Systematics and ecology of *Gastrocopta (Gastrocopta) rogersensis* (Gastropoda: Pupillidae), a new species of land snail from the Midwest of the United States of America

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ABSTRACT

Gastrocopta rogersensis, a new species of recent gastropod mollusk (Pupillidae, Gastrocoptinae) is described from the vicinity of the Ozark Uplift and Paleozoic Plateau ("Driftless Area") in the midwestern USA. The structure of the angulo-parietal "tooth" in *G. rogersensis* consists of two discrete sub-parallel lamellae borne on a rectangular callus, distinguishing it from all *Gastrocopta procera* (Gould, 1840) subspecies and variants, including *Gastrocopta procera mcclungi* (Hanna and Johnston, 1913), *Gastrocopta procera riparia* (Pilsbry, 1912), and *Gastrocopta procera sterkiana* (Pilsbry, 1912). Morphometric analyses demonstrate that even at sites of co-occurrence, *G. rogersensis* shells are significantly ($P<0.0005$) smaller than *G. procera*. Additionally, while *G. rogersensis* exhibits no variation in shell size with latitude ($P = 0.876$), a highly significant ($P<0.0005$) clinal variation exists in *G. procera*. *G. rogersensis* populations appear restricted to undisturbed calcareous bedrock outcrops in areas that escaped Wisconsinan glaciation. The limited range, habitat specificity, and potential fire sensitivity of this species suggests that it should be given a high priority for conservation.

Additional key words: *Gastrocopta procera*, morphometrics, biogeography, ecology, midwestern USA.

INTRODUCTION

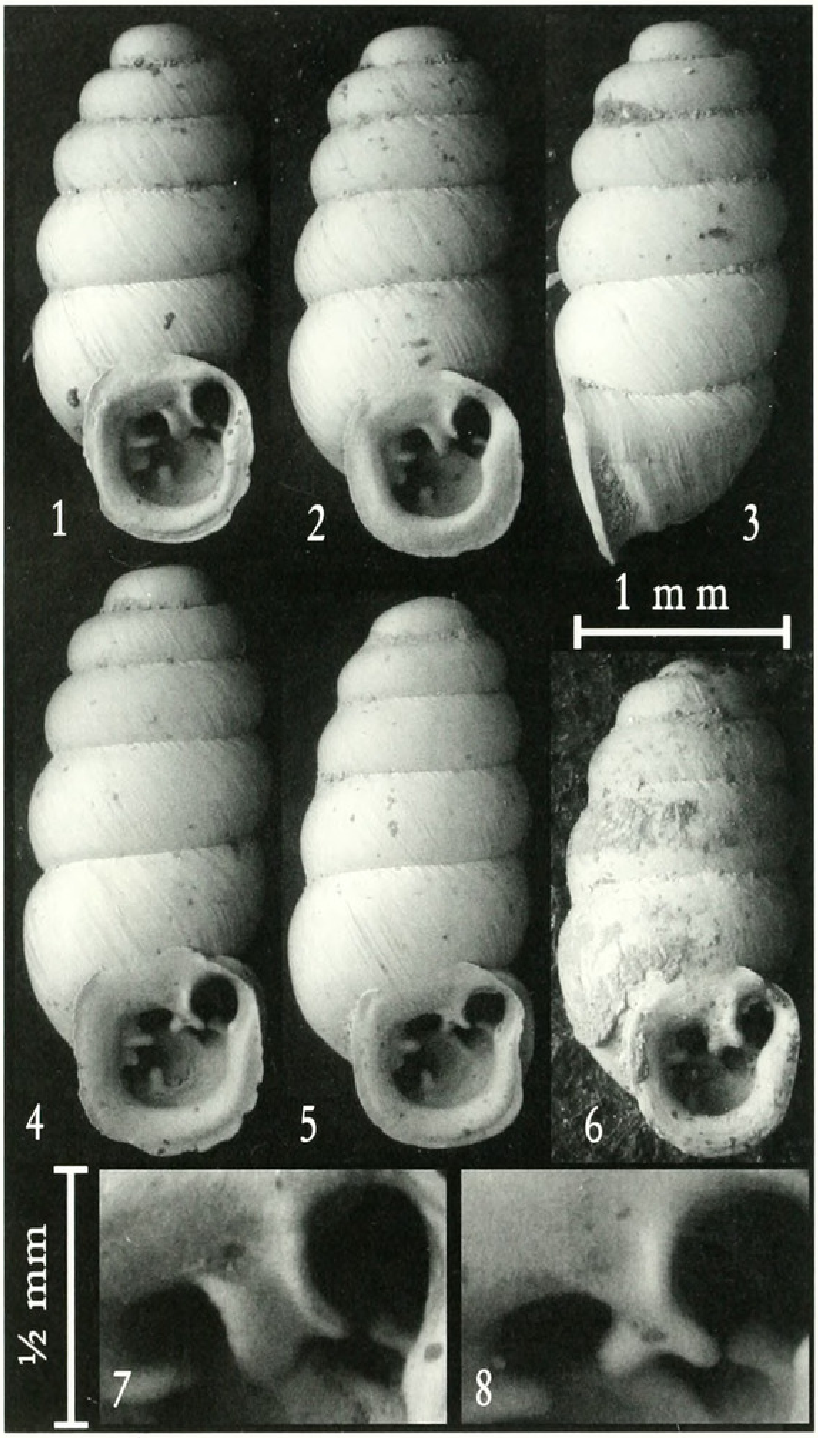
The genus *Gastrocopta* (Wollaston, 1878) comprises a group of pupillid mollusks of nearly global distribution (Pilsbry, 1948). In the Americas, this genus extends into the nearctic where at least 18 recent species occur east of the continental divide (Hubricht, 1985). Because of variability in apertural dentition and shell size, *Gastrocopta (Gastrocopta) procera* is one of the most taxonomically challenging members of this group. Pilsbry (1912, 1948) regarded *G. procera* to consist of four weakly differentiated taxa: *G. procera*, *Gastrocopta procera mcclungi*, *Gastrocopta procera sterkiana*, and *Gastrocopta procera* form *riparia*. However, Hubricht (1977) considered *G. p. mcclungi* synonymous with *G. procera* and elevated the remaining two forms to specific rank. Unfortunately, no data was presented to support these conclusions.

