Sex Ratio of Common Musk Turtles (Sternotherus odoratus) in a North-Central Indiana Lake: a Long-Term Study

ABSTRACT.—We studied the sex ratio of a population of common musk turtles (*Sternotherus odoratus*) from Dewart Lake in north-central Indiana. From 1979 to 2000 we trapped *S. odoratus* nearly annually using wire traps or fyke nets. Sex ratios were consistently male biased (average = 64.9% males) and did not vary between trap types or time of day. Available evidence points to differential mortality of the sexes as a possible cause for the biased sex ratios. However, additional work is needed.

INTRODUCTION

Observed sex ratios can be indicators of ecological processes occurring in a population. Because selection is likely to lead to the evolution of a 1:1 sex ratio (Fisher, 1930), deviations from a 1:1 sex ratio in a population demand an explanation. Biased sex ratios (male or female) could be caused by a number of possible mechanisms, each of which might be important to understanding a population's dynamics and characteristics. For example, sex ratios in turtle populations diverging from 1:1 may be the result of differential mortality, differential activity, differential habitat use, temperature-dependent sex determination or simply trapping bias.

In natural populations of turtles, sex ratios often vary significantly from the expected 1:1 ratio (*see* review in Gibbons, 1990). In the common musk turtle, *Sternotherus odoratus*, observed sex ratios have been observed to vary from strongly female biased (74% female; Dodd, 1989) to strongly male biased (72.1% male; Edmonds and Brooks, 1996). We studied the sex ratio of a single population of *S. odoratus* in a lake in northern Indiana for 21 y (1979–2000).

We attempted to answer the following questions. What is the sex ratio of this population of *Sternotherus odoratus*? Have sex ratios varied over the 21 y of this study? Do sex ratios vary during the day? Do they differ between trap types? The answers to these questions can lead us to a better understanding of the structure of this and other populations of turtles and indicate areas for future investigation.

MATERIALS AND METHODS

We studied a population of *Sternotherus odoratus* in the marsh at the SE end of Station Bay in the SE corner of Dewart Lake (area of our study area = 4.5 ha) near Syracuse, Kosciusko Co., Indiana (41°22′N, 85°45′W). This population was sampled 14 times from 1979 to 2000 using a variety of trapping methods. Each trapping session typically lasted 3–5 d, and occurred between July 15 and September 1. Surveys before 1993 used 6 to 15 aquatic wire funnel traps baited with canned sardines or fresh fish (*see* Iverson, 1979). After 1992, we exclusively used fyke nets (N = 3 to 8) deployed with 50 ft leads between a pair of 3 ft diameter hoop traps. Traps were placed throughout the bay, or in the case of fyke nets, in a continuous wall across the width of Station Bay. Traps were checked every 2–3 h from sunrise to 1–2 h postsunset. No species of turtle entered the traps during the night. For each trap check, we recorded the number of male and female musk turtles, sexed them on the basis of relative plastral sizes (smaller in males), tail size (larger in males), and presence of scale patches on the rear legs (lacking in females) (*e.g.*, Risley, 1930). All captured turtles were retained and released at the end of the trapping session.

A previous study of *Sternotherus odoratus* (Edmonds and Brooks, 1996) found a significant relationship between sample size and sex ratio. However, we did not find any relationship between sample size and the proportion of males in the sample (N = 14, r^2 = 0.10, P = 0.27). Therefore we did not set a minimum sample size for inclusion in our statistical analyses.

To facilitate statistical analyses of sex ratios, we used the proportion of males in a sample as the dependent variable. Proportions were transformed, when necessary, using an arcsin square-root transformation to conform to the assumptions of parametric statistical analyses. We determined if the sex ratio over the years studied were biased by comparing the distribution of sex ratios over the entire study period (1979–2000) to a hypothetical 1:1 sex ratio using a one-sample *t*-test vs. a proportion of

