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SEASONAL ACTIVITY AND MOVEMENTS OF BOG TURTLES (*CLEMMYS MUHLENBERGII*) IN NORTH CAROLINA.—Movements within and among animal populations have numerous causes and consequences. In a recent review of movement patterns in turtles, Gibbons et al. (1990) listed four major causes of intrapopulational movements, including (1) feeding, (2) reproduction (mate seeking, courtship, and nesting), (3) basking, and (4) seeking favorable sites in which to hide or remain dormant for variable periods of time. Gibbons and his coauthors defined extrapopulational movement as "terrestrial departure from a circumscribed aquatic habitat or any long distance movement of more than 0.5 km." These extrapopulational movements are essentially motivated for the same reasons but also include departure from unsuitable habitats and migration from the nest by hatchlings. Although it is often difficult to determine the cause of movements in turtles, some consequences, such as genetic exchange between populations, are readily apparent (Scribner et al., 1986). Sanderson (1966) noted that, because techniques for locating and observing animals are far ahead of techniques for interpreting the data, emphasis should shift from the movements themselves to the reasons for the movements.

In this paper we describe and compare the seasonal activity cycles of male and female bog turtles (*Clemmys muhlenbergii*) from populations in western North Carolina and compare seasonal activity cycles in western North Carolina with those reported for other regions. In addition, we provide data on short-term movements of several individuals in one population. We define movement as linear displacement between two points of capture under the assumption that such displacements are unidirectional. Because male turtles of many species move greater distances and more frequently than females at certain times of the year due to divergent reproductive strategies (Morreale et al., 1984), we predicted that male *C. muhlenbergii* would exhibit greater rates of movement than would females.

Materials and methods.—Twenty-nine disjunct study sites in 11 North Carolina counties were visited periodically from 1975–89. The exact location of these sites is confidential due to the threatened status of the bog turtle in North Carolina (Herman, 1989a, 1989b). Field collecting efforts were concentrated from April–Sept. A total of 276 specimens were captured 382 times. All turtles were hand collected, sexed using characters given by Ernst and Barbour (1989), and marked for future identification by cutting notches in the marginal scutes (Ernst et al., 1974). Seasonal activity data were compared between categories of interest (sex, time interval, locality) using contingency table analysis (Zar, 1984) under the null hypothesis that rows and columns were independent assuming no collector bias or significant year-to-year variation. Activity levels were estimated as the total number of captures and recaptures for all sites during each month. Monthly sampling intensity was weighted by calculating the number of turtles captured per human hour. The decision to combine data for the various study sites was based on the results of a first-order log-linear analysis. Sufficient data were available to test for interactions among monthly activity, sex, and county at the two most highly sampled counties (Macon and Henderson counties, 11 sites). There was no significant difference in monthly activity levels of males and females between counties ($G = 21.84$, $df = 26$, $P = 0.70$).

Radio transmitters were attached to five adult bog turtles (three males, two females) at a 3-ha bog in Henderson County. Specimens were relocated at intervals of between two and 27 days from June through the following April. Because relocations did not occur at equal intervals, data on short-term activity are reported as meters per day (m/d). This measure assumes constant rate of movement. Not all specimens were relocated equally during the period of study due to battery failure on some transmitters. Males and females were relocated a total of 38 and 26 times, respectively. Straight line distances between points of capture were measured in the field with a tape measure. Statistical tests were considered significant if $P \leqq 0.05$.

Results.—Levels of bog turtle activity, as estimated by frequency of hand capture, were highest in the spring for both sexes (Fig. 1). This perceived activity pattern was unaltered by the use of weighted data based on the number of turtles collected per human hour (Table 1). Peaks in the number of turtles collected per human hour in Aug., Nov., and Dec. (Table 1)

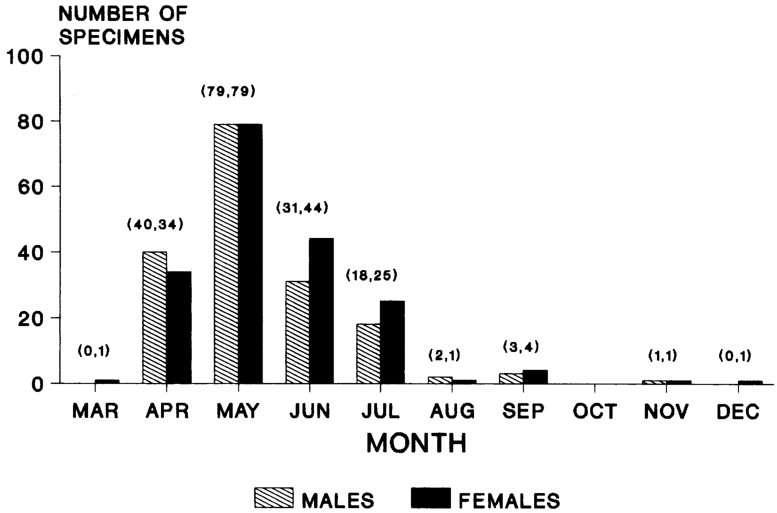

Fig. 1. Monthly levels of activity in 29 North Carolina bog turtle (*Clemmys muhlenbergii*) populations as measured by the total number of captures and recaptures during each month.