During studies on the recent land mollusks of the midwestern USA, we located 19 *Gastrocopta* populations from Arkansas, Illinois, Iowa, and Missouri that could be readily distinguished from *Gastrocopta procera* and its subspecies via a consistent suite of characteristics, even at sites of co-occurrence. An additional 10 populations of this form were documented from northwestern Illinois and southwestern Wisconsin through examination of *G. procera* material at the Field Museum of Natural History (FMNH). Inspection of *G. procera* material from the Academy of Natural Sciences of Philadelphia (ANSP) revealed that a specimen from Rogers, Arkansas also represented this form. This specimen had previously been identified and illustrated as *Gastrocopta procera mcclungi* (Pilsbry, 1948, figs 493:4–5). Pilsbry (1948) did not specifically discuss this specimen, even though conspicuous differences can be seen between it and the other illustrated *G. p. mcclungi* specimen (op. cit., figs 493: 1–3), which was stated by him to be "identical" to the type.

In this paper we describe these distinct populations as *Gastrocopta rogersensis* new species and comment on its relationship to the *Gastrocopta procera* complex, morphometrically compare it to *G. procera*, and consider its biogeography and ecology.

MATERIALS AND METHODS

Study Populations: All populations of *Gastrocopta* collected by the authors from the central USA were examined. Specimens of *Gastrocopta procera* sensu lato at FMNH and ANSP were also examined. Included in these were the Pilsbry (1948) figured specimens of *Gastrocopta procera mcclungi* from Rogers, Arkansas and South Dakota. Additionally, the holotype of *G. p. mcclungi* (USNM 226395) was examined.



Figures 1–8. Scanning electron micrographs of *Gastrocopta rogersensis* and *Gastrocopta procera*. **1, 3.** *Gastrocopta rogersensis*, UWGB 3914, Fults Hill Prairie Nature Preserve, Monroe County, Illinois, USA (90°11′15″ W, 38°9′19″ N). **2.** *Gastrocopta rogersensis*, UWGB 1061, Maquoketa South Glade, Clinton County, Iowa, USA (90°39′5″ W, 42°1′12″ N). **4.** *Gastrocopta procera*, UWGB 3916, Fults Hill Prairie Nature Preserve, Monroe County, Illinois, USA (90°11′15″ W, 38°9′19″ N). **5.** *Gastrocopta procera*, UWGB 575, Juniper Hill Shale Glade, Floyd County Iowa, USA (92°59′2″ W, 43°3′10″ N). **6.** *Gastrocopta procera mcclungi*, holotype, USNM 226395, Long Island, Phelps County, Kansas. **7.** *Gastrocopta rogersensis*, angulo-parietal lamella, UWGB 3914, Fults Hill Prairie Nature Preserve, Monroe County, Illinois, USA (90°11′15″ W, 38°9′19″ N). **8.** *Gastrocopta procera*, angulo-parietal lamella, UWGB 3916, Fults Hill Prairie Nature Preserve, Monroe County, Illinois, USA (90°11′15″ W, 38°9′19″ N).

