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DEMOGRAPHY OF A SMALL POPULATION OF LOGGERHEAD MUSK TURTLES (*Sternotherus minor*) IN THE PANHANDLE OF FLORIDA

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The loggerhead musk turtle (*Sternotherus minor*) is a small, aquatic species restricted to the southeastern United States and thought to prey primarily on invertebrates (Tinkle 1958). In Florida, the animal is currently recognized as *S. m. minor* (Agassiz 1857). Much of what we know of this animal is based on studies conducted within spring and spring run habitats (e.g., Marchand 1942, Cox and Marion 1979, Cox et al. 1988, 1991) and these habitats have been considered optimal for the species (Chapin and Meylan 2011). However, loggerhead musk turtles can be found in many different types of wetlands (Ernst et al. 1994) and little research has been conducted on the species in these other habitats for comparison.

The clear water of springs and spring habitats facilitates use of a sampling method (i.e., goggling, Meylan et al. 1992) that is unlikely to be effective in other habitat types. This method is relatively efficient at detecting loggerhead musk turtles in riverine systems (Huestis and Meylan 2004, Sterrett et al. 2010), but it is important to consider sampling-specific biases when making population-level inferences. Trapping is a common and standardized method of capturing turtles, but there are few published accounts of trapping efforts for loggerhead musk turtles (e.g. Sterrett et al. 2010).

The probability of detecting a species when it is present is often assumed to be 100%, though this is unlikely to be true (MacKenzie et al. 2002). Failing to incorporate heterogeneity in detection probability is likely to bias abundance estimates, and this is perhaps particularly true for reptiles (Mazerolle et al. 2007). For example, unequal catchability of individual turtles may limit the ability of population models to produce useful or accurate estimates (Koper and Brooks 1998). Given the imperiled status of turtles worldwide as well as few natural history studies of loggerhead musk turtles in varied habitats, we undertook an intensive trapping study over a relatively short time-scale in an impounded stream in northwestern Florida. We used mark-recapture to generate a population estimate informed by capture probability.

Study Site

Our study site was a pond located on Eglin Air Force Base, Okaloosa County, Florida (Figure 1). The pond (approximately 0.71 ha, as determined via Google Earth and AutoCAD v. 2007) was impounded on its north end where it leads into a culvert under a road. A beaver dam was also present on the north end near the culvert; thus the creation of the pond was likely influenced by both beaver activity and flows altered by the culvert. The pond was formed along a tributary of the Yellow River, roughly 2 km downstream of the steephead ravine from which the tributary originated, and 1.5 km upstream from the point at which the channel becomes obscured as it flows into a floodplain swamp. The creek draining into the pond was sand-bottomed and fed from seepage springs.

Vegetation surrounding the north end of the pond was characterized by black gum (*Nyssa sylvatica*), sweet bay magnolia (*Magnolia virginiana*), black titi (*Cliftonia monophylla*), swamp titi (*Cyrilla racemiflora*), water oak (*Quercus nigra*), and laurel oak (*Q. hemisphaerica*) near the water's edge, with mimosa (*Albizia julibrissin*) and sand pine (*Pinus clausa*) farther from the water. The uplands surrounding the remainder of the pond could be characterized as fire-suppressed longleaf pine (*Pinus palustris*) sandhills, with a midstory of oaks (*Quercus* spp.), chinkapin (*Castanea pumila*), yellowleaf hawthorn (*Crataegus flava*), yaupon (*Ilex vomitoria*), and saw palmetto (*Serenoa repens*). The pond was relatively shallow (likely not exceeding ~2 m in depth) with emergent herbaceous vegetation in shallow edges. Coarse woody debris was abundant in the pond; much of the submerged wood was partly obscured from sight by algae and other submergent aquatic vegetation.