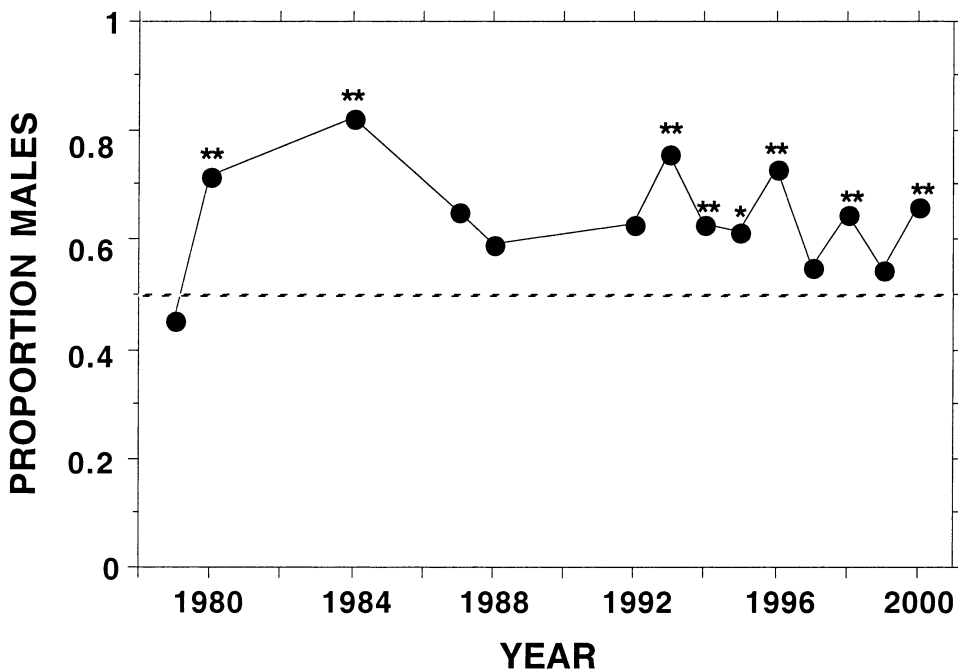[1] Corresponding author: e-mail: smithg@denison.edu

FIG. 1.—Proportion of males in samples from a population of *Sternotherus odoratus*. Dashed line is a 1:1 sex ratio, and the solid line is the mean proportion of males. Proportions marked with * are significantly different from a 1:1 sex ratio at the 0.05 level, and those marked with ** are significant at the 0.01 level

0.5 (using the transformed value). We determined if each year's sex ratio differed from 1:1 using chi-square tests. We compared sex ratios between trap types (wire vs. fyke) using an unpaired *t*-test. To determine whether there was a diel change in the sex ratio, we compared the sex ratios of turtles caught in the morning (0600–1200) to the sex ratios of turtles caught in the afternoon/evening (after 1200) for a pooled 1993 to 2000 data set (*i.e.*, only fyke net years) using a chi-square test. We determined whether sex ratios varied depending on when the turtles were captured (*e.g.*, early in a trapping session vs. late) (data limited to 1995–2000; years for which there were the largest sample sizes) using a paired *t*-test. Means are given ±1 SE.

RESULTS

Combining all captures we found an overall sex ratio of 451 males to 266 females or 62.9% males. Sex ratios for individual sampling periods were consistently male biased (Fig. 1; mean proportion males = 0.649 ± 0.026, N = 14; df = 13, t = 5.17, P = 0.0002). Trap type had no effect on observed sex ratio (wire trap: 0.657 ± 0.052, N = 6; fyke net: 0.643 ± 0.027, N = 8; df = 12, t = 0.27, P = 0.79).

In the morning the sex ratio was 1.63 males to 1 female (244 males: 150 females), and in the afternoon the sex ratio was 1.98 males to 1 female (127 males: 64 females), but the differences were not statistically significant (df = 1, χ^2 = 1.16, P = 0.28).

Comparison of the proportion of males captured during the first day of trapping (early) vs. the proportion of males captured during the last day of trapping (late) revealed no difference (paired *t*-test; df = 5; t = 1.09, P = 0.33).

Discussion

Observed sex ratios for this population of common musk turtles were consistently male-biased during our study (mean ≈ 65% male), as well as for a study conducted at Dewart Lake in the early 1960s (58.5% male; Wade and Gifford, 1965). These sex ratios also did not vary by time of day. Sex ratios have been reported for several populations of *Sternotherus odoratus* from throughout its range. Populations with male-biased, female-biased and essentially 1:1 sex ratios have been observed, but no pattern or trend to explain the variation among populations is apparent (reviewed in Iverson and Meshaka, *in press*), although it warrants additional investigation.

The consistently male-biased sex ratio found in this population of common musk turtles begs for an explanation, although our results do not allow us to choose among several potential explanations. (1) The male-biased sex ratio may result from differential mortality, with males surviving better than females. Lower mortality in males has been postulated to help explain male-biased sex ratios in a population of *Sternotherus odoratus* in Ontario, Canada, where males are more abundant than females in every large size class, suggesting that they possibly live longer than females (Edmonds and Brooks, 1996). However, Mitchell (1988) found that male and female *S. odoratus* had similar survivorship rates, with males actually having slightly lower survivorship estimates than females. Because we lack long-term survivorship data for our population, we cannot exclude this explanation for male-biased sex ratios in our population.

(2) The male-biased sex ratio may result from males being more active than females, thus making them more likely to be caught in the traps. Previous studies on *Sternotherus odoratus* have found males make longer movements than females (*e.g.*, Mahmoud, 1969; but *see* Bancroft *et al.*, 1983), and have larger home ranges (Mahmoud, 1969; Edmonds, 1998), suggesting this as a possible explanation for our results. However, our observed sex ratios did not differ between the first day of trapping each year and the last day of trapping. Since we held all turtles, this suggests that differential activity levels may not explain our results since one would expect the sex ratio to become less male-biased late in a trapping session as all the more active males were captured early in the session.

(3) The male-biased sex ratio may result from differential habitat use. We know of no existing information on differential habitat use by male and female common musk turtles in ponds and lakes. Although we cannot exclude this hypothesis, our trap arrays spanned nearly all available aquatic microhabitats from 0.5 m to over 1 m in depth (from water lily patches, to duckweed-covered pools, to areas of thick submergent vegetation to open water).

(4) The male-biased sex ratio may result from temperature-dependent sex determination (TSD). Common musk turtles exhibit TSD (Vogt *et al.*, 1982; Ewert and Nelson, 1991). Edmonds and Brooks (1996) suggested a scenario whereby TSD could contribute to a male-biased sex ratio through occasional variations in environmental temperatures that support male-biased hatching ratios (*i.e.*, colder summers) while the typical year would produce 1:1 hatching ratios. This pattern would result in male-biased sex ratios on average. We think that such an explanation is unlikely to explain the continuous male-biased sex ratio over the 20 y of this study (40 y if one includes Wade and Gifford, 1965); however, we cannot completely exclude the possibility.

(5) Our results refer only to the observed sex ratio of turtles captured using these traps. We do not know whether or not these observed sex ratios are the same as the actual adult sex ratios of our population. Our sampling techniques may be biased in favor of capturing males or against catching females. Recent studies of sex ratios in turtles have found no differences in observed sex ratios using different capture methods in the same population (*e.g.*, Lovich and Gibbons, 1990; Georges *et al.*, 1993; Burgin *et al.*, 1999); however, Ream and Ream (1966) did find that baited hoop traps differentially captured male painted turtles (*Chrysemys picta*). We think that our observed sex ratios are good estimates of actual sex ratios. For example, we found no differences in sex ratios between the two methods we used in our study. In addition, our methods are similar to methods used by others to collect such estimates, and many of those are not sex-biased or are significantly female-biased, suggesting that our population is indeed different from most other populations (but also *see* Edmonds and Brooks, 1996). The lack of any effect of the day of trapping (*i.e.*, first day vs. last day of a trapping session) is further evidence that the sex ratios we observed are truly representative of our population. If trap-bias were to explain the observed sex ratio, one would expect a decrease in the proportion of

males captured within an annual trapping session (*see* above #2), something we did not see. Whether or not our estimates reflect the actual adult sex ratio, or only reflect an ''activity'' sex ratio should not detract from our main finding of male bias. Such a sex-ratio suggests that males and females, at the least, behave differently in this population. Additional demographic research is needed to differentiate among these possible explanations for our observed male-biased sex ratios.

Because the sex ratios of all our samples of this population have remained consistently male-biased during 21 y of study (even longer if one includes the results in Wade and Gifford, 1965), the mechanism behind this bias must have been at work for over the past 20–40 y. We suggest that long-term studies on sex ratio may help focus research on potential causes of why sex ratios deviate from 1:1.

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