Morphometric analyses: Individuals were assigned to either *Gastrocopta* new species or *Gastrocopta procera* based on apertural lamella configuration. Twenty-five *Gastrocopta* new species and 24 *G. procera* populations from the states of Arkansas, Illinois, Iowa, and Wisconsin were used for shell morphometric analysis (table 1). Included were all 9 known stations at which these taxa co-occurred. The geographic coordinates for each population was determined using a Trimble hand-held GPS, appropriate USGS 7.5 minute topographic maps or DeLorme Gazetteer, and converted to UTM Zone 16 coordinates using ARCINFO.

Table 1. Location and collection information for known *Gastrocopta rogersensis* sites and measured *Gastrocopta procera* sites, with numbers of shells used in morphometric analyses. An 'x' represents known *G. rogersensis* sites from where no specimens were measured.

				# Measured	
Site	Location	Collector	Collection number	*G. rogersensis*	*G. procera*
Arkansas					
Baxter County					
Norfork	92°16′44″ W, 36°13′22″ N	Brian Coles	1996/6/2.3	10	
Salesville	92°16′52″ W, 36°13′02″ N	Brian Coles	1996/5/10.4	75	
Benton County					
Rogers		Pilsbry 1948	Figure 493:4–5	x	
Boone County	93°06′00″ W, 36°29′00″ N	George Walsh		x	
Carroll County					
Beaver Dam	94°01′36″ W, 36°19′59″ N	Brian Coles	1995/10/12.2	32	
Table Rock Lake	93°46′18″ W, 36°28′22″ N	Brian Coles	1998/6/6.1		4
Independence County					
Cushman N	91°47′27″ W, 35°53′58″ N	Brian Coles	1998/4/19.2		13
Izard County					
Calico Rock East	92°08′14″ W, 36°06′48″ N	Brian Coles		x	
Calico Rock West	92°08′55″ W, 36°07′01″ N	Brian Coles	1995/8/5.3	24	33
Madison County					
Withrow Springs Park	93°43′55″ W, 36°09′07″ N	Brian Coles	1995/10/13.2	4	2
Searcy County					
Harriet E	92°29′42″ W, 35°59′08″ N	Brian Coles	1999/10/24.2		1
Leslie S	92°33′19″ W, 35°49′15″ N	Brian Coles	1998/5/13.1		2
Marshall NW	92°41′39″ W, 35°57′51″ N	Brian Coles	1998/5/16.2		3
Marshall S	92°35′41″ W, 35°54′21″ N	Brian Coles	1998/5/31.2		12
Stone County					
Allison	92°07′23″ W, 35°56′35″ N	Brian Coles		x	
Barfoot Recreation Area	92°15′18″ W, 36°01′16″ N	Brian Coles	1997/7/12.2	2	
Calico Rock South	92°08′30″ W, 36°06′22″ N	Brian Coles	1997/7/17.2	1	2
South Side S	91°36′46″ W, 35°40′00″ N	Brian Coles	1999/4/4.4		6
Illinois					
Calhoun County					
Franklin Hill	90°36′38″ W, 39°03′57″ N	Jeff Nekola	UWGB 3868		42
Jackson County					
Kings Ferry Bluff	89°26′15″ W, 37°36′02″ N	Jeff Nekola	UWGB 3846		37
JoDaviess County					
Elizabeth	90°09′18″ W, 42°19′59″ N	John Slapcinsky	FMNH 286835	1	
Madison County					
Alton	90°13′36″ W, 38°54′51″ N	Jeff Nekola	UWGB 4311		31
Monroe County					
Fountain Gap	90°15′33″ W, 38°22′36″ N	Jeff Nekola	UWGB 3939	25	
Fults Reserve	90°11′15″ W, 38°09′19″ N	Jeff Nekola	UWGB 3914; UWGB 3916	45	42
Randolph County					
Chester	89°53′06″ W, 38°56′42″ N	Jeff Nekola	UWGB 4267; UWGB 4269	9	1
Prairie du Rocher	90°11′56″ W, 38°06′28″ N	Jeff Nekola	UWGB 3894; UWGB 3896	43	24
Iowa					
Allamakee County					
Fish Farm Mounds	91°17′11″ W, 43°27′12″ N	Jeff Nekola	UWGB 5366; 5368	5	2

Table 1. Continued.

