

Diagnostic Characteristics in Lower Tennessee River Populations of the Map Turtles *Graptemys pseudogeographica* and *Graptemys ouachitensis*

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ABSTRACT. – Map turtles of the *Graptemys pseudogeographica* clade that occur in the Mississippi River drainage have been the source of ongoing taxonomic confusion. Three taxa, diagnosable only by head markings, were recently classified as two species, *G. ouachitensis* and *G. pseudogeographica*, with the latter containing *G. p. kohnii* as a southern subspecies. I studied diagnostic markings of the two species in Kentucky Lake, an impoundment of the lower Tennessee River, where *G. p. pseudogeographica* and *G. p. kohnii* are thought to intergrade. Based on postorbital markings, head width relative to body size, and color and markings of the iris, the *kohnii* influence seems predominant in *G. pseudogeographica* at this location. Diagnostic markings of *G. ouachitensis* clearly separate it from *G. pseudogeographica*, and are compared to markings reported from throughout the species' range. The two species can also be distinguished on the basis of head and alveolar surface width, and females can be distinguished on the basis of the width of the gular scutes of the plastron. The iris of most specimens in both species was white, whereas other *Graptemys* have a yellow iris. The presence (*G. ouachitensis*) or absence (*G. pseudogeographica*) of a black line bisecting the iris in front of and behind the pupil was diagnostic in nearly all specimens. Specimens atypical for one or two characteristics were readily identified based on other characteristics determined to be diagnostic.

KEY WORDS. – Reptilia; Testudines; Emydidae; *Graptemys pseudogeographica*; *Graptemys ouachitensis*; turtle; taxonomy; morphology; intergradation; Kentucky; Tennessee River; USA

The taxonomy of map turtles of the *Graptemys pseudogeographica* clade (*sensu* Lamb et al., 1994) endemic to the Mississippi River drainage has been very unsettled during the 20th century (reviewed in Vogt, 1993). Three taxa—*pseudogeographica* (Gray, 1831), *kohnii* (Baur, 1890), and *ouachitensis* (Cagle, 1953)—have been described, and have been differentiated exclusively by head markings and skull characteristics. Disagreement has centered on which taxa are conspecific; *ouachitensis* was originally described as a subspecies of *pseudogeographica* (Cagle, 1953), while *kohnii* was considered to be a separate species (Carr, 1949). The only attempt to analyze multiple morphological characteristics of specimens from throughout the geographic range of the complex was by Vogt (1978, 1993), who placed *kohnii* as a subspecies of *pseudogeographica* and elevated *ouachitensis* to a full species. In the interim between Vogt's doctoral dissertation (1978) and publication (1993), some reference works adopted his taxonomy (King and Burke, 1989; Iverson, 1992), while others did not (Dundee and Rossman, 1989; Conant and Collins, 1991), with the latter authors commenting that they chose not to use Vogt's taxonomy. Ernst and Barbour (1989) treated each taxon as a separate species, but Ernst et al. (1994) later adopted Vogt's taxonomy. A study of mtDNA variation in *Graptemys* (Lamb et al., 1994) supported Vogt's taxonomy, in that no genetic differences were found within *G. pseudogeographica* (including specimens of *G. p. kohnii*), but *G. pseudogeographica* differed from *G. ouachitensis*.

Diagnostic characteristics of *Graptemys* in the Mississippi drainage (Vogt, 1993) include the number of yellow or orange neck lines reaching the orbit and size, shape, and connectivity of three yellow or orange markings on the head. These markings are termed the postorbital, subocular, and mandibular spots, and are larger in *G. ouachitensis* than in *G. pseudogeographica*. The two species exhibit reverse latitudinal gradients in connectivity of the postorbital and subocular spots (Vogt, 1993). In the north, *G. ouachitensis* tends to have these joined to form a crescent that is relatively wide, while in the south the spots are usually not joined, and 1–9 neck lines extend to the orbit. In the northern subspecies *G. p. pseudogeographica*, postorbital and subocular spots tend not to be joined, and 3–6 lines extend to the orbit, while in the southern subspecies *G. p. kohnii*, a crescent is generally formed by the meeting of the spots, although it is sometimes broken with 1–3 neck lines reaching the orbit.

Vogt's (1993) review of this complex, although based on a large number of specimens, included small sample sizes from the Tennessee drainage, a region he believed was an intergrade zone between *G. p. pseudogeographica* and *G. p. kohnii*. In the present study, I summarize observations made of living specimens of *G. pseudogeographica* and *G. ouachitensis* captured between 1994 and 1996 in Kentucky Lake, an impoundment of the lower Tennessee River. I present data on postorbital marks and compare data from throughout the ranges of the two species (Vogt, 1993). In addition, I present data on eye color and eye markings, which have previously attracted little attention in *Graptemys* tax-

onomy, as well as data on head width and a shell characteristic that distinguishes females of the two species in the area studied.

METHODS

This study was conducted as part of a larger study of *Graptemys* ecology in Kentucky Lake (Lindeman, 1999, 2000a). The lake is a long reservoir created by the impoundment of the lower Tennessee River, and has numerous side coves representing former creek beds. Most of the specimens from which I report data were from a single cove of the lake in Marshall County, Kentucky (36°58'N, 88°12'W), although a few *G. ouachitensis* were also captured at more southerly sites in Trigg and Calloway Counties, Kentucky. Data on head markings and measurements (see below) were also collected from 16 *Graptemys* specimens from Kentucky Lake and the adjacent Lake Barkley (an impoundment of the lower Cumberland River) that are housed in the Austin Peay State University Museum. All specimens used in the present study were captured at latitudes between 36°35' and 37°00'N and at longitudes between 87°50' and 88°15'W.

Graptemys were captured primarily by basking traps of the sort described by MacCulloch and Gordon (1978), although many captures in 1995 were made with a fykenet (Vogt, 1980), and basking hatchlings were captured by hand. Data taken included plastron length (PL) in mm (measured along the midline with a flexible metal tape); sex (if > 77 mm PL, the minimum size at which males of both species are mature; Lindeman, 2000); number of lines extending to the orbit on each side of the head (recorded as -1 for a postorbital crescent blocking lines and 0 for an interrupted crescent with no lines extending to the orbit;

Vogt, 1993); whether or not each postorbital mark was continuous posteriorly with a neck line; color of the iris of each eye; presence or absence of black markings on the iris; head width (HW), measured to the nearest 0.1 mm with Vernier calipers placed just above and parallel to the upper jaw; alveolar width (AW), measured to the nearest 0.1 mm with Vernier calipers aligned against the rear margin of the upper jaw alveolar (= triturating) surfaces and the outside margin of the jaw; straightline width at the outer margin of the anterior borders of the gular scutes (gular width, GW) of the plastron, measured with a flexible metal tape; and curved width of the plastron at the bridge of the shell (bridge width, BW), measured with a flexible metal tape held between sutures joining abdominal and inframarginal scutes on either side of the plastron.

Head width is sexually dimorphic and allometric in both sexes in these and other *Graptemys* species (Lindeman, 2000b). I therefore tested for interspecific differences in $\log(\text{HW})$, $\log(\text{AW})$, $\log(\text{GW})$, and $\log(\text{BW})$ using ANCOVA with $\log(\text{PL})$ as the covariate and treating each sex separately.

RESULTS

Markings. — The typical postorbital marking in *G. pseudogeographica* was a crescent that blocked any lines from entering the orbit, found in 62% of the specimens observed (Figs. 1, 2a). Mean score of the number of lines reaching the orbit was 0.09 (range = 1–4, $n = 47$). Fourteen specimens had 1–4 lines reaching the orbit; however, the combination of the postorbital and subocular spots was suggestive of the curvature of a crescent in all except one adult female that had four lines reaching the orbit (Fig. 2f–g). Four *G. pseudogeographica* had broken crescents with no

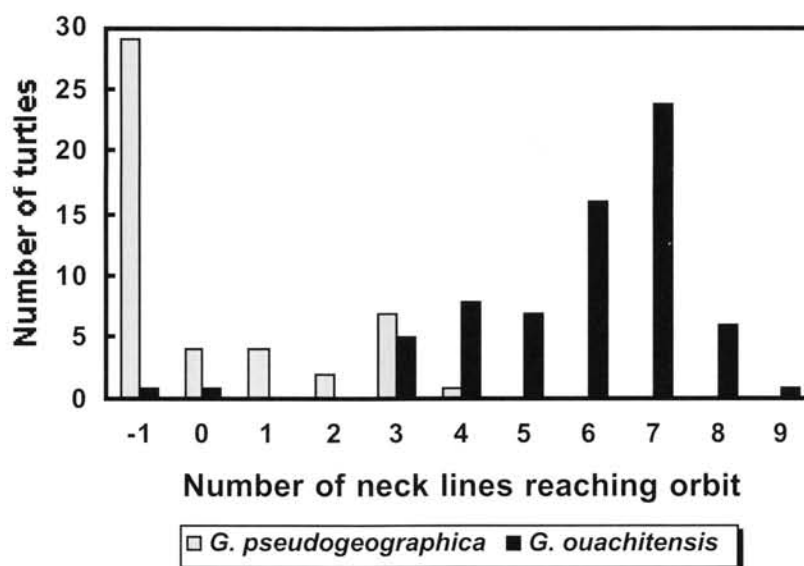


Figure 1. Frequency distribution of number of neck lines reaching the orbit in *G. pseudogeographica* and *G. ouachitensis*. Following Vogt (1993), a value of -1 indicates a crescent that blocks any neck lines from extending to the orbit and 0 indicates a broken postorbital mark with no neck lines extending to the orbit.

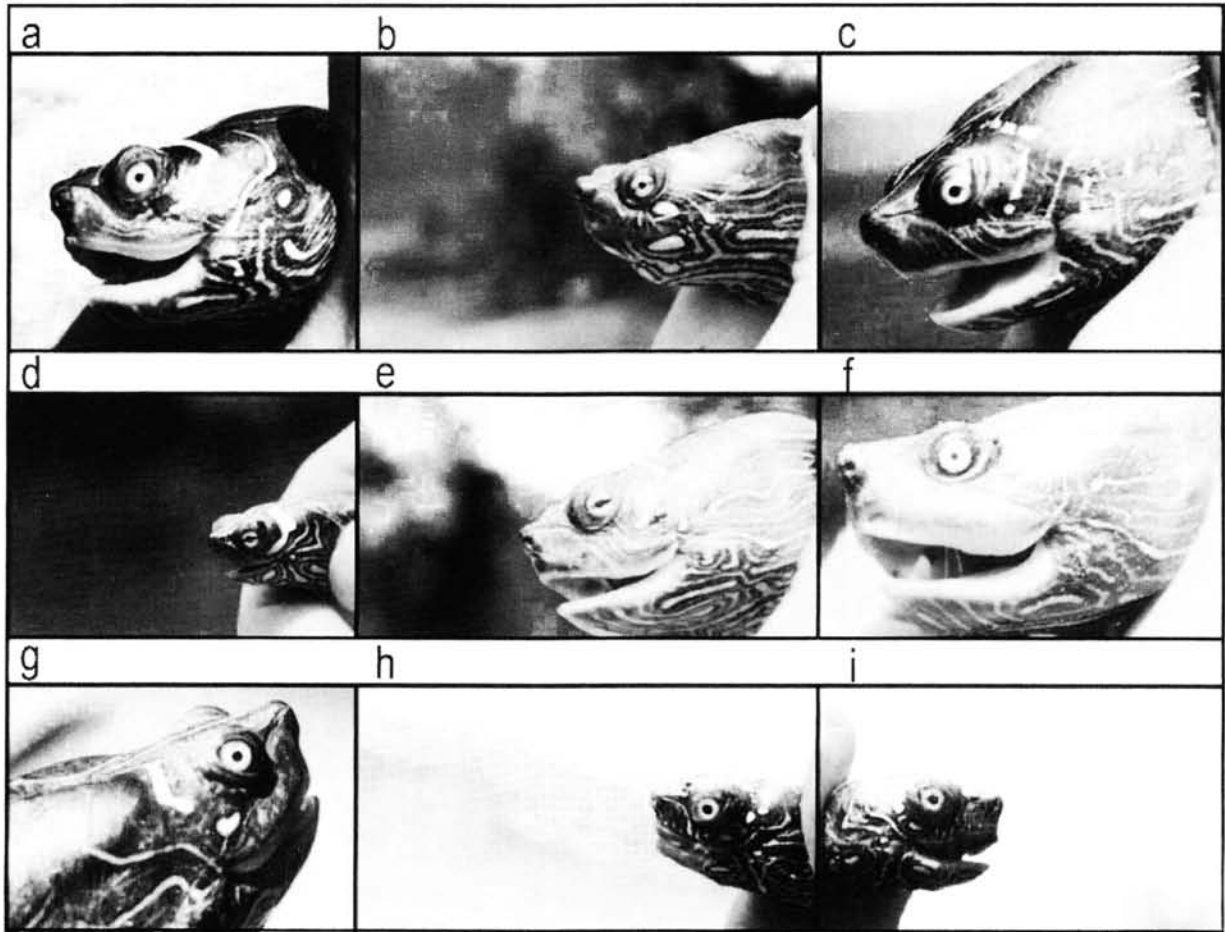


Figure 2. Examples of head markings of two map turtle species in Kentucky Lake: (a) typical *Graptemys pseudogeographica* showing a postorbital crescent blocking neck lines from reaching the orbit and white iris (female, 151 mm PL); (b) typical *G. ouachitensis* showing seven lines reaching the orbit and black stripes on white iris (female, 182 mm PL); (c) *G. pseudogeographica* with interrupted postorbital crescents (female, 198 mm PL); (d) *G. ouachitensis* with postorbital crescent (male, 91 mm PL); (e) *G. pseudogeographica* with black stripes on the iris (female, 170 mm PL); (f) *G. pseudogeographica* with four neck stripes reaching the orbit (female, 190 mm PL); (g) *G. pseudogeographica* with one neck stripe reaching the orbit (female, 186 mm PL); (h and i) left and right sides of a *G. pseudogeographica* with highly atypical head markings (male, 105 mm PL).

lines reaching the orbit. In one female, the crescent was broken into four parts on the right side of the head and five parts on the left side of the head (Fig. 2c). In one male, the right side of the head had a crescent with a single break with one neck line extending to the orbit, while the crescent on the left side of the head was broken into seven spots, with no neck lines reaching the orbit (Fig. 2h-i).

The typical postorbital marking in *G. ouachitensis* was a wide vertical bar that permitted seven lines to reach the orbit, seen in 35% of specimens observed (Figs. 1, 2b). Mean score of the number of lines reaching the orbit was 5.83 (range = 1–9, $n = 69$). One male had a wide vertical bar that merged with the subocular spot at the angle of the jaw to form a crescent blocking lines from reaching the orbit (Fig. 2d), and another male had a postorbital bar that nearly merged with the marking above the angle of the jaw, with no lines reaching the orbit. All other specimens had 3–9 lines reaching the orbit.

Both left and right postorbital markings were continuous with neck lines in 36 of 41 (88%) *G. pseudogeographica*

and 28 of 66 (42%) *G. ouachitensis*. This condition existed on one side of the head but not the other in 2 (5%) *G. pseudogeographica* and 12 (18%) *G. ouachitensis*, and neither postorbital mark was continuous with a neck line in 3 (7%) *G. pseudogeographica* and 26 (39%) *G. ouachitensis*. The distribution of this character is significantly different between the two species ($\chi^2 = 21.73$, d.f. 2, $p < 0.001$).

All 55 *G. ouachitensis* examined had black stripes that bisected a white iris (Fig. 2b, d). This condition existed in only 2 of 44 (5%) *G. pseudogeographica* examined (Fig. 2e), although an additional seven (16%) had black dots in front of or behind the pupil, in one ($n = 3$) or both ($n = 4$) eyes. The iris was completely white in 42 of 44 (95%) *G. pseudogeographica* and 54 of 55 (98%) *G. ouachitensis*, with the remaining three turtles having partial suffusion of yellow into an otherwise white iris.

Measurements. — After correction for log(PL), the two species differed for both sexes in log(HW) (males: $F_{1,47} = 60.29$, $p < 0.0001$; females: $F_{1,61} = 289.1$, $p < 0.0001$) and log(AW) (males: $F_{1,39} = 48.28$, $p < 0.0001$; females: $F_{1,51} =$

Table 1. Means of measurements of two map turtle (*Gratemys*) species from western Kentucky.

Variable	Species	Males			Females		
		<i>n</i>	Mean	Range	<i>n</i>	Mean	Range
Plastron length	<i>G. pseudogeographica</i>	28	99.1	77-121	31	163.4	83-215
	<i>G. ouachitensis</i>	103	88.5	75-109	58	148.9	89-201
Head width	<i>G. pseudogeographica</i>	22	15.8	13.9-19.3	27	31.4	16.4-43.8
	<i>G. ouachitensis</i>	26	12.7	11.1-14.4	35	21.2	14.8-30.3
Alveolar width	<i>G. pseudogeographica</i>	22	3.6	2.9-4.7	25	8.2	3.9-11.3
	<i>G. ouachitensis</i>	18	2.6	2.1-3.0	27	4.3	2.9-6.2
Gular width	<i>G. pseudogeographica</i>	13	23.2	19-29	15	45.8	24-63
	<i>G. ouachitensis</i>	13	21.8	19-25	23	35.7	25-45
Bridge width	<i>G. pseudogeographica</i>	13	65.0	50-88	15	112.3	62-150
	<i>G. ouachitensis</i>	10	58.6	54-68	18	97.9	69-116

163.16, $p < 0.0001$). Females of the two species differed in $\log(\text{GW})$ ($F_{1,37} = 24.34$, $p < 0.0001$) but not $\log(\text{BW})$ ($F_{1,32} = 0.17$, $p = 0.68$), while males did not differ in either measurement ($\log(\text{GW})$, $F_{1,25} = 0.33$, $p = 0.57$; $\log(\text{BW})$, $F_{1,22} = 0$, $p = 0.95$). All means were greater in *G. pseudogeographica* (Table 1).

Atypical Specimens. — These were defined as those specimens with combinations of characteristics not found to be diagnostic for either species, or with unique versions of a characteristic. In all cases, use of all characteristics together allowed for species identification. The two most atypical specimens were a male (PL 105 mm) with the postorbital markings described above, and a female (PL 190 mm) with four lines to the orbit on each side of the head, vertical postorbital spots with no curvature, and partial yellow suffusion of the iris. Both specimens were identified as *G. pseudogeographica* based on the relatively small size of postorbital and subocular spots and relatively broad head and alveolar surfaces; the male also exhibited small black dots in the iris anterior and posterior to the right pupil and a completely white left iris, both of which are conditions seen only in some *G. pseudogeographica*.

DISCUSSION

Gratemys pseudogeographica and *G. ouachitensis* in microsympatric populations in western Kentucky can be readily differentiated on the basis of a suite of diagnostic characteristics, including postorbital markings and number of neck lines reaching the orbit, iris color and stripes, and relative width of the head, alveolar surfaces, and in females, gular scutes of the plastron. In some specimens, reference to more than one characteristic was necessary for proper species identification, but all specimens could be assigned to a species on the basis of a combination of characteristics.

Interspecific differences in iris color and stripes have previously received little attention in *Gratemys*, but were the most consistent characteristic differentiating the two species I studied. The norm in *Gratemys* appears to be a yellow iris with black stripes in front of and behind the pupil, based on color photographs in Ernst et al. (1994) and my own observations of *G. ernsti*, *G. flavimaculata*, *G. geographica*,

G. gibbonsi, *G. nigrinoda*, *G. oculifera*, *G. pulchra*, and *G. versa*; even *G. p. pseudogeographica* has a yellow iris with black stripes. Vogt (1993) suggested that differences in head markings of *G. ouachitensis* and *G. pseudogeographica* may be important for species recognition in face-to-face courtship. Perhaps iris color and markings play a similar role.

Differences in head and alveolar width are concordant with differences in diet. In Kentucky Lake, *G. pseudogeographica* are heavily molluscivorous, while *G. ouachitensis* rarely take mollusks (Lindeman 2000a; see also Vogt, 1981; Shively and Jackson, 1985). These differences are undoubtedly also related to the significant difference in width of the plastron at the outer margins of the gular scutes in females. The anterior margins of the gular scutes are curved upward dorsolaterally, such that their outer margins lie to either side of the head when it is retracted. The wider heads of *G. pseudogeographica*, most strongly developed in adult females, appear to be accommodated by widening of the gular scutes, independent of width of the plastron at the bridge.

Vogt (1993) suggested that *G. pseudogeographica* in the lower Tennessee River were *pseudogeographica* × *kohnii* intergrades, but based his assertion on a small sample. The presence of high frequencies of specimens of both taxa in the Mississippi drainage in western Tennessee may have influenced Vogt's (1993) designation of an intergrade status for the lower Tennessee drainage. My observations, however, suggest a predominant *kohnii* influence, in that crescents and broken crescents characterized all but one specimen, and head size was enlarged. Based on postorbital markings and associated neck lines, Kentucky Lake samples of *G. pseudogeographica* were more similar to southern populations from Arkansas, Texas, Louisiana, and Mississippi than they were to northern populations from Tennessee, Missouri, Illinois, and Indiana (Vogt, 1993).

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