are considered to be artifacts of small sample sizes and low search efforts in those months. Sixty-four percent (n = 233) of all adult captures (n = 364) was made prior to June. Of these, 43% (n = 158) of the total was collected in May. In June and July, more females than males were encountered. However, a 2 × 4 contingency-table analysis of male and female captures from April through July revealed no significant differences in monthly frequency of captures between the sexes ($\chi^2 = 3.32$, $P > 0.10$). Arndt (1977) provided the only tabulation of monthly captures (April—10, May—24, June—11, July—5, Aug.–Oct.—5) for a single geographic region (Delaware) that is comparable to our data. A 2 × 5 contingency-table analysis comparing monthly captures from April–Oct. (Aug.–Oct. combined to maintain statistically appropriate cell frequencies) revealed no significant difference between our sample and his ($\chi^2 = 6.2$, $P > 0.10$).

Radio-tagged male and female turtles exhibited different rates of movement (Fig. 2). Males exhibited a median rate of movement of 2.1 m/d, females 1.1 m/d. The difference was statistically significant (Kruskal-Wallis test; H = 3.89; $P = 0.05$). Rates of movement remained fairly constant for males from June through Sept. The mean rate of movement for females during the interval from July to Nov. was 2.3 m/d (range 1.7–3.2 m/d). Small movements were also recorded during the winter months of Dec. and Jan. Distances between relocations ranged from 0–87 m ($\bar{x} = 24.3$ m) for males and 0–62 m ($\bar{x} = 15.8$ m) for females.

Discussion.—Previous studies have reported that *C. muhlenbergii* is most active in the spring (Arndt, 1977; Ernst, 1977). In Delaware, 82% (n = 45) of the captures reported by Arndt (1977) were made prior to July. Following this peak in activity, some *C. muhlenbergii* reportedly aestivate during the drier months (Ernst and Barbour, 1989; Nemuras, 1967). Later, in Sept., they become active again (Arndt, 1977; Ernst and Barbour, 1989) until Oct. when hibernation begins (Ernst et al., 1989). This pattern of bimodal activity is surprising because *C. muhlenbergii* supposedly requires more heat than other syntopic turtle species to initiate activity (Barton and Price, 1955; Ernst and Barbour, 1989). In fact, Barton and Price (1955) reported that the species is active throughout the summer.

Our results are in general agreement with previously published accounts in that most activity, as estimated by frequency of capture, occurs in the spring. We observed no convincing evidence of bimodal activity as reported by Arndt (1977) and Ernst and Barbour (1989). Instead, hand captures declined dramatically in Aug. and remained low until the following April. It is possible that *C. muhlenbergii* populations in North Carolina terminate surface activity earlier in the year because of higher mean monthly environmental temperatures relative to northern localities. Geographic variation in seasonal activity was reported for populations of the congeneric *C. guttata* by Lovich (1988). In that study, populations of *C. guttata* in South Carolina exhibited earlier and shorter cycles of annual activity than populations in Maryland, Ohio, and Pennsylvania. However, comparison of our data with those of Arndt (1977), from Delaware, reveals no significant overall difference.

Male turtles of many species appear to move greater distances and more frequently than females at certain times of the year (Gibbons, 1986; Gibbons et al., 1990; Morreale et al., 1984), and our results suggest that *C. muhlenbergii* is no different. Rates of movement between recaptures for males were almost two times higher than those for females. Sexual differences in rates of movement are expected if male reproductive success benefits by increasing movements in search of females (Lovich, 1990; Gibbons et al., 1990).

Chase et al. (1989) reported that movements determined with thread trailers on *C. muhlenbergii* in Maryland indicated a six-month activity period. Recaptures during July and Aug. suggested movements of only 1–2 m. However, by measuring the total thread trailed, they determined that overall movements were as high as 30 m in less than 24 h in an area of less than 4 m^2. Their data suggest that a small distance between captures is not necessarily indicative of inactivity. Home ranges of males in Maryland ($\bar{x}$ = 0.176 ha) were significantly larger than those of females ($\bar{x}$ = 0.066 ha), with males exhibiting greater variance (Chase et al., 1989). Ernst (1977) reported that the mean home range of male *C. muhlenbergii* in Pennsylvania was 1.33 ha, whereas females had a mean of 1.26 ha. Overland movements of up to 750 m were recorded for bog turtles with radiotelemeters in New York during a four-year study (Eckler et al., 1990).