Site	Location	Collector	Collection number	# Measured *G. rogersensis*	# Measured *G. procera*
Clayton County					
Turkey River Mounds	91°02′11″ W, 42°42′45″ N	Jeff Nekola	UWGB 6468		47
Clinton County					
Maquoketa South	90°39′05″ W, 42°01′12″ N	Jeff Nekola	UWGB 6142	31	
Dubuque County					
Roosevelt Road	90°44′30″ W, 43°32′55″ N	Jeff Nekola	UWGB 3783	18	
Floyd County					
Juniper Hill Shale Glade	92°59′02″ W, 43°03′10″ N	Jeff Nekola	UWGB 575		11
Jackson County					
Hamilton Glade	90°34′08″ W, 42°04′23″ N	Jeff Nekola	UWGB 3732	16	
Winneshiek County					
Decorah Glade	91°46′10″ W, 43°18′55″ N	Jeff Nekola	UWGB 6315		17
Missouri					
Taney County					
Hollister	93°13′41″ W, 36°37′00″ N	Brian Coles		x	
Wisconsin					
Buffalo County					
Landfill Road	91°52′45″ W, 44°15′56″ N	James Theler	FMNH 285717		1
Crawford County					
Leitner Hollow	91°05′05″ W, 43°13′03″ N	James Theler	FMNH 286076	8	3
Rush Creek	91°07′54″ W, 43°21′56″ N	James Theler	FMNH 285824	6	
Grant County					
Dewey Heights	91°01′14″ W, 42°44′03″ N	James Theler	FMNH 286131	8	
Zimmer	91°02′50″ W, 42°50′30″ N	James Theler	FMNH 285680	11	
LaCrosse County					
Experimental Farm	91°00′47″ W, 43°50′12″ N	James Theler	FMNH 285670	8	
Hixon	91°12′00″ W, 43°49′14″ N	James Theler	FMNH 285761	8	
Pierce County					
Hager City	92°31′36″ W, 44°36′20″ N	James Theler	FMNH 285920		3
Trempealeau County					
Brady's Bluff	91°28′59″ W, 44°01′12″ N	James Theler	FMNH 285730	13	
Vernon County					
Battle Bluff	91°12′38″ W, 43°27′36″ N	James Theler	FMNH 286049	8	
Victory	91°12′45″ W, 43°29′26″ N	James Theler	FMNH 285843	4	4

For small populations (<40 individuals) all mature, undamaged shells were measured. For larger populations, a random sample of approximately 45 undamaged, adult shells was selected. Shell height and width was measured in increments of 0.01 mm using a dissecting microscope with a calibrated ocular micrometer. Maximum dimensions were recorded for each shell. Shell height was measured from the tip of the protoconch to the base of the lip, while shell width was measured from the right-most margin of the aperture to the left-most margin of the body whorl.

Differences in shell height and width for both *Gastrocopta* new species and *Gastrocopta procera* were analyzed via full 2-way ANOVAs in which taxon and geographic location served as independent variables. Because of natural groupings in occurrence, populations were assigned to one of three geographic regions: Paleozoic Plateau, southern Illinois, or Ozarks. Differences in shell height and width within the 9 sites of co-occurrence were also documented using full 2-way ANOVAs in which taxon and site served as the independent variables.

The central tendencies in these relationships were graphically represented via box plots. In box plots, the central line represents the median of the sample, the margins of the box represent the interquartile distances, and the fences represent 1.5 times the interquartile distances. For data having a Gaussian distribution, approximately 99.3% of the data will fall inside of the fences (Velleman and Hoaglin, 1981). Outliers falling outside of the fences are shown with asterisks.

The strength of clinal variation in shell height vs. latitude (as expressed in UTM Zone 16 coordinates) was estimated for both species using least-squares linear regression. UTM coordinates were used to preclude potential bias originating from use of polar-coordinate latitude coordinates.

Scanning electron microscopy: Scanning electron micrographs of *Gastrocopta rogersensis* and *Gastrocopta procera*, taken with a Hitachi S-2460N Scanning Electron Microscope in N-SEM Mode (10 Pa; 22 kV) with a backscatter detector and no. 2 gamma correction.

Habitat associations: The physical habitat and associated plant communities were noted during field collection of sites documented by the authors. This information was determined for other sites through museum records and/or the published literature (e.g., Theler, 1997).

SYSTEMATICS AND DISCUSSION

Family Pupillidae Turton, 1831
Subfamily Gastrocoptinae Pilsbry, 1918
Genus *Gastrocopta* Wollaston, 1878
Subgenus *Gastrocopta* Wollaston, 1878

Gastrocopta rogersensis new species
(Figures 1–3)

Gastrocopta procera mcclungi Pilsbry, 1948, figure [plate] 493; in part, only specimen in figures 4–5.