Methods

We trapped turtles from 21 August 2009 through 5 October 2009 using crayfish traps (Johnson and Barichivich 2004). Traps were of rectangular mesh (2.5 × 1.25 cm) and consisted of three funnels (4.5 cm opening) leading into a trap body; a neck on the top of the trap emerged from the water to allow trapped animals to breathe. Crayfish traps and their use are described in detail in Johnson and Barichivich (2004). Eight traps were employed between 21 August and approximately 28 August, at which point one trap was lost. The seven remaining traps were used until 8 September. On this date and for the

Figure 1. Wetland trapped for loggerhead musk turtles (*Sternotherus minor*) 21 August 2009 through 5 October 2009, Okaloosa County, Florida.

duration of the study, five additional traps were put in use, for a total of twelve traps. Traps were checked daily except on two occasions, when they were checked after two days. All traps were baited with sardines until 16 September. After this date, we baited eight traps and left four unbaited. Bait was replaced as needed. Given the relatively small size of our study wetland as well as the movement patterns demonstrated by the closely-related stripe-necked musk turtle (*S. minor peltifer*; i.e., up to 61 m in 2 hours, Ennen and Scott 2008) and other species of the same genus (e.g., Rowe et al. 2009), we assume all individuals in the population were available to sample with our traps.

Upon initial capture, all turtles were held to take measurements and generally released the next day (four turtles were held for five days and one turtle was held four days). Measurements included mass, straight-line carapace length and width, plastron length, and head width. Turtles were given individual marks by marking marginal scutes (Cagle 1939). Finally, we examined turtles for the presence of leeches (*Placobdella* sp.). Sex was determined based on secondary sexual characteristics; specifically, turtles were designated as males if the cloaca extended past the carapace (Ernst et al. 1994). We considered turtles as juveniles if their carapace length was less than 60 cm (Etchberger and Ehrhart 1987, Etchberger and Stovall 1990) except for one individual male (53.1 cm CL) that was clearly identifiable.

We used a Huggins Closed Capture model (Huggins 1989) in Program MARK 6.0 (White and Burnham 1999) to estimate population size. By assuming that the population is closed (no deaths, immigration, or emigration) over the sample period, the closed capture models are able to estimate population size by modeling the probability of initial capture and the probability of recapture. We used the Huggins Closed Capture model because it allows for the incorporation of covariates such as age and sex (Huggins 1989) in the estimation of initial capture and recapture. We developed a set of *a priori* models to determine the best method of modeling capture and recapture probabilities. Models included those in which we modeled these capture probabilities as a function of age (adult vs. juvenile) and group (juvenile, male, and female). Since our trapping effort was haphazard, we also included models that allowed capture and recapture probability to vary depending on the number of traps used on a given night (Table 1). We ranked models using Akaike's Information Criterion (AIC), adjusted for small sample size (AIC_c, Burnham and Anderson 2002). To aid in interpretation of results, we also calculated the difference between the best model (the best model being the one with the lowest AIC_c value) and any other model (ΔAIC_c), as well as the probability that any given model that we built was the best model within the model-set (w_i, Table 2, Burnham and Anderson 2002). The best model was the model that allowed recapture probability to vary as a function of age and assumed that the probability of initial capture was constant across individuals; we used this model to derive our population estimate. We determined whether the observed sex ratio of adults differed from 1:1 with a chi-square test.

Table 1. AIC_c table of Huggins closed capture models built to describe the probability of capture (p) and recapture (c) of loggerhead musk turtles as functions of age, sex, and number of active traps (trap). Model weight and total parameters are indicated by w_i, and k, respectively.

Model	AIC_c	ΔAIC_c	w_i	k
c(age)p(.)	518.13	0.00	0.24	3
c(age)p(age)	518.70	0.57	0.18	4
c(sex, trap)p(.)	518.85	0.71	0.17	4
c(.)p(.)	519.91	1.78	0.10	2
c(group)p(.)	520.13	2.00	0.09	4
c(.)p(age)	520.48	2.35	0.08	3
c(.)p(group)	521.88	3.74	0.04	4
c(age)p(trap)	521.91	3.77	0.04	3
c(sex)p(sex)	522.11	3.98	0.03	6
c(sex, trap)p(trap)	522.28	4.15	0.03	5

Table 2. Morphological data and associated parameters for 25 loggerhead musk turtles captured in a beaver pond in Okaloosa County, Florida, August-October, 2009. Mass is reported in grams. Carapace length (CL), carapace width (CW), shell depth (Depth), plastron length (PL), and head width (HW) are reported in mm.

Sex	Mass	CL	CW	Depth	PL	HW	Leeches[a]
F	62	74.2	53.8	31.9	52.6	13.1	2
F	54	69.5	53	27.4	49.7	12.4	5
F	77	80.2	55.8	33	56.4	13.8	2
F	69	75.3	52.1	32.6	51.2	12.9	5
F	77	79.8	54.1	35	58	12.9	1
F	65	72.9	54	33.2	51.8	12.5	12
F	91	84.2	57.4	35.5	62.9	13.7	2
F	75	80.1	56.6	35.2	57.1	13.5	3
J	25	54.3	39.2	24.2	37.3	10.3	2
J	21	53.7	41.1	21.7	36.3	8.9	7
J	26	58.1	42.8	23.9	39.8	10	5
J	7	38.4	32.3	16.3	25.6	6.6	3
M	89	84.2	62.6	33.6	55.8	14.2	4
M	45	67.9	47.9	27.3	46	12.3	1
M	47	70	51.3	28.8	46.9	11.2	3
M	90	88.2	58.7	32.7	59.8	16	1
M	51	68.6	49.1	27.2	47.2	13.6	3
M	87	85.7	58.4	33.9	56.9	14.8	2
M	81	81.6	57.1	33.1	57	14.7	2
M	88	84.4	58.3	34.1	57.2	15.3	4
M	97	88.1	58.7	34.5	62.8	16.2	12
M	33	60.4	44.3	25.2	39	10.6	10
M	98	82.9	57.5	32	55.9	14.1	13
M	55	73.7	51.3	32	55.9	12.8	9
M	23	53.5	42.2	21.1	35.4	9.2	0

[a] Total number of leeches (*Placobdella* sp.) found on individual turtles upon first capture.

RESULTS

We captured 25 individual loggerhead musk turtles (Figure 2) a total of 71 times over the course of the study. Loggerhead musk turtles were recaptured, on average, 2.8 times (range 1-7, standard deviation = 1.89). We estimated that there were 4.38 juveniles (standard error = 0.74, 95% confidence intervals 4.03-8.37), 14.29 males (standard error = 1.64, 95% confidence intervals 13.19-21.82), and 8.83 females (standard error = 1.20, 95% confidence intervals 8.10-14.64) in the population (a total population estimate of 27.5). We observed a 1:1.63 ratio of females to males, which did not differ from 1:1 (P = 0.28). Based on our observed numbers and confidence intervals surrounding our population estimates, we estimate there were between 25 and 45 individuals in the population and a population density of 35.21-63.38 turtles/ha.

Figure 2. Loggerhead musk turtle (*Sternotherus minor*) captured within study wetland, Okaloosa County, Florida.

DISCUSSION

Our population-size estimates for loggerhead musk turtles differ markedly from previously published estimates for populations of the species in central Florida (e.g., thousands of individuals, Chapin and Meylan 2011), or densities (127/ha, Meylan et al. 1992, 2,857/ha, Cox and Marion 1979, Iverson 1982). Therefore, our results are consistent with the suggestion that ponds are suboptimal habitat for loggerhead musk turtles as compared to other spring runs in central Florida (Chapin and Meylan 2011), at least in terms of turtle density. It is unlikely that ponds represent the best habitat for loggerhead musk turtles in the Florida Panhandle, as the species is thought to be associated with higher-order streams in the area (Enge 2005). As has been observed for the genus elsewhere (Dodd 1988), turtles at our site were parasitized extensively by leeches (up to 13 leeches; mean = 4.52 leeches, standard deviation = 3.8). We captured only one individual without any leeches (Table 2).

By conducting an intensive trapping effort in a small pond over a relatively short time-span, we were able to assume the population was closed to emigration, immigration, births, or deaths, and to generate population estimates with relatively narrow confidence intervals. That our population estimate was nearly identical to our observed numbers suggest we can be reasonably confident we captured the majority of adult turtles within the population. Juveniles made up a majority of a loggerhead musk turtle population elsewhere (Onorato 1996) and we captured relatively few. Small turtles may have been able to escape through the mesh of our traps and juveniles were recaptured relatively infrequently (1-2 occasions); therefore, we may have underestimated the number of juvenile turtles in the population. Similarly, although we captured relatively large turtles (up to 88.2 mm carapace length; Table 2), some large individuals may have been unable to enter trap funnels.

Crayfish traps (Johnson and Barichivich 2004) might not be an appropriate method to sample loggerhead musk turtles in lotic habitats such as spring runs because of high flow and deep water. However, we demonstrate that this technique can be used to effectively sample loggerhead musk turtles in a relatively small wetland. In this case, in addition to generating population estimates with relatively little effort, we also collected natural history information for a species about which we know little, particularly in ponds.

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