HISTORICAL TURTLE POPULATION DECLINE AND COMMUNITY CHANGES IN AN OZARK RIVER

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ABSTRACT

Turtle populations are declining worldwide yet few long term studies exist to confirm this trend. Mark-recapture data collected in 1969 and 1980 exist for the turtle community inhabiting a 4.6 km section of the North Fork of White River, Ozark County, Missouri. Using the available data, we compared the turtle communities and common map turtle (*Graptemys geographica*) populations observed in the research section in 1969 and 1980. Community composition changes indicated that red-eared sliders (*Trachemys scripta elegans*), a native species that was not observed in the research section in 1969, became established in the research section by 1980. Population estimates for *G. geographica* indicated that the population declined significantly ($N_{1969} = 274$, $N_{1980} = 139$, $z = 3.39$, $P < 0.001$) between 1969 and 1980 and the decline was associated with a marked decrease in the number of large adult females. The loss of large adult female *G. geographica* suggested the decline may have been a result of targeted harvest for the food trade as females of this species attain much larger body sizes and would therefore be preferred for the food trade. The results of this study elucidate changes that occurred in a turtle community and provide a historical baseline for comparison with future studies of this community.

Key Words: turtles, Missouri, *Graptemys geographica*, *Trachemys scripta elegans*, community, population decline, harvest.

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INTRODUCTION

River turtle populations are threatened by many factors (e.g., habitat degradation and destruction, exploitation, pollution, disease) and are believed to be declining globally (Ernst et al. 1994; Buhlmann & Gibbons 1997; Jacobson 1997; van Dijk et al. 2000; Moll & Moll 2004). Because turtles are long-lived, long-term studies on the scale of decades are required to accurately assess changes in population size, yet few long-term studies exist to substantiate claims of widespread turtle population declines (Congdon et al. 1993, 1994; Foscarini & Brooks 1997; Moll & Moll 2004). Documenting population estimates and trends is essential for identifying and conserving imperiled populations (Gibbons et al. 2000) and every attempt should be made to use and publish historical data in order to evaluate changes in turtle populations and minimize the shifting baseline effect that often occurs with studies of declining populations (Pauly 1995; Zeller et al. 2005).

Extensive herpetological data dating back to 1968 exist for the North Fork of White River (NFWR), Ozark County, Missouri (Nickerson & Mays 1973; Nickerson unpubl. data). Included in the NFWR data set are data resulting from two intensive mark-recapture surveys of turtles conducted in 1969 and 1980. We revisited the available turtle data from the NFWR in an effort to 1) characterize the turtle community in the NFWR as it was during the time of the studies, 2) estimate and compare the historical population size of the predominant turtle species, and 3) provide a baseline for comparison with future studies.

MATERIALS AND METHODS

Study Site

The NFWR is a third order river of the White River system (Nickerson et al. 2007) located in a region typified by dolomite and sandstone geology with prominent karst features (Miller & Wilkerson 2001). The NFWR receives a large volume of water from springs including Double (i.e., Rainbow) and North Fork Springs – the two largest of the 283 springs located within the North Fork Watershed (Nickerson & Mays 1973; Miller & Wilkerson 2001). Nickerson and Mays (1973) documented many of the abiotic and biotic characteristics of the NFWR and the surrounding landscape as it was from 1968–1971. During the 1968–1971 time period, the NFWR was characterized by low turbidity and minimal siltation (Nickerson & Mays 1973). Shallow riffles were interspersed among deeper pools and the substrate of the NFWR varied between dolomite or limestone bedrock and gravel beds (Nickerson & Mays 1973). The landscape surrounding the NFWR was predominantly forested with oak-hickory and oak-pine dominated stands (Nickerson & Mays 1973).

A 4.6 km section of the NFWR was selected for intensive surveys based on ease of accessibility. The 4.6 km research section was divided into fifty 92 m-long stations (for map and detailed site description, see Nickerson & Mays 1973). Stream width was measured at each station marker using a measuring tape. Area surveyed was estimated as the product of the research section length and the mean stream width.