The apparent lack of correspondence between seasonal measures of activity as shown by monthly incidence of capture (Fig. 1, Table 1) and monthly rate of movement (Fig. 2) is important. In brief, the data based on radiotelemetry indicate that *C. muhlenbergii* in North Carolina are active from Aug.–Dec. when hand captures are minimal or absent. Unlike the data reported by Chase et al. (1989), our data show that movements were not confined to a small area during these months, but instead ranged from 0.3–87 m between captures. We can suggest two possible reasons for the disparity between levels of activity shown by hand capture

TABLE 1. SUMMARY OF MONTHLY CAPTURE FREQUENCY AND EFFORT FOR BOG TURTLES IN NORTH CAROLINA. Totals differ from Figure 1 because juveniles are included in table.

Statistic	Month												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Turtles	0	0	1	75	167	80	46	3	7	0	2	1	382
Days in field	2	4	3	32	72	36	34	5	14	18	3	4	227
Turtles/day	0	0	0.33	2.34	2.32	2.22	1.35	0.60	0.50	0	0.67	0.25	1.68
Human hours	2	10	12	263	561	250	257	12	106	73	3	4	1553
Turtles/human hour	0	0	0.08	0.29	0.30	0.32	0.18	0.25	0.07	0	0.67	0.25	0.25

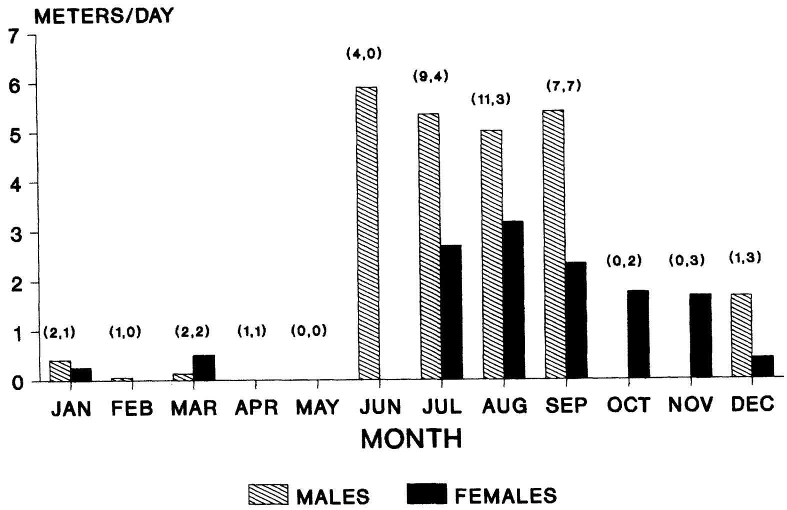

Fig. 2. Rates of movement of radio-tagged bog turtles (*Clemmys muhlenbergii*) at a single site in North Carolina. The numerals in parentheses indicate the number of relocations of males and females (respectively) during each month. Refer to text for details.

and radiotelemetry. First, we, like other collectors, tend to concentrate hand collecting during the early spring months, thus biasing our perception of activity. However, seasonally biased censuses did not appear to affect our estimated activity levels (Table 1) or those reported by Arndt (1977). He calculated the relative monthly catch (number caught per hour of hunting turtles per month) for his data and found almost complete agreement between his raw measure of activity (number of captures per month) and the weighted measure. Second, the proliferation of vegetation in the latter part of the summer makes it very difficult to visually locate and hand collect this small, secretive, semiaquatic species. They are still active at this time in North Carolina but essentially impossible to find without radiotelemetry.

Our data suggest that the predominantly vernal activity cycles reported for *C. muhlenbergii*, and perhaps other similar turtles, may be an artifact of collecting bias and the difficulty of locating turtles at certain times of the year. Detailed studies of movement using radiotelemetry or thread trailers are necessary to determine the true cycle of activity.

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EFFECT OF INTERMALE SPACING ON FEMALE FREQUENCY PREFERENCES IN THE PAINTED REED FROG.—A well-recognized limitation of phonotaxis experiments is that conditions in a test arena are very different from those in a natural chorus. It has been shown that, although females have strong preferences for certain male call characteristics under test conditions, these preferences are not reflected in their choices under natural conditions (Passmore and Telford, 1983; Forester and Czarnowsky, 1985; Gerhardt et al., 1987). This finding has led to the suggestion that the highly complex nature of breeding assemblages may place severe limitations on a female's ability to discern differences among the calls of individual males.

Female painted reed frogs *Hyperolius marmoratus,* show strong preferences for low frequency calls associated with large males in two-choice phonotaxis experiments (Dyson and Passmore, 1988). However this preference is not manifested in natural populations. We have investigated a number of factors that may contribute to this inability of females to discern differences among males' calls in natural breeding assemblages. These include (1) the number of males calling (Telford et al., 1989); (2) the level of background noise (Dyson, 1989); and (3) the timing of male vocalizations (Dyson and Passmore, 1988).

In this study, we investigate the effects of variation in intermale spacing on the ability of females to discriminate between conspecific calls that differ in frequency. We also determine whether Telford's (1985) finding that females preferentially approach the more spatially isolated of three identical stimuli persists when stimuli differ in frequency.