al.*, 2003) and hibernation (Ball, 2002). Habitat conversion as the result of increasing urbanization, in particular, affects a wide array of organisms, from large carnivores (Reilly *et al.*, 2003) to butterflies (Collinge *et al.*, 2003) to plants (Fransisco-Ortgea *et al.*, 2000) in terrestrial situations and from salamanders (Willson and Dorcas, 2003) to fish (Paul and Meyer, 2001) to algae (Fore and Grafe, 2002) in aquatic environments.

Turtle populations have been significantly impacted by human activity, development and urbanization. Negative effects include fragmentation of genetic structure (Rubin *et al.*, 2001), demographic effects (Garber and Burger, 1995; Lindsay and Dorcas, 2001) and direct mortality (*e.g.,* through collision with automobiles, Gibbs and Shriver, 2002). Nonetheless, some turtle species may be very resilient in the face of human activity and continue to exist in highly modified habitats when other wildlife is extirpated (Mitchell, 1988). Data on the specific impacts of human activity on turtle populations and assemblages, and how these effects may be ameliorated, provide essential components to sound conservation practices in human-dominated landscapes. The purpose of the present study is to understand the basic ecology of a turtle assemblage living within an urban landscape. These descriptive population and community ecology data can then serve as a baseline for more thorough investigations of the effects of urbanization.

MATERIALS AND METHODS

The Central Canal is a man-made riverine habitat created in the 1830s in Indianapolis, Indiana, the 12th largest city in the USA (2000 census population 791,900+ residents). The remnant of a much larger uncompleted canal system, the Central Canal originates from the White River and flows south through commercial, residential and recreational areas for 11.2 km. At least a dozen roads cross the canal, including four major thoroughfares and one interstate highway. At the southern terminus, the canal enters a water treatment facility operated by the Indianapolis Water Company (IWC). The canal transports approximately 70% of the city's annual water use; water level, flow rate, submergent and emergent aquatic vegetation are all controlled in part by the IWC. The canal varies from 15 to 25 m wide and is usually less than 2 m at its deepest points. Shorelines are practically non-existent in most places, with banks 1–2 m high on either side. Fragmented woodlots border portions of the canal and fallen trees and snags serve as basking sites; however, many of these basking sites are removed on a regular basis. Approximately 8.5 km of the canal (76%) is bordered by a greenway (the Central Canal Towpath) maintained by IndyParks, the City of Indianapolis Department of Parks and Recreation. Most of our field work for this study in the canal was in this 8.5 km section. In this section, the canal is never more than 1 km from the White River and is as close as 25–40 m at several points.

In addition to the canal, we also studied the turtle community inhabiting a man-made lake owned by the Indianapolis Museum of Art (IMA Lake). The 14.7 ha lake is situated in close proximity to both the canal (165 m) and the White River (30 m). Relictual woodlots surround about 75% of the lake's shoreline and the lake is frequently used by recreational fisherman.

We captured 1044 individual turtles a total of 1409 times between April–October 2002 (<0.5% of the captures were made during a preliminary trapping period in September–October 2001). Most captures were made through the use of aquatic hoop traps (76.3 cm diameter hoops, 30 × 30 cm coated nylon mesh with a funned at one end and a closed bag at the other) although occasional captures (<1%) were made by hand or with a dip net. While no trapping method is without species-specific biases (*see* Gibbons, 1990a), the use of aquatic traps for turtle population and community studies has gained wide acceptance (Bodie *et al.*, 2000; Smith and Iverson, 2002; Bury and Germano, 2003) when limitations are properly acknowledged (*see* Results and Discussion, below). In the canal we deployed 6–20 traps spaced approximately 100 m apart; spacing was considerably greater in the lake (>250 m) where trapping was limited to September–October 2002. We baited traps with sardines and/or chicken livers (refreshed every 4–5 d), checked traps daily and changed trap locations weekly in order to maximize coverage of the canal. Traps were submerged save for the top 5–20 cm. For each turtle we recorded mid-line carapace length (CL to the nearest mm) using calipers, mass (to the nearest g) using a benchtop electronic balance, species, sex, location of capture and any notable damage. Each turtle was given an individual mark by notching the marginal scutes in a unique pattern to allow for future identification (Cagle, 1939). Turtles were processed and returned to the point of capture within 24 h.

RESULTS AND DISCUSSION

COMMUNITY COMPOSITON

The same assemblage of six species was captured in both the canal and lake habitats: spiny softshell turtle (*Apolone spinifera*), painted turtle (*Chrysemys picta*), common snapping turtle (*Chelydra serpentina*), common map turtle (*Graptemys geographica*), common musk turtle (*Sternotherus odoratus*) and red-eared slider (*Trachemys scripta*). However, relative abundances of these species differed significantly in the two habitats (Fig. 1). For the purposes of a quantitative comparison, we used data collected only during September–October 2002, the time period when both habitats were sampled contemporaneously (Table 1). Three species, *A. spinifera*, *C. picta* and *C. serpentina*, collectively constituted <20% of the total captures in either habitat. In the Central Canal, *G. geographica* was most abundant with *T. scripta* representing <10% of all captures, whereas in IMA Lake *T. scripta* alone accounted for more 65% of the captures and *G. geographica* represented <5%.

Differences in composition may be due in part to the unequal distribution of aquatic mollusks between these habitats. Freshwater mollusks are the primary prey for *Graptemys geographica* (Gordon and MacCulloch, 1980; Vogt, 1981; White and Moll, 1992). The Central Canal supports several species of freshwater snails (*e.g.*, members of the genera *Pleurocera*, *Goniobasis* and *Vivaparus*) and are found at high densities locally; similar sampling efforts in IMA Lake have failed to detect the presence of aquatic snails. The lake, thus, represents sub-optimal habitat for *G. geographica* due to a lack of preferred food. In contrast, *T. scripta* is more omnivorous and opportunistic in feeding (Ernst et al., 1994) and is the most abundant species in the lake. It may be that the lack of *G. geographica* in IMA Lake due to the absence of suitable food has allowed the *Trachemys scripta* population to grow more successfully than in the habitat where *G. geographica* is abundant. The extent to which these two species interact competitively, however, is unclear and the differences in distribution may simply reflect microhabitat preferences (*see* Ernst *et al.*, 1994). The relative consistency of the rest of the species abundances speaks to the overall similarity of the two sites despite the differences inherent in lentic and lotic habitats.

The rarity of *Chrysemys picta* in both habitats is unexpected, as it is one of the most common and abundant species throughout its range and particularly in the Midwest (Anderson *et al.*, 2002; Bury and Germano, 2003) and Southeast (Lindsay and Dorcas, 2001). Moreover, it can be very abundant in urban habitats; Mitchell (1988) estimated more than 500 individuals in a *C. picta* population inhabiting a small creek (6 m wide) and two small associated beaver ponds in urban Richmond, Virginia. We speculate that the White River is the source of the turtle populations inhabiting the Central Canal and IMA Lake.

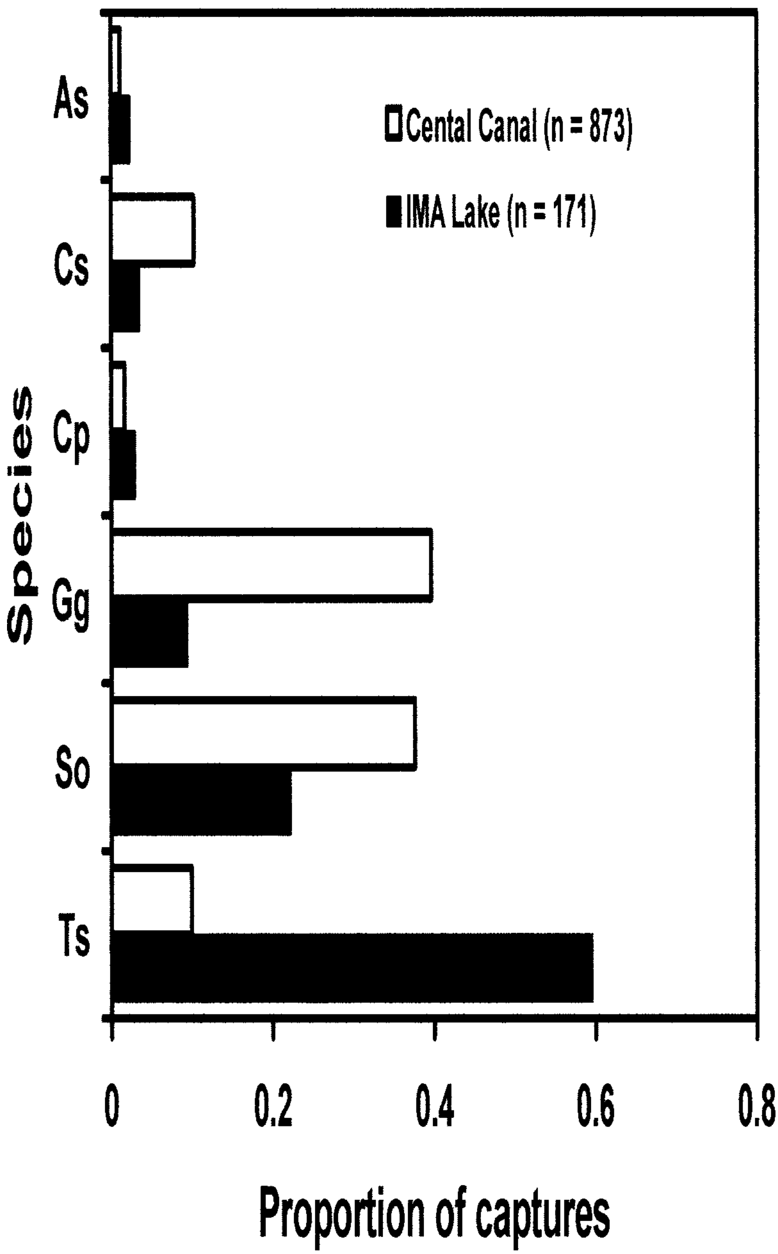

FIG. 1.—The proportion of six aquatic and semi-aquatic turtle species captured in a man-made canal (Central Canal) and lake (IMA Lake) within an urban landscape in Indianapolis, Indiana, USA. The total number of individuals collected between is indicated in the figure legend (see text for details). Abbreviations are as follows: As = *Apolone spinifera*, Cp = *Chrysemys picta*, Cs = (*Chelydra serpentina*), Gg = *Graptemys geographica*, So = *Sternotherus odoratus*, Ts = *Trachemys scripta*

TABLE 1.—Number and proportion of six aquatic and semi-aquatic turtle species collected in September–October 2002. Because the sample size was low for *Apolone spinifera*, *Chelydra serpentina* and *Chrysems picta* in both habitats, the goodness-of-fit-test was conducted using only the three more common species

	Central canal		IMA lake	
	number	proportion	number	proportion
Apolone spinifera	4	0.032	3	0.020
Chelydra serpentina	18	0.143	4	0.026
Chrysemys picta	5	0.040	4	0.026
Graptemys geographica	50	0.397	7	0.046
Sternotherus odoratus	43	0.341	32	0.211
Trachemys scripta	6	0.048	102	0.671
TOTAL	126		152	

Goodness-of-fit-test: $\chi^2 = 115.8$, df = 2, $P < 0.0001$

Although *C. picta* is frequently abundant in ponds and lakes, it is notably less common in rivers (Ernst *et al.*, 1994) and, thus, the current low density may reflect a historical low density in this region. It is worth noting also that these populations may suffer from very low recruitment rates, as all 19 individuals we captured in both habitats were mature adults, whereas we have collected or observed hatchlings for the other five species.

SEXUAL SIZE DIMORPHISM

We found significant sexual size dimorphism for the three most frequently captured species, with females significantly larger than the males in both CL and mass in each case (Table 2). Sexual size dimorphism, with females larger than males, is the norm for most emydid turtles (Ernst *et al.*, 1994) and has been documented in populations of *Graptemys geographica* and *Trachemys scripta* throughout their ranges (*e.g.*, Cagle, 1950; Vogt, 1980; Gibbons and Lovich, 1990), as well as in central Indiana (Minton, 2001). Sexual size dimorphism, however, is less common in kinosterid turtles, particularly in *Sternotherus*

Table 2.—Sex ratios and body sizes of *G. geographica*, *S. odorauts*, and *T. scripta*, the major species of the Central Canal (canal) and IMA Lake (lake) turtle assemblages. For each population we report the number, and mean (and SE) carapace length (CL) and mass of each sex; we used Chi-square goodness-of-fit tests to detect skewed sex ratios and one-way analysis of variance on log-transformed CL and mass to detect sexual size dimorphism

	G. geographica (canal)		*S. odorauts* (canal)		*T. scripta* (canal)		*T. scripta* (lake)	
	female 146	male 159	female 122	male 170	female 45	male 36	female 50	male 48
Number	$\chi^2 = 0.554$, $P = 0.457$		$\chi^2 = 7.89$, $P = 0.005$		$\chi^2 = 1.00$, $P = 0.317$		$\chi^2 = 0.041$, $P = 0.840$	
CL (mm)	168.7 (4.54)	102.7 (1.03)	107.1 (0.81)	98.6 (0.82)	175.1 (6.98)	151.0 (4.90)	178.2 (6.36)	148.6 (4.61)
	$F_{1,303} = 209.7$, $P < 0.0001$		$F_{1,290} = 46.9$, $P < 0.0001$		$F_{1,78} = 5.04$, $P = 0.028$		$F_{1,96} = 11.0$, $P = 0.001$	
Mass (g)	800.6 (51.9)	137.3 (3.45)	212.4 (4.34)	157.7 (3.36)	988.0 (130.0)	542.0 (46.6)	972.8 (78.0)	522.3 (44.4)
	$F_{1,301} = 235.2$, $P < 0.0001$		$F_{1,290} = 76.1$, $P < 0.0001$		$F_{1,76} = 9.82$, $P = 0.002$		$F_{1,96} = 14.4$, $P < 0.0001$	

(Gibbons and Lovich, 1990; Ernst *et al.*, 1994). Lovich and Gibbons (1992) promoted a straightforward index for quantifying these differences, the sexual dimorphism index (SDI):

$$\text{SDI} = (\text{mean length of larger sex/mean length of smaller sex}) + 1 \text{ when males} > \text{females}$$

or

$$\text{SDI} = (\text{mean length of larger sex/mean length of smaller sex}) - 1 \text{ when females} > \text{males}$$

with the value of size ratio being positive when females are the larger sex and negative when males are the larger sex. The SDI in 14 populations of *Sternotherus odoratus* ranged between –0.068 and 0.127, with a mean absolute value of 0.039 (Gibbons and Lovich, 1990). In other words, on average there is less than a 4% difference in body size between the sexes of *S. odoratus* in most populations. In our study, the SDI value is 0.086, more than twice the mean difference. The CL of *S. odoratus* adults in our population is comparable to other populations in natural habitats throughout its range (*see* Gibbons and Lovich, 1990). Tinkle (1961) found a comparable degree of sexual size dimorphism in *S. odoratus*, but only in extreme southern populations. The absence of sexual size dimorphism in *Sternotherus* is generally attributed to the early age of maturation both males (3–4 y) and females (4–8 y) (Mahmoud, 1969; Mitchell, 1988). The significance of sexual dimorphism in our population of *S. odoratus* is at this point unclear and in need of further study.

The SDI values for *Graptemys geographica* (0.643) and *Trachemys scripta* (0.160 and 0.199 for the canal and lake habitats, respectively) in our study are comparable to, but generally less than, values reported for these species elsewhere throughout their range (*G. geographica* mean SDI = 0.810 for three populations; *T. scripta* mean SDI = 0.251 for five populations in the United States; Gibbons and Lovich, 1990). The smaller SDI may be due to smaller adult female body size. In the populations summarized by Gibbons and Lovich (1990), adult females are about 17% larger than the females in our population (mean CL = 196.8, SE = 11.7; compare with Table 2), whereas the difference between males in our and other populations is 8.5%, half the difference (mean CL = 112.3, SE = 3.7; compare with Table 2).

SEX RATIOS

We observed parity in sex ratios for *Graptemys geographica* and for both the canal and lake populations of *Trachemys scripta* (Table 2). Male-bias is the norm in South Carolina *T. scripta* populations studied by Gibbons and Lovich (1990), but not in Midwestern populations (Bodie and Semlitsch, 2000; Anderson *et al.*, 2002). Likewise, sex ratios are variable among populations of *G. geographica*. For example, a riverine population in Pennsylvania had a non-significant male bias (male:female ratio = 1:0.82; Pluto and Bellis, 1986), but other population are notably male-biased (1:0.59 in Quebec, Gordon and MacCollouch 1980; 1:0.33 in Wisconsin, Vogt, 1980).

In our study, only the *Sternotherus odoratus* population inhabiting the Central Canal exhibits a significant bias, with a male:female ratio of 1:0.67. A significant female bias (Dodd, 1989), male bias (Edmond and Brooks, 1996; Smith and Iverson, 2002) and equal sex ratios (Bancroft *et al.*, 1983; Ernst, 1986; Mitchell, 1988), have been documented in other populations of *S. odoratus*. Smith and Iverson (2002) advanced several potential explanations for a consistent (>20 y) male-bias in a north-central Indiana population of *S. odoratus*, including differential mortality, higher rates of activity among males, differential habitat use, temperature-dependent sex determination and sampling technique-bias. Each of these explanation are plausible in our population, however, we currently lack the data to test these hypotheses.

CONSERVATION IMPLICATIONS

The Central Canal-IMA Lake habitats support a robust turtle assemblage, despite the challenges of nesting in an urban landscape and the heightened risk of collision with motor vehicles during terrestrial movement. Recruitment is a critical for the persistence of populations, especially for long-lived species with a relatively old age at first reproduction (Congdon *et al.*, 1993). Access to suitable nesting sites is a critical precursor to successful recruitment and finding such sites is potentially difficult in highly urbanized landscapes. For example, the Central Canal is surrounded predominantly by impervious surfaces (roads and parking lots in the commercial districts), scattered woodlots and residential lawns. Of these, the latter is the most likely to be used by nesting females because of reduced cover and relatively uncompacted soils. We have anecdotal data on the use of lawns as nesting sites in some areas around the canal (unpubl. data). A further complication is that nesting females and hatchlings frequently have to cross roads when moving to and from the canal; this is a definite and persistent threat (Gibbs and Shriver, 2002) that may result in male-biased populations (Steen and Gibbs, 2004). For example, in May 2002, we collected the carcasses of five *Graptemys geographica* nestlings on a major thoroughfare, approximately 35 m from the Central Canal. In addition, we have noted shell damage consistent with automobile collision and have collected roadkill *G. geographica* females during June and July, the height of nesting season. We have documented individuals moving between aquatic habitats (including the White River) through mark-recapture and radiotelemetry studies (Ryan *et al.*, in review). Risk of collision with motor vehicles is likely less between the two aquatic habitats as few roads (if any) usually need to be crossed. Death associated with terrestrial movement likely represents one of the greatest sources of mortality in our community. Removal of individuals by fisherman and turtle "enthusiasts" is also a threat.

The Central Canal is more than 160 y old, however the history of the turtle community inhabiting it and surrounding man-made aquatic habitats (*e.g.,* IMA Lake) is unclear. Minton (2001) observed "large numbers" of *Graptemys geographica* in the canal in the 1950s. He described a general decline in the abundance of *G. geographica* and other species (Minton, 1968) between the 1950s and the 1990s (Minton, 2001). Unfortunately, he did not conduct regular sampling to detect population trends with any confidence. We have initiated a long-term mark-recapture study (with associated studies on movements and habitat use) to monitor turtle population trends in an area of considerable human activity. The current data set, thus, serves not only as a description of the ecology of turtles in an urban setting, but also as a baseline for long-term monitoring efforts. In the future, we will use recapture data to develop estimates of population sizes. Although there are a few notable long-term studies turtle community ecology in natural environments [*e.g.,* at the Savannah River Site in South Carolina (Gibbons, 1990b) and the E. S. George Reserve in Michigan (Congdon and Gibbons, 1996)], such efforts are also needed to ensure the persistence of wildlife in highly modified urban habitats.

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