Survey Methods

Diurnal (0900–1900 h) turtle surveys were conducted between 1968 and 1980 with surveying dates occurring in every calendar month. Sampling effort was temporally concentrated with the most intensive surveys occurring between 12 June–7 August 1969 [33 survey days; 344 person hours; surveys targeted turtles and hellbenders (*Cryptobranchus alleganiensis*)] and 26 August–15 October 1980 (15 survey days; 129 person hours; surveys targeted turtles only). Surveys conducted between 12 June–7 August 1969 were spatially concentrated within the 4.6 km research section. Surveys conducted between 26 August–15 October 1980 were spatially concentrated within a 4.0 km subsection of the 4.6 km research section. We surveyed areas upstream and downstream of the 4.6 km research section on 13 separate occasions during the months of June–October to assess the extent to which turtles moved outside of the 4.6 km research section, including seasonal migrations, during the months relevant to this study (i.e., data collected outside of the 4.6 km research section allowed us to assess whether the populations located within the 4.6 km research section studied in 1969 and 4.0 km research section studied in 1980 were closed). Downstream surveys encompassed the area up to 8.0 km downstream from the downstream terminus of the research section. Upstream surveys encompassed the area up to 16.0 km upstream from the upstream boundary of the research section.

Surveys were conducted by hand capturing turtles while snorkeling. This method proved effective for capturing turtles within the NFWR due to high water clarity and the prevalence of basking turtle species. Basking turtle species, especially the common map turtle (*Graptemys geographica*), are often wary of traps (Pluto & Bellis 1986) and may be unresponsive to bait (Lagler 1943). To assess movement of individual turtles, we noted the station in which each turtle was captured for each capture/recapture event.

We uniquely marked each turtle using carapace notching or Turtox mammalian ear tags (General Biological Supply House, Inc., Chicago, IL), depending on size. We measured the midline plastron length (PL) to the nearest 0.1 cm using a flexible measuring tape. Sex was visually determined when possible based on morphological diagnostic characteristics including tail length and thickness, foreclaw characteristics, and relative position of the anal opening, depending on species (Ernst et al. 1994). We released turtles at their capture site.

Community and Population Analyses

We used the data collected from the 4.6 km research section between 12 June–7 August 1969 and from the 4.0 km subsection of the 4.6 km research section between 26 August–15 October 1980 for turtle community and population estimates as concentrated sampling efforts yielded data conducive for community-level analyses and population size estimation. We measured species richness of the turtle community observed in 1969 and 1980 using the rarefaction method which allows comparison of communities from which unequal sample sizes were collected (Krebs 1989). We assessed heterogeneity, which accounts for species richness and evenness (Krebs 1989), using Hurlbert's Probability of an Interspecific Encounter (PIE) index. We used EcoSim v7.72 (Gotelli & Entsminger 2011) to complete the community analyses. Model parameters were set at 1000 iterations and a random number seed of 0.

Population-level analyses were limited to *Graptemys geographica* due to greater sample sizes. We calculated population size estimates and 95% confidence intervals for *G. geographica* using the Schumacher-Eschmeyer method, which assumes a closed population (Krebs 1989). We compared population estimates using the Chapman and Overton (1966) method to identify significant differences ($P \leq 0.05$) between sampling years. To ensure that uneven sampling area between the 1969 and 1980 survey seasons did not significantly affect the population and density estimates and comparisons, we calculated and compared population estimates based on *G. geographica* found in both the 4.6 km and 4.0 km study areas in 1969. We calculated standardized density estimates using the Schumacher-Eschmeyer estimated population sizes and the areas calculated from the products of the mean stream width and research section length

Table 1. Total number of individual turtles captured from the North Fork of White River, Ozark County, Missouri in 1969 and 1980.

Turtle species	1969	1980
Apalone spinifera	5	0
Chelydra serpentina	6	2
Graptemys geographica	132	68
Pseudemys concinna concinna	2	2
Sternotherus odoratus	12	9
Trachemys scripta elegans	0	15