Diagnosis: *Gastrocopta rogersensis* is similar in form to *Gastrocopta procera* but is distinguished by the shape of the angulo-parietal lamella. In *G. rogersensis* the angular and parietal lobes form two discrete, offset, subparallel ridges borne on a rectangular callus (figures 1, 2, 7). In *G. procera* these two lobes converge, creating a triangular structure (figures 4, 5, 8).

Description: Shell elongate-ovoid with a weakly conical spire, brown, weakly striate, 1.77–2.58 mm tall (mean = 2.11 mm) × 0.81–1.05 mm wide (mean = 0.92 mm); 6 whorls, the last 2 of approximately equal width; suture pronounced. The aperture is elongate and rounded with a non-continuous peristome. The weakly reflected lip is of lighter color than the rest of the shell, and is strongly reinforced with a shallow sulcus immediately behind. The aperture has 5 lamellae. The angulo-parietal consists of two discrete, approximately straight, sub-parallel lamellae borne on a rectangular callus with the angular portion originating near the junction of lip and body whorl. The columellar lamella is bilobed, the upper prominent and the lower nodular. The upper palatal lamella is short and placed in front of the angulo-parietal. The lower palatal is long and deeply inserted behind the angulo-parietal. The basal lamella is short, columnar, and inserted in front of the angulo-parietal.

Type material: Holotype (figures 1, 3), FMNH 296651, 2.16 mm length × 0.96 mm width, Jeff Nekola leg. 11 Jul. 1998; Paratypes: FMNH 296657, 20 specimens collected with the holotype at Fults Hill Prairie Nature Preserve, Jeff Nekola leg.; Florida Museum of Natural History 285352, 5 specimens collected with the holotype at Fults Hill Prairie Nature Preserve, John Slapcinsky leg.; FMNH 296558, 10 specimens, Calico Rock West, Izard County, Arkansas (92°8′55″ W, 36°7′1″ N), Brian Coles leg; FMNH 296559, 10 specimens, Salesville, Baxter County, Arkansas (92°16′52″ W, 36°13′2″ N), Brian Coles leg.; FMNH 296660, 10 specimens, Prairie du Rocher, Randolph County, Illinois (90°1′56″ W, 38°6′28″ N), Jeff Nekola leg.; FMNH 296661, 10 specimens, Maquoketa South Glade, Clinton County, Iowa (90°39′5″ W, 42°1′12″ N), Jeff Nekola leg. FMNH 285730, 13 specimens, Brady's Bluff, Trempealeau County, Wisconsin (91°28′59″ W, 44°1′12″ N), James Theler leg.

Type locality: Fults Hill Prairie Nature Preserve (90°11′15″ W, 38°9′19″ N), Monroe County, Illinois, USA, approximately 3 km SE of Fults along Bluff Road; on dry limestone outcrops, under Red Cedar (*Juniperus virginiana* L.) at the crest of a bluff. We selected this locality as it is centrally located within the known range of *Gastrocopta rogersensis*, and exists within a protected natural area. Additionally, the locality is included in part of the range of *G. rogersensis* where the new species occurs sympatrically with *Gastrocopta procera*.

Etymology: The specific name honors the town of Rogers, Arkansas. This is the collection location for the specimen upon which the first published illustration was based. Even though we have been unable to relocate them in Rogers, extant populations are known within 40 km at Withrow Springs State Park and Beaver Dam.

Subgeneric allocation: The approximately straight angulo-parietal lobes as seen in basal view, columnar basal lamella, and brown shell color indicate that *Gastrocopta rogersensis* belongs in the subgenus *Gastrocopta*. Superficially, its angulo-parietal lamella resembles that of several species in *Gastrocopta* subgenus *Immersidens*, notably *Gastrocopta bilamellata* (Sterki and Clapp, 1909) and *Gastrocopta dalliana* (Sterki, 1898) (Pilsbry, 1948; figure 490: 1–4). However, members of

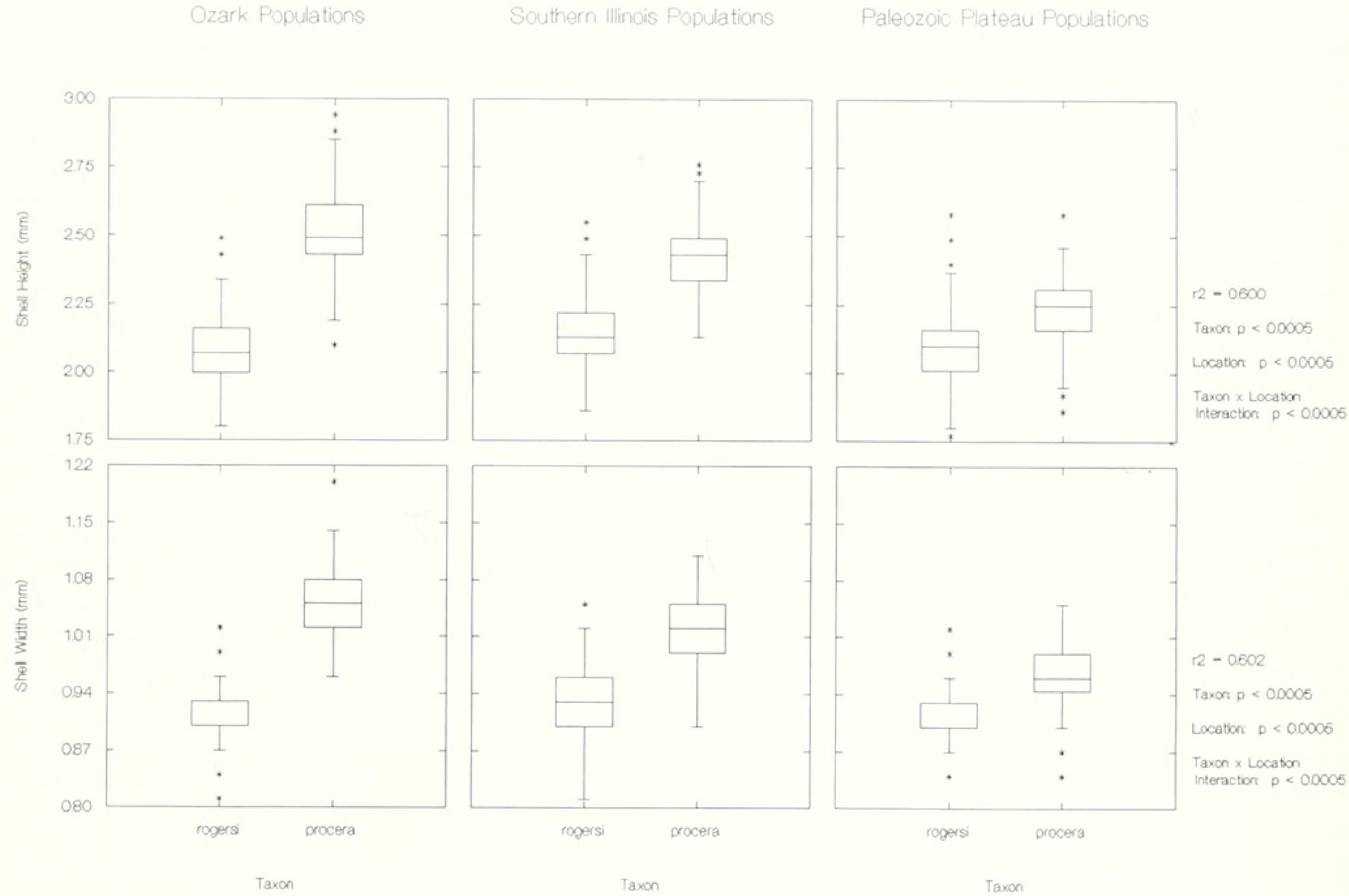


Figure 9. Box-plot diagram of variation in *Gastrocopta rogersensis* and *Gastrocopta procera* shell height and width within the Ozarks, southern Illinois, and Paleozoic Plateau. Statistical results are based on a 2-way ANOVA with interaction.

this subgenus are characterized by having angular and parietal lobes that are curved or bent at their distal ends, an elongate basal lamella whose long axis is parallel to the lip, and a clear to white shell color.

Morphometrics: Shells from 414 *Gastrocopta rogersensis* (146 from Paleozoic Plateau populations, 121 from southern Illinois, 147 from the Ozarks), and 343 *Gastrocopta procera* (88 from Paleozoic Plateau populations, 177 from southern Illinois, 78 from the Ozarks) were measured. Comparison of these demonstrated that *G. rogersensis* averaged 2.11 mm in height whereas *G. procera* averaged 2.40 mm (figure 9). This difference was highly significant ($P<0.0005$). Additionally, the difference in height between Ozark and southern Illinois populations was greater than for Paleozoic Plateau populations ($P<0.0005$). Similar trends were noted in shell width (Figure 3), with *G. rogersensis* averaging 0.92 mm and *G. procera* averaging 1.02 mm. This difference was highly significant ($P<0.0005$) and also varied between population centers ($P<0.0005$), with maximum divergence occurring in the Ozarks.

One-hundred and forty three of the measured *Gastrocopta rogersensis* and 113 of the measured *Gastrocopta procera* shells originated from sites of co-occurrence. When analyses were limited to these stations, highly significant differences ($P<0.0005$) were still noted in both shell height and width (figure 10). Additionally, a highly significant interaction between site and shell height ($P<0.0005$) and width ($P = 0.002$) was noted, with maximum divergence occurring between the two species in the Ozarks.

Linear regression of shell height vs. UTM N-S coordinates (table 2) demonstrated that while *Gastrocopta procera* shell height strongly ($r^2 = 0.375$) and significantly ($P<0.0005$) increased towards the south, no clinal variation occurred in *Gastrocopta rogersensis* ($P = 0.876$; $r^2 = 0.000$). Because of this, differences in shell size are less marked between *G. rogersensis* and *Gastrocopta procera* in the north. It is not clear why these taxa respond differently to identical environmental gradients.

Geographic distribution: The 30 known stations for *Gastrocopta rogersensis* appear restricted to three distribution centers: the Ozark uplift of northern Arkansas and southern Missouri, southwestern Illinois, and the Paleozoic Plateau (or "Driftless Area"; see Prior, 1991) of northeastern Iowa, northwestern Illinois, and southwestern Wisconsin (figure 11). The majority of known sites in the Ozarks are restricted to limestone bluffs near the upper western (Benton, Carroll and Madison coun-

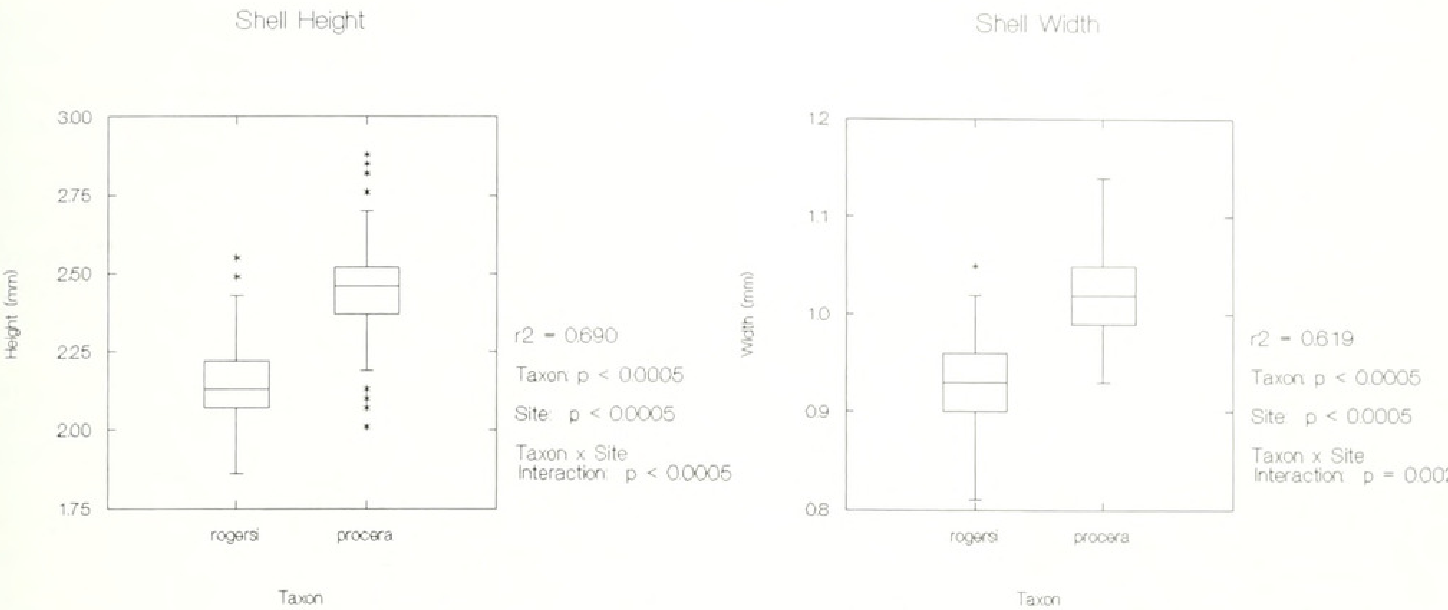


Figure 10. Box-plot diagram of variation in *Gastrocopta rogersensis* and *Gastrocopta procera* shell height and width within sites of co-occurrence. Statistical results are based on a 2-way ANOVA with interaction.

ties) and eastern (Baxter, Izard, and Stone counties) White River and its tributaries. In southwestern Illinois, *G. rogersensis* is limited to a 60 km extent of limestone bluffs along the Mississippi River in Randolph and Monroe counties. The Paleozoic Plateau populations lie within 50 km of the Mississippi River in Jo Daviess County (Illinois), Allamakee, Clinton, Dubuque, and Jackson counties (Iowa), and Crawford, Grand LaCrosse, Trempealeau, and Vernon counties (Wisconsin). The localized distribution of *G. rogersensis* contrasts markedly with *Gastrocopta procera procera*, which is widespread throughout much of the eastern and midwestern USA (Hubricht, 1985).

Even though we have documented land snails at over 700 sites in the region, as neither our own collections (nor those museum collections that we have examined) fully cover this landscape, we cannot unequivocally state that *G. rogersensis* is limited to only these three distributional centers. This is particularly true in the south, where undercollection in southern Missouri may well account for the apparent disjunction between Ozark and southern Illinois populations.

The dominant distribution for localized midwestern

Table 2. Summary statistics for regression of shell height vs. UTM N-S location for *Gastrocopta rogersensis* vs. *Gastrocopta procera*. The best-fit slope is calculated as the mm change in shell height per 10^6 meters.

Species	*G. rogersensis*	*G. Procera*
n	415	343
slope	−0.003	−0.367
standard error	0.021	0.026
t	−0.156	−14.289
p (2-tailed)	0.876	<0.0005
r^2	0.000	0.375

USA Polygyridae and Zonitidae species (Hubricht, 1985; Emberton, 1995) is typically centered on the northwestern Arkansas Ozarks [e.g., *Inflectarius edentatus* (Sampson, 1889), *Paravitrea simpsoni* (Pilsbry, 1889), *Stenotrema labrosum* (Bland, 1862), and *Ventridens brittsi* (Pilsbry, 1892)]. However, other localized midwestern distributions also exist [e.g., *Discus macclintocki* (F.C. Baker, 1928), *Euchemotrema hubrichti* (Pilsbry, 1940), and *Triodopsis discoidea* (Pilsbry, 1904)]. *Gastrocopta rogersensis* possesses one of these latter patterns, being limited to the Ozarks and the Paleozoic Plateau. Its range is most closely matched by that of *Vertigo meramecensis* VanDevender, 1979 which exhibits an almost identical distribution (Frest and Fay, 1981; Hubricht, 1985; Frest, 1991; author's unpublished data). Both of these regions are underlain by carbonate bedrock, have a rugged terrain, and escaped glaciation during the Wisconsinan. Unlike *G. rogersensis*, however, *V. meramecensis* is restricted to cool, mesic carbonate cliffs (Frest, 1991).

Taxonomic remarks: Pilsbry (1948) differentiated forms and subspecies in the *Gastrocopta procera* group based primarily on the degree of separation of the angular and parietal portions of the angulo-parietal lamella, grading from *Gastrocopta procera* form *riparia* (least separated) through *Gastrocopta procera procera* and *Gastrocopta procera sterkiana* to *Gastrocopta procera mcclungi* (most separated). *Gastrocopta p. mcclungi* was also thought to differ from the nominate species by being shorter and having a thicker and more convex lip (Baker, 1939; Franzen and Leonard, 1943; Pilsbry, 1948). Subsequent workers have considered *G. p. mcclungi* as simply a variant of *G. procera* (Leonard, 1959; Hubricht, 1985). Hubricht (1977; 1985) differentiated the remaining taxa as distinct species based primarily on the position and slope of the lower palatal

Figure 11. Distribution of *Gastrocopta rogersensis*.

tooth, ranging from *G. procera* (most deeply inserted) through *G. sterkiana* to *G. riparia* (least deeply inserted) but failed to give adequate reasoning for these conclusions. We have found these features to be highly variable, with continuous variation apparently existing both within and between populations. Further morphometric and taxonomic investigations will be necessary to help determine the appropriate taxonomic categories within this group.

Despite continued ambiguity over the status of forms within the *Gastrocopta procera* complex, *Gastrocopta rogersensis* new species is distinct in all aspects. It differs most conspicuously by having the angular portion of the angulo-parietal lamella arising near the lip and running parallel and separate from the more deeply set parietal portion. While the angular and parietal portions show a variable degree of distal separation in *G. procera*, in all cases they fuse at approximately mid-length. Sympatric populations of *G. rogersensis* and *G. procera* do not intergrade in this feature. Additionally, *G. rogersensis* individuals appear consistently smaller (ca. 0.25 mm) than *G. procera*. Less striking differences include the distinctly reflexed lip of *G. rogersensis* as seen in profile (figure 3), and its somewhat longer and more deeply inserted lower palatal lamella.

Based on these criteria, examination of the holotype of *Gastrocopta procