A TRIBUTE TO HENRY S. FITCH

With this issue of *Reptiles & Amphibians* we complete our tribute to the late Henry S. Fitch. Although originally envisioned as a two-issue memorial, the response from the herpetological community was so enthusiastic that the number of contributions could only be accommodated in four issues of the journal. Dr. Fitch's influence, and the esteem in which he was (and is) held, have been reflected in the taxonomic and geographic breadth of the submissions. Contributors ranged from graduate students to well-known senior scientists with spectacular publication records. At least 22 U.S. states and ten additional nations (Australia, Brazil, Canada, China, Costa Rica, Czech Republic, India, Mexico, South Africa, and Taiwan) were represented. Every author in some way wanted to pay respect to a man that might have been mentor, colleague, friend, and/or source of inspiration. Although this marks the end of our dedicated tribute, we are confident that future contributions to this and many other journals will, to one degree or another, reflect the boundless enthusiasm and high level of scholarship displayed in the natural history publications of Henry Fitch.

The Editors of *Reptiles & Amphibians*

Population Size and Sex Ratio of Snapping Turtles on the Crescent Lake National Wildlife Refuge

John B. Iverson[1] and Geoffrey R. Smith[2]

[1]Department of Biology, Earlham College, Richmond, Indiana 47374 (johni@earlham.edu)
[2]Department of Biology, Denison University, Granville, Ohio 43023 (smithg@denison.edu)

Abstract.—Mark and recapture studies of Common Snapping Turtles (*Chelydra serpentina*) on the Crescent Lake National Wildlife Refuge in the Sandhills of western Nebraska revealed a sex ratio strongly biased toward males by a factor of two, an average density of 2.32 adults and subadults per hectare, and a standing crop biomass of 19.35 kg/ha. Sex ratios were most biased (7.5:1.0) in July–August. Density and biomass were comparable to values from previously studied lakes, and were inversely related to wetland size across all studies of snapping turtles.

Common Snapping Turtles (*Chelydra serpentina*) are known predators of waterfowl (review in Ernst and Lovich 2009), and hence are a concern for wildlife managers charged with maximizing waterfowl production. In order to assess the potential impact of snapping turtles on waterfowl populations, knowledge of the population dynamics of the turtle is necessary, in addition to data on feeding habits.

On the Crescent Lake National Wildlife Refuge in Nebraska, unpublished data (Iverson and French) revealed that 45% of 49 snapping turtles contained avian body parts, although American Coots (*Fulica americana*) were the only identifiable bird species, and determining whether the birds were taken alive or as carrion was not possible. To evaluate the potential impact of snapping turtles on waterfowl, the Refuge authorized this study of the density and biomass of these turtles in one of the largest lakes on the refuge.

Methods

Using mark-recapture techniques, we studied the snapping turtle population of Island Lake on the Crescent Lake National Wildlife Refuge in Garden County, Nebraska during 2008 and 2009. Island Lake is a shallow 298-ha water-table lake, with a maximum depth of about 3 m, and about 209 surface hectares with depths less than one meter (CLNWR records). The perimeter of the Lake is cattail or bulrush marsh, and numerous "islands" (one up to 6 ha) of emergent vegetation occur in open water areas. The lake is managed for gamefishing and for waterfowl production. Immediately prior to this study (early June 2008), 87 subadult and adult snapping turtles (mean carapace length 332 mm; range 254–412; mean body mass, 8,250 g [total sample mass = 717.75 kg]) were culled from Island Lake for dietary analysis (n = 48) or removal and translocation to wetlands off the Refuge (n = 39).

Snapping turtles were captured in baited fyke nets (n = 40, plus 5 recaptures), incidentally by hand (e.g., while nesting; n = 24, plus two recaptures), or dip-netted from an airboat during transects undertaken at approximately weekly intervals to collect bird carcasses for avian flu monitoring (n = 184, plus 68 recaptures). Fyke nets baited with pieces of rough fish were deployed on 24–28 June 2008 and 20–24 June 2009 along the eastern or western shores of the lake. In addition, airboat sampling was undertaken on 9 days in 2008, and 20 days in 2009. For simplicity, sampling was initially divided into 10 time periods (Table 1), and only turtles with carapace lengths (CL) > 225 mm were included in this analysis.

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Snapping turtles captured in single fyke net set for 24 h.

A nesting female with characteristic spoil mounds. These mounds (one behind each rear leg) always remain after the female has completed the nesting process, making location of nests very easy for humans and predators.

Each captured turtle was measured (maximum carapace length and plastral length to the nearest mm), some were weighed (body mass [BM] to the nearest 50 g), and all were marked individually by screwing a numbered circular metal tag into the right rear margin of the shell. All turtles were released where caught, typically within 15 min of capture.

Table 1. Sex ratios for snapping turtle samples from Island Lake, Nebraska, based on airboat (number of days indicated) or fyke net captures of sexable turtles over 225 mm carapace length. Captures of females at nesting areas in June are excluded. Sample sizes include recaptures and so some individual turtles are represented more than once in these tallies. * $P < 0.05$; ** $P < 0.01$.

Sample period	Males	Females	Ratio (M/F)
June 2008 (fyke)	17	10	1.70
July 2008 (1 day)	10	1	10.00**
September 2008 (6 days)	41	19	2.16**
October 2008 (2 days)	31	15	2.07*
April–May 2009 (5 days)	25	6	4.17**
June 2009 (fyke/1 day)	15	20	0.75
July–August 2009 (4 days)	20	3	6.67**
1–15 September 2009 (2 days)	13	3	4.33*
28 September–5 October 2009 (2 days)	19	4	4.75**
16 October–18 November 2009 (7 days)	23	15	1.53
All periods	214	96	2.23**
All airboat captures	186	69	2.70**
All fyke net captures	28	17	1.65
July–August only	30	4	7.50**
September only	44	22	2.00**
October–November only	73	34	2.15**

To estimate the population size, capture/recapture data were divided into five sampling periods: June–July 2008, September–October 2008, April–June 2009, July–15 September 2009, and 28 September–18 November 2009. These data were subjected to Schumacher-Eschmeyer, Schnabel, and Modified Leslie Method analyses (Krebs 1999). For density and biomass comparisons, we used the average population size estimate of these three estimates. Chi square analyses were used to test sex ratio bias in samples.

Results

We marked a total of 250 subadult and adult snapping turtles and made 69 recaptures (319 total captures). For 286 snapping turtles (CL range 120–442 mm) from Island Lake and Gimlet Lake, BM (g) was related to CL (mm) by the equation $BM = 0.0003847CL^{2.909}$ ($r = 0.97$; $P < 0.0001$). Mean CL for the first capture only of all subadult and adult Island Lake snapping turtles was 333 mm (range 226–462 mm). Application of the BM-CL equation estimates average BM as 8,373.6 g.

Sex ratios were male-biased in every sample but one that included mainly incidental captures of nesting females in June 2009 (Table 1). With one notable exception, about twice as many males were captured as females during a given sampling period. Samples in July–August in both 2008 and 2009 included very few females, and a combined male to female sex ratio of 7.5:1.0. This latter sex ratio is significantly male biased ($P = 0.016$), even if the expected sex ratio was that of all samples combined (2.23:1.0; Table 1).

Population estimates of subadults and adults based on the capture/recapture data were 606 (95% Confidence Interval 485–804; Schumacher-Eschmeyer), 622 (95% CI 448–1,018; Schnabel), and 580 (Leslie Method). The average of these estimates suggests a population of 603 subadults and adults. Assuming a mean BM of 8,374 g per individual and an estimate of 603 subadult and adult turtles in Island Lake suggests a standing crop

Typical adult male Common Snapping Turtle (*Chelydra serpentina*) from Island Lake.

Table 2. Variation in sex ratio (males/females) among populations of *Chelydra serpentina* arranged by declining latitude. Note the absence of a latitudinal pattern in sex ratio. * P < 0.05; ** P < 0.01.

Location	Body of Water	Latitude	Males	Females	M/F Sex Ratio	Source
Ontario	Lake Sasajewun	45.5	17	26	0.654	Galbraith et al. 1988
Ontario	Broadwing Lake	45.5	5	4	1.250	Galbraith et al. 1988
Quebec	Lake Champlain	45	27	28	0.964	Mosimann and Bider 1960
Michigan	Lower Peninsula	43–44	74	77	0.961	Lagler and Applegate 1943
Ontario	West Pond	43.25	47	24	1.958**	Galbraith et al. 1988
New York	Hudson River Bay	42	75	46	1.630**	Kiviat 1980
Michigan	ES George Reserve	42	97	80	1.213	Congdon et al. 1986
Nebraska	Island Lake	41.7	214	96	2.229**	This paper
Nebraska	Blue Creek Pond	41.5	15	14	1.071	Iverson et al. 2000
Illinois	Gilbert Lake	40	16	3	5.333**	Tucker and Lamer 2004
Illinois	Swan Lake	40	18	16	1.125	Tucker and Lamer 2004
Illinois	Lower Stump	39	13	3	4.333**	Tucker and Lamer 2004
West Virginia	Pond 39 and Pond 40	38	23	26	0.885	Major 1975
Tennessee	Tennessee River	33.9	14	8	1.750	Froese and Burghardt 1975
South Carolina	Savannah River Plant	33	21	8	2.625**	Congdon et al. 1986
South Carolina	Savannah River Plant	33	55	21	2.619**	Gibbons and Lovich 1990
Florida	McCord Pond	30.5	30	25	1.200	Aresco et al. 2006
Florida	Canal System	25.25	25	24	1.042	Johnston et al. 2008

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Juvenile snapping turtles, at least in the western Sandhills, often are washed ventrally with orange or yellow-orange pigment, possibly a reflection of diet.

Table 3. Density and biomass estimates for snapping turtles.

Location	habitat (ha)	density (#/ha)	biomass (kg/ha)	Source
Ontario	bog (5.5)	2.73	17.94	Galbraith et al. 1988
Ontario	lake (27.5)	2.03	13.5	Galbraith et al. 1988
Ontario	marsh (261)	4.4	25.8	Hogg 1975, Galbraith et al. 1988
Ontario	pond/marsh (9.8)	65.91	341.3	Galbraith et al. 1988
Wisconsin	lake (18.0)	1.9–2.2	—	Pearse 1923, Petokas 1981, Galbraith et al. 1988
South Dakota	lake (23.9)	1.2	9.1	Hammer 1969, Iverson 1982
South Dakota	lake (91.1)	1.01	8.9	Hammer 1972, Galbraith et al. 1988
New York	tidal marsh (154)	4.0	23.0	Kiviat 1980
Michigan	swamp/pond (7.3)	13.3	30.0	Congdon et al. 1986
Michigan	marsh (4.0)	12.8	33.9	Congdon et al. 1986, Congdon and Gibbons 1989
Michigan	farm/pond (0.6)	6.8	15.9	Congdon et al. 1986
Michigan	lake (40.5)	4.69	21.91[a]	Lagler 1943
Michigan	lake (16.2)	1.54	6.42[a]	Lagler 1943
Michigan	lake (8.1)	2.59	—	Lagler 1943
Nebraska	pond (0.71)	50.7	242	Iverson et al. 2000
Nebraska	lake (298)	2.32	19.35	This study
West Virginia	pond (0.4)	55.0	—	Major 1975
West Virginia	pond (0.4)	67.5	—	Major 1975
Indiana	swampy bay in lake (4.5 ha)	4.44	25.51	Smith et al. 2006, and unpublished
Illinois	lake (30)	4.99	19.01	Dreslik et al. 2005
Illinois	pond (2)	6.5	21.5	Reehl et al. 2006
Illinois	lake (125)	0.104	0.434	Tucker and Lamer 2004; Tucker, pers. comm.
Illinois	lake (101)	0.188	1.497	Tucker and Lamer 2004; Tucker, pers. comm.
Illinois	lake (1174)	0.029	0.207	Tucker and Lamer 2004; Tucker, pers. comm.
Oklahoma	pond (2.1)	22	52	Stone et al. 2005
Oklahoma	pond (1.0)	10	17	Stone et al. 2005
Oklahoma	pond (0.4)	49	166	Stone et al. 2005
North Carolina	pond (0.4)	27.5	153	Brown 1992
Tennessee	pond (0.81)	59	181.3	Froese and Burghardt 1975, Iverson 1982
South Carolina	Carolina bay (10.0)	8.0	21.6	Congdon et al. 1986, Congdon and Gibbons 1989
South Carolina	farm/pond (1.1)	7.3	20.6	Congdon et al. 1986
Florida	pond (1.5)	43.0	261	Aresco et al. 2006
Florida	pond (0.5)	22.0	69.5	Aresco et al. 2006
Florida	pond (1.0)	3.0	10.6	Aresco et al. 2006
Florida	lake (405)	0.04	0.10	Aresco et al. 2006
Florida	canal (0.18)	34.3	72.6	Johnston et al. 2008

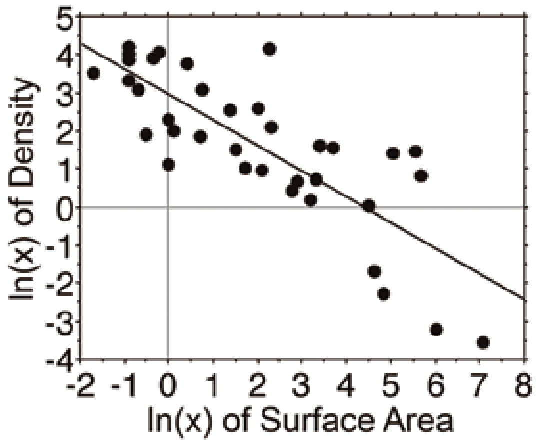
[a] estimated from CL/BM regression in Iverson (1984) based on Lagler and Applegate (1943) for Michigan turtles.

biomass of 5,049 kg. However, since 87 turtles (717.5 kg) were removed from Island Lake at the beginning of the study, a more justifiable estimate of the subadult and adult population of snapping turtles in the lake would be 690 (603 + 87), estimated to weigh approximately 5,767 kg.

These estimates would suggest a density of 2.32 subadults and adults per ha in Island Lake (or 3.30 per ha if the area with depths over 1 m are excluded). Similarly, standing crop biomass across the entire lake would be estimated at 19.35 kg/ha (27.59 if the area over 1 m depth is excluded).

Discussion

Sex ratios of fyke net and airboat samples were decidedly male-biased in our study, a pattern observed in most (but not all) other studies of snapping turtles (Table 2). Because we believe that airboat captures are likely to be more random than fyke net captures, we are confident that the sex ratios in our samples reflect the true population sex ratio. That every statistically significant sex ratio reported in this study (Table 1) and in the literature (Table 2) was male-biased is noteworthy.



Relationship of the natural log of wetland area and the natural log of snapping turtle (Table 3) density for 36 study populations (r = -0.67; P < 0.0001).

Given that snapping turtles exhibit temperature-dependent sex determination (i.e., sex is determined by nest temperatures during the middle third of incubation; Yntema 1979), the bias at our site may be a consequence of typical incubation temperatures. Snapping turtle nests at our field site average 174 mm to the top and 257 mm to the bottom of the eggs (mean 215.5 mm; Iverson et al. 1997). Mean hourly July soil temperatures at 20 cm depth at our refuge temperature station in full sun on the side of a south-facing sandhill (i.e., the warmest possible site available) averaged 25.68 °C in 1997, 21.01 °C in 1999, 28.78 °C in 2003, and 26.18 °C in 2004, most being well below the male-female pivotal temperature expected at this latitude (ca. 28 °C) and within the range of temperatures producing mostly males (Ewert et al. 1994). Hence, the skew in sex ratio in at least this population may most likely be explained by incubation temperatures rather than biased sampling, differences in age at maturity, differential mortality, or differential movements (Gibbons 1990).

Seasonal variation in the sex ratio of samples of snapping turtles has not previously been reported. Our July/August samples were about four times more skewed toward males than our other seasonal samples (Table 1). This suggests a distinctive post-nesting niche and/or activity difference between the sexes that deserves further study.

The density (2.32/ha) and biomass (19.35 kg/ha) of snapping turtles in Island Lake was similar to that reported for other lakes across the species' range (Table 3). Densities in 12 other lakes ranged from 0.03 to 4.99 per ha (mean 1.71), and standing crop biomass in 10 other lakes ranged from 0.10 to 21.91 kg per ha (mean 8.11 kg). Galbraith et al. (1988) showed that snapping turtle density was inversely related to wetland surface area for 16 published studies. Our analysis of density data for 36 studied populations of snapping turtles supports the conclusion of Galbraith et al. (1988). This pattern no doubt reflects the facts that: (1) Smaller wetlands can be more completely sampled than larger ones; (2) smaller wetlands are likely to have higher overall primary productivity, because production is presumably lower in the open water of larger water bodies; and (3) snapping turtles typically exploit shallow water environments, and in larger, deeper wetlands, most of the surface area may actually be only rarely used by turtles.

Although our work and those of others suggest that snapping turtle densities are relatively low in large lakes such as Island Lake, given the high incidence of birds in their diet, their impact on managed waterfowl species is still unclear. Snapping turtles might depredate only small, unmanaged species such as coots, but only detailed feeding studies (including fecal analysis) of telemetered turtles will reveal the impact of snapping turtles on managed species such as ducks, geese, and swans.

Acknowledgments

Although Henry Fitch published very little on turtles, his autecological approach to studies of reptiles provided the early (and essential) inspiration for Iverson's career path. Refuge managers Neil Powers and Mark Koepsel authorized this study; Monty Shaul and Charley Chadwick piloted the airboats; and Marlin French collected the data from the airboat captures. John Tucker provided valuable unpublished data. Joe Augustin of Lilly Library at Earlham tracked down obscure publications.

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Some Natural History Notes on the Brooding Behavior and Social System of Two Oklahoma Skinks, *Plestiodon fasciatus* and *Plestiodon obtusirostris*

Cybil N. Cavalieri and Stanley F. Fox

Department of Zoology, Oklahoma State University, Stillwater, Oklahoma 74078, USA

Photographs by the senior author.

The purpose of this study was to quantify the social and reproductive behavior of *Plestiodon fasciatus* and *P. obtusirostris*. We conducted laboratory experiments with brooding behavior and field experiments to test for mate-guarding and territoriality. To determine the use of space by both species, we conducted a mark-recapture study. We constructed two permanent 1-ha trapping grids of can pitfall traps and cover-boards, with an inter-trap distance of 10 m. One was in a mixed woodland-grassland habitat and one in a grassland habitat. We manipulated the hydric environment to determine parental behavior of brooding female *P. obtusirostris*. We size-matched male *P. fasciatus* and *P. obtusirostris* for dyadic encounters with and without females and both on and off home ranges in order to determine social behavior. Change in hydric conditions did not induce female *P. obtusirostris* to move eggs to more suitable nest sites in our experiments. *Plestiodon fasciatus* exhibited behavior associated with mate-guarding. *Plestiodon obtusirostris* did not display behavior associated with territoriality, and our experiment examining mate-guarding calls for a more intensive study.

Natural history is ultimately the foundation of all research at the organismal level. Without a basic understanding of a species' natural history, conclusions regarding the toxicology, population genetics, developmental biology, or physiology of that species cannot be drawn, nor can any knowledge in these fields or others be placed in proper context. Yet the study of natural history has increasingly become less popular in lieu of more specialized fields. The bloom of natural history studies dealing with herpetofauna in the United States mostly took place in the 1940s and 1950s. These days, natural history information on U.S. herpetofauna is still gathered, but usually subsidiary to other main objectives, such as conservation status, ecological genetics, or phylogeography. The herpetofauna of the United States is arguably the most well known in the world. Despite this and the fact that *Scincella lateralis*, for example, is one of the most common lizards in the southeastern United States, little is known of its ecology (most of which is anecdotal), and what research has been done is contradictory (Fitch and Greene 1965, Lewis 1951, Fitch 1970, Collins and Conant 1998).

Much of our current knowledge of skink natural history is built upon anecdotal evidence based on single observations without regard to the rigor of the account; very little of our knowledge is based on detailed field studies or experimental work. The recent taxonomic elevation of *Plestiodon septentrionalis* subspecies into the full species *P. septentrionalis* and *P. obtusirostris* (Powell et al. 1998) raises the question of whether these two species might differ in their natural history and behavior. *Plestiodon obtusirostris* reportedly exhibits coiling around and brooding of eggs, manipulation or retrieval of eggs, communal care of eggs or young, and, because it is a close relative of *P. septentrionalis*, possibly shows hydroregulation and thermoregulation of the nest site, oophagy of bad or unfertilized eggs, parental assistance and

Cover-board being checked for skinks at the grassland site near Stillwater, Oklahoma.