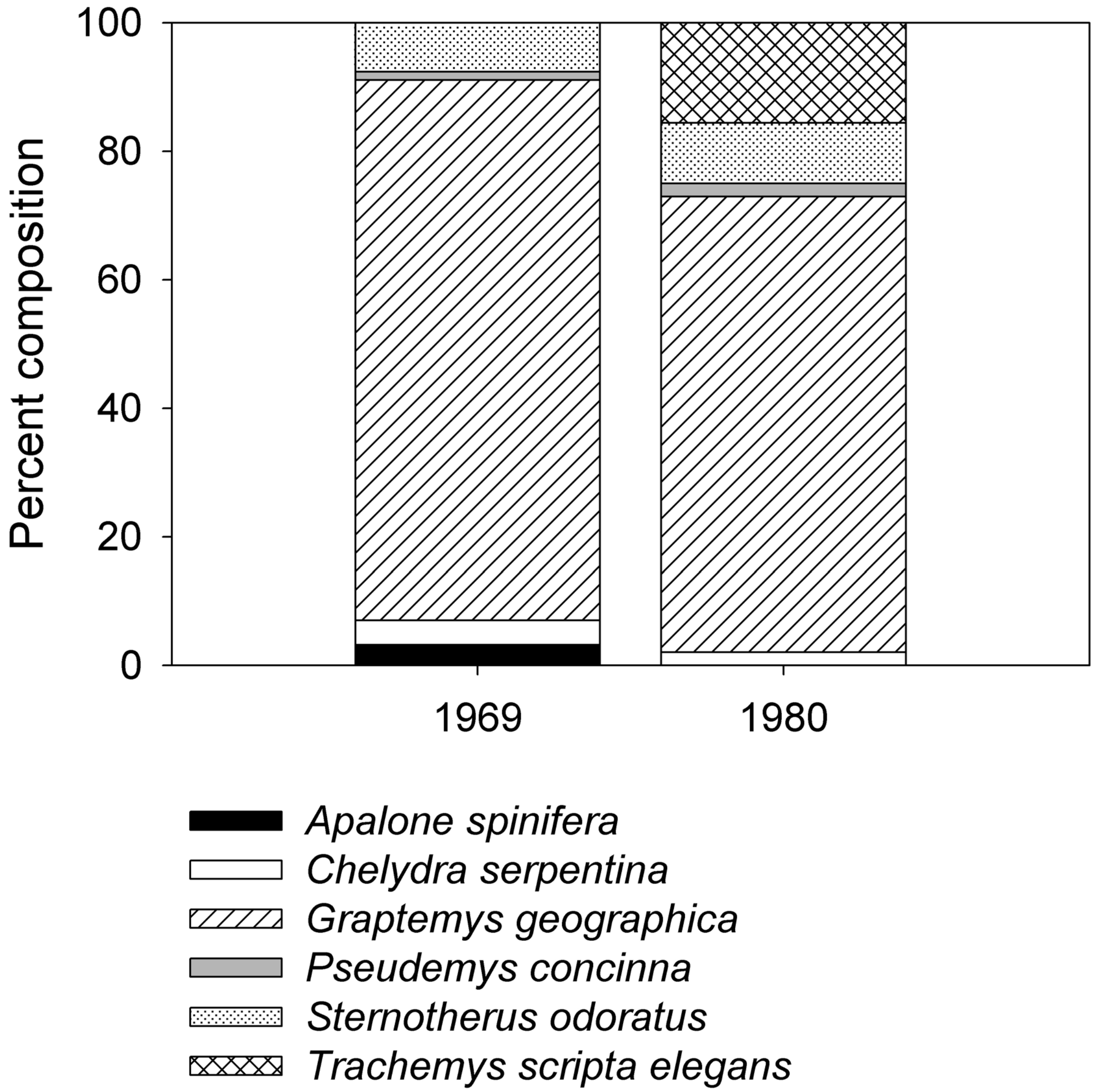

Figure 1. Turtle community composition in the North Fork of White River, Ozark County, Missouri in the years 1969 and 1980.

from 1969 and 1980. We compared the mean plastron length of *G. geographica*, partitioned by sex, using independent samples *t*-tests. We used a chi-square (χ^2) test of independence to identify if sex ratios remained the same between sample years. Statistical analyses were performed using SPSS version 11.5 (2002, SPSS Inc., Chicago, IL).

RESULTS

The mean stream width (± SD) of the NFWR was 41.6 ± 9.9 m. Area estimates for the survey sections for 1969 and 1980 were 191,360 m^2 and 166,400 m^2, respectively.

Graptemys geographica was the most abundant turtle species within the research section in both sampling years (Table 1; Fig. 1). Common musk turtles (*Sternotherus odoratus*), snapping turtles (*Chelydra serpentina*), and eastern river cooters (*Pseudemys concinna concinna*) were present in low numbers in both years (Table 1). Red-eared sliders (*Trachemys scripta elegans*) were observed within the 92 m section above the 4.6 km research section in 1969, but none were found within the research section (Table 1). In 1980, we observed *T. s. elegans* within the research section (Table 1). Spiny softshells (*Apalone spinifera*) were

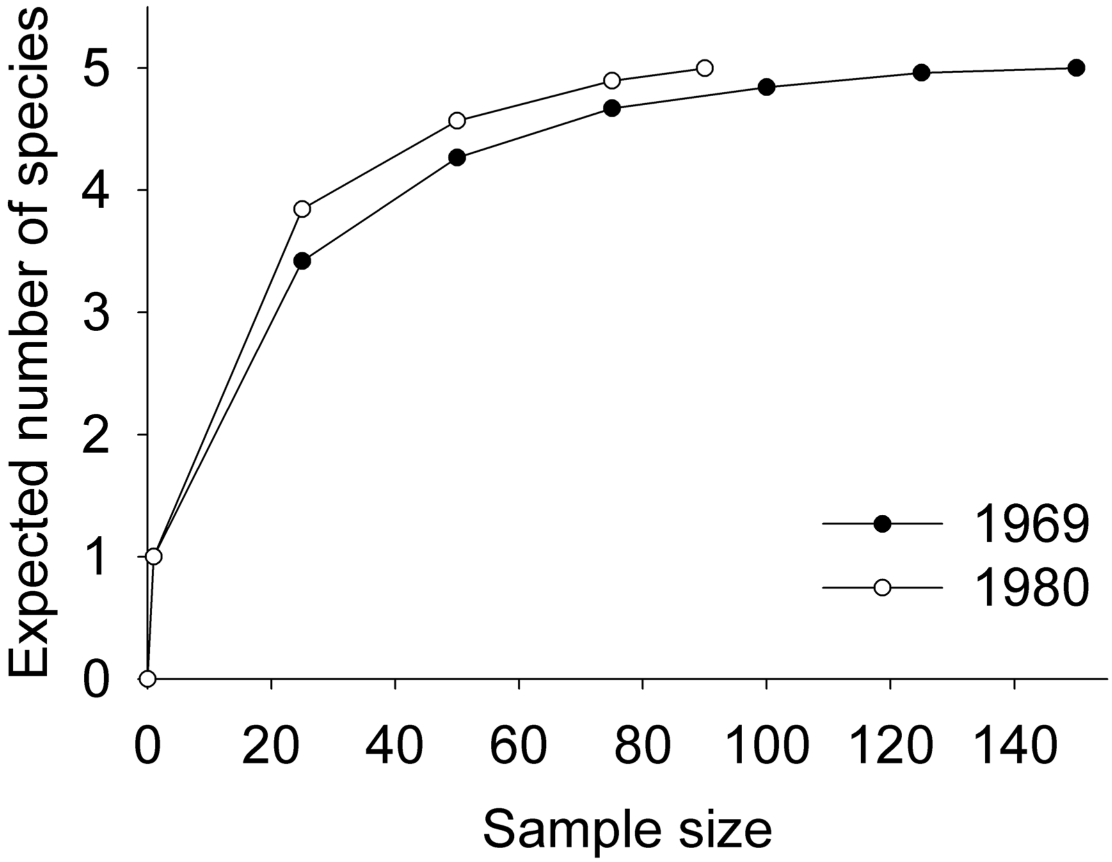

Figure 2. Rarefaction curves indicating species richness of the turtle community in the North Fork of White River, Ozark County, Missouri in the years 1969 and 1980.

Table 2. Schumacher-Eschmeyer estimations of population size (N), 95% confidence interval (CI), and density of common map turtles (*Graptemys geographica*) in the North Fork of White River, Ozark County, Missouri.

Year	Area Sampled (m^2)	N	95% CI	Estimated Density
1969	191,360	274	237–324	1 turtle/ 698 m^2
				14 turtles/ ha
1969	166,400	261	225–311	1 turtle/ 638 m^2
				16 turtles/ ha
1980	166,400	139	94–264	1 turtle/ 1197 m^2
				8 turtles/ ha

present in 1969, but were not observed in 1980. Rarefaction curves indicated that species richness was slightly higher in 1980 than in 1969 (Fig. 2). Similarly, heterogeneity was higher in 1980 ($PIE_{1980} = 0.469$) than in 1969 ($PIE_{1969} = 0.286$).

The *Graptemys geographica* population declined significantly between 1969 and 1980 ($z = 3.39$, $P < 0.001$; Table 2). The exclusion of the stations that were not sampled in 1980 did not significantly affect the 1969 population estimate ($z = 0.335$, $P = 0.738$; Table 2). Mean female PL was significantly larger in 1969 (mean ± SD = 13.4 ± 4.7 cm, $n = 33$) than in 1980 (mean ± SD = 9.9 ± 5.0 cm, $n = 26$; $t = 2.76$, $P = 0.008$, df = 52; Fig. 3).

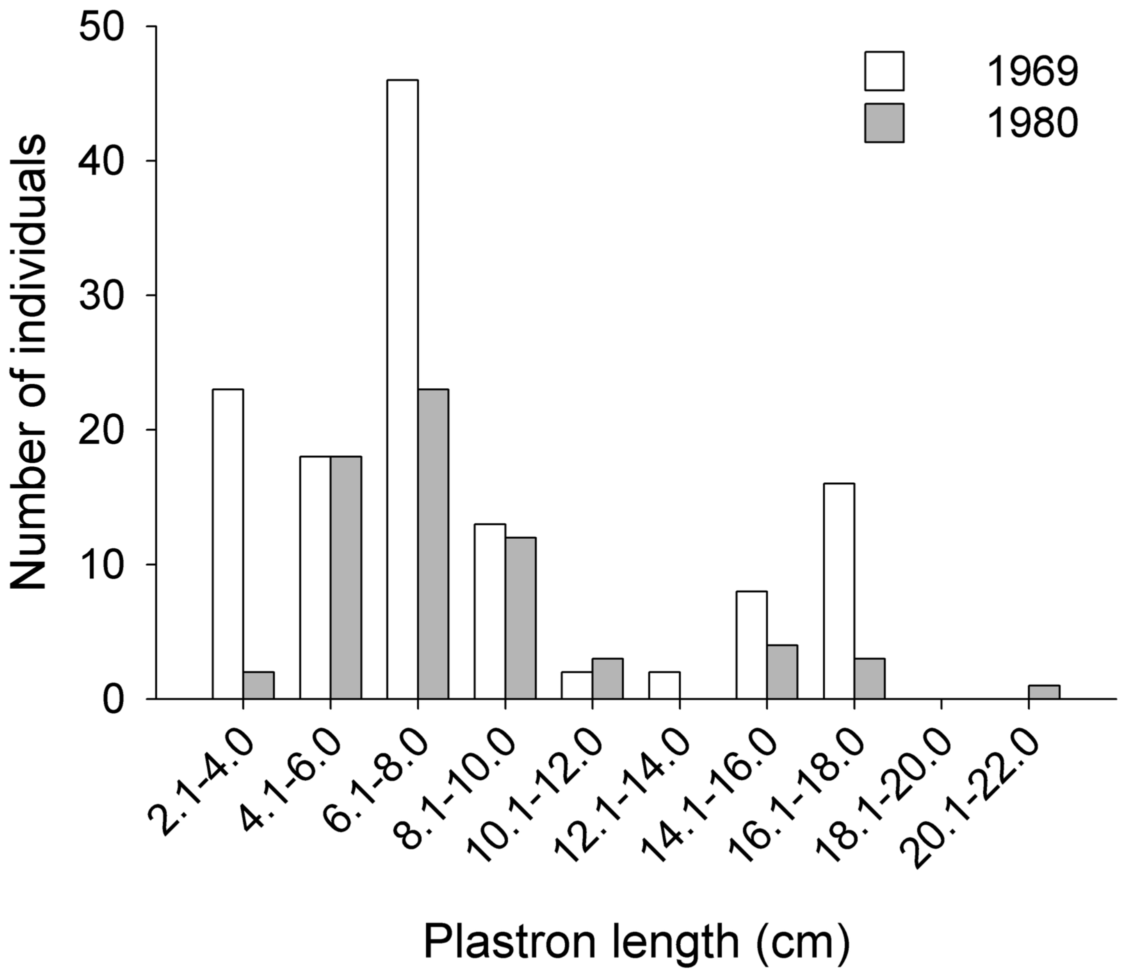

Figure 3. Size distribution of the population of common map turtles (*Graptemys geographica*) in the North Fork of White River, Ozark County, Missouri in the years 1969 and 1980 (1969: n = 128; 1980: n = 66). Individuals with plastron length > 10 cm are all females.

Mean male PL did not differ significantly between sample years ($\text{mean}_{1969} \pm \text{SD} = 7.9 \pm 2.4$ cm, $n_{1969} = 39$; $\text{mean}_{1980} \pm \text{SD} = 7.1 \pm 1.4$ cm, $n_{1980} = 38$; $t = 1.88$, $P = 0.064$, df = 61; Fig. 3). Sex ratios of mature turtles were not significantly different between sampling years ($\chi^2 = 0.309$, df = 1, $P = 0.578$; Fig. 4).

In 1969, 75% of the recaptured *Graptemys geographica* were found within 460 m of their original capture site; 52% of all recaptured *G. geographica* were found within 92 m of their original capture site. The longest documented distance moved by an individual was that of a small female which traveled 3,725 m upstream between 14 June and 8 July 1969. In 1980, 85% of the recaptured *G. geographica* were found within 460 m of their original capture site; 53% of all recaptured *G. geographica* were found within 92 m of their original capture site. The longest documented distance moved by an individual was 1,255 m. During our 13 surveys conducted outside of the research section, we recaptured five *G. geographica* that had been originally captured and marked in our research area. All five recaptures were within 200 m of the downstream terminus of the research section. In 1980, we recaptured two *Trachemys scripta elegans* within 50 m of their original capture sites with one recaptured 27 days after the original capture.

DISCUSSION

The NFWR turtle community exhibited diversity patterns typical of a North American river turtle assemblage in that it had low species richness and

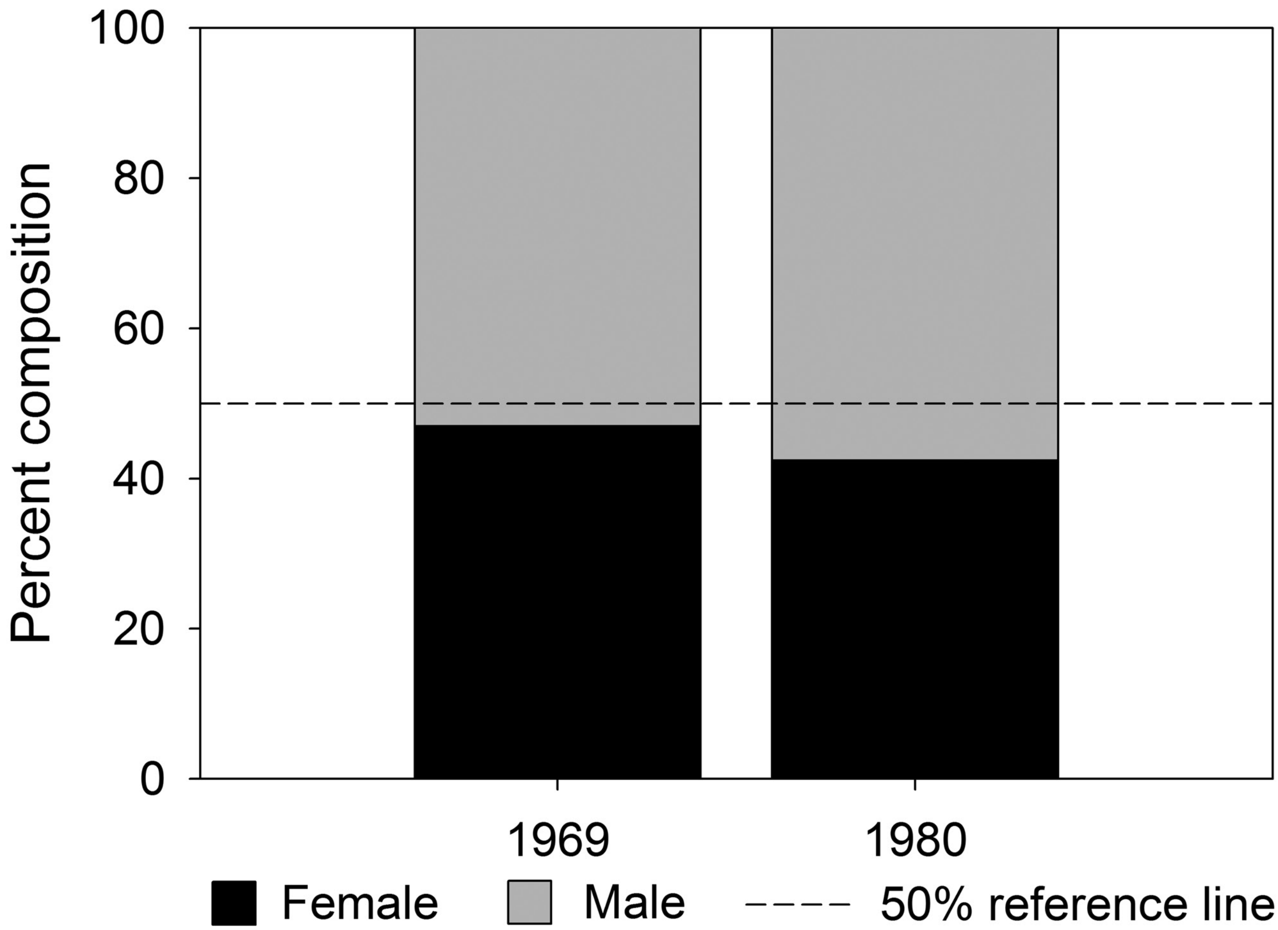

Figure 4. Sex ratios of mature common map turtles (*Graptemys geographica*) in the North Fork of White River, Ozark County, Missouri in the years 1969 and 1980 (1969: n = 83; 1980: n = 66).

the community was dominated by a single species of emydid turtle (Moll & Moll 2004). Species richness and heterogeneity of the NFWR turtle community were higher in 1980 than in 1969 due to the addition of *Trachemys scripta elegans* to the community and increased community evenness, respectively. The population of *Graptemys geographica* had significantly declined by 1980. Changes in the size class distributions and mean PL values for *G. geographica* indicated that there were fewer large adult females and hatchlings in 1980, suggesting the population decline was due to stressors that were disproportionately affecting large adult female *G. geographica*. Adult female turtles can suffer disproportionately high death rates during nesting migrations if they must cross roads or are subjected to high populations of terrestrial predators (Cochran 1987; Moll & Moll 2004). In such cases, all adult female size classes would be reduced, unlike the pattern observed in the NFWR population where the mean PL of female *G. geographica* was significantly smaller in 1980 than in 1969. Close and Seigel (1997) found that harvesting could result in smaller mean body size for populations of *T. s. elegans* in other locations. *Graptemys geographica* are highly sexually dimorphic with females achieving much larger body size than males (Gordon & MacCulloch 1980) and larger turtles would be selectively harvested for the food trade (Close & Seigel 1997). *Graptemys geographica* has been and continues to be a popular species in the food trade, both domestically and internationally (Arndt & Potter 1973; Roche 2002; Moll & Moll 2004). The reduced mean PL observed for female *G. geographica* in 1980 relative to 1969 are consistent with what would be expected if humans were harvesting this species for the food trade. Anecdotal evidence supporting this hypothesis was provided by a local merchant who observed and conversed with two wetsuit-wearing men who were hand-catching turtles to sell to St. Louis restaurants (M. Tole pers. comm.). Our ability to efficiently and effectively hand-capture *G. geographica* while snorkeling suggests that individuals using this technique could greatly affect the population structure of *G. geographica* in the NFWR research section in one or two days time. Additionally, illegal harvest of Ozark hellbenders (*Cryptobranchus alleganiensis bishopi*) in this section of the NFWR during this time period is one of the best documented examples of herpetofauna harvest in the U.S. (Nickerson & Briggler 2007) and it is reasonable to suspect that other species in this area may have been subjected to harvest. The decrease in hatchling numbers may be attributed to the reduction of mature females and accordingly, reproductive output. Turtle reproductive output is positively correlated with body size (Congdon & Gibbons 1985) so the reduced number of reproductive female *G. geographica*, especially those of larger body size, is a plausible explanation for the observed corresponding reduction in number of hatchlings in 1980.

Because our sampling efforts were during different seasons, we reviewed the movement data we collected to determine if we could legitimately compare our population estimates. Movement data suggest that *Graptemys geographica* retain a small home range in the studied area of the NFWR at least during the months relevant to this study, but likely year-round. In general, movement is related to acquisition of resources (e.g., food, mates, shelter) and movement patterns correspond with the spatiotemporal distribution of necessary resources (Pough et al. 2004). Turtles may undergo seasonal migrations to locate food, mates, nesting habitat, and hibernaculum (Gordon & MacCulloch 1980; Pluto & Bellis 1988; Ryan et al. 2008; Carrière et al. 2009). White and Moll (1992) found that *G. geographica* in the Niangua River, Missouri were dietary specialists that fed primarily on the snail *Elimia potosiensis*. Evidence suggests that *G. geographica* in the NFWR may have had a similar diet as that documented by White and Moll (1992). During this study, we regularly observed *G. geographica* of all size classes selectively feeding on snails (Nickerson unpubl. data). Additionally, the stomach contents of a small number of *G. geographica* collected from an area within the NFWR but outside of the research section revealed a specialized diet of snails (Nickerson unpubl. data). These snails were abundant and provided a seasonally stable food source for *G. geographica* throughout the research section (Nickerson & Mays 1973; Cooper 1975) therefore we do not suspect that *G. geographica* would have needed to move outside of the research section to acquire sufficient food. Courtship and mating of *G. geographica* likely occur from late March through May in Missouri (Johnson 2000) so any movement related to courtship and mating would not have taken place during the months included in our study periods. Nesting migrations have been reported for female *G. geographica* in other locations (Gordon & MacCulloch 1980; Carrière et al. 2009) and may occur to some extent in the NFWR. However, recapture data coupled with our direct observations of nesting in two cleared areas that bordered the research section near stations 15–17 and 50 suggests that nesting migrations were minimal as nesting habitats were available adjacent to the research section. Seasonal movements into and out of hibernacula have also been reported for *G. geographica* (Pluto & Bellis 1988; Graham et al. 2000). Graham et al. (2000) believed that hibernacula were deeper areas with slow-moving water and ample structural components (e.g., ledges, boulders, tree trunks) that could provide some form of security or shelter for overwintering turtles. Three areas within the 4.6 km research section of the NFWR fit this physical description: an approximately 3 m deep pool in station 3; a very large 2–3 m deep pool that encompassed portions of stations 18–24; and a 2–2.5 m deep pool at the end of station 50. Winter surveys confirmed the presence of *G. geographica* in the pool between stations 18–24 (Nickerson unpubl. data). The majority of studies that address overwintering of *G. geographica* have occurred in the northern portion of the species' range where turtles must deal with extreme cold, ice, and anoxic conditions (Ultsch 2006). Turtles inhabiting the NFWR face far less extreme winter temperatures than turtles located in states and provinces within the northern distribution of *G. geographica* and these milder conditions allow at least occasional winter basking of *G. geographica* in Missouri (Johnson 2000). Within stream characteristics are also less extreme as the NFWR receives a large volume of water from springs which effectively buffers the water temperature and inhibits ice formation (Mundt & Turner 1926; Nickerson & Mays 1973). The NFWR's dissolved oxygen content and pH remain relatively stable year-round (Nickerson & Mays 1973). The availability of deep water pools and the less extreme conditions likely allow *G. geographica* to avoid seasonal migrations to hibernaculum outside of our research section.

Movement data suggest that *Trachemys scripta elegans* was established within the study area by 1980. We hypothesize that the significant reduction of large *Graptemys geographica* made available some component of the total chelonian niche for *T. s. elegans* to exploit. The sudden removal of adult female *G. geographica* would create the availability of suitable unoccupied basking sites and may be one factor enabling *T. s. elegans* to successfully establish within this section of the river. In other sections of the NFWR, *T. s. elegans* were often encountered basking on sites similar to those utilized by *G. geographica*, including small rocks jutting from the water. These rocky basking sites were scarce in many portions of the research area and large female *G. geographica* occupied them almost immediately at daybreak.

This study provides information regarding the population status of *Graptemys geographica* in a southerly portion of its range and illustrates community changes that may be precipitated by the population decline of just one species. The data presented in this study are no less relevant or necessary today as they were during the collection period in that they provide evidence of a turtle population decline and serve as a reference for future comparative turtle population and community studies in the NFWR. Indirect evidence suggests that river turtle populations are declining worldwide (Moll and Moll 2004) but few long-term population studies are available to assess this hypothesis. Publishing historical studies, such as this one, will provide the direct evidence necessary for determining whether river turtle populations have declined, as well as provide baseline data to compare with current and future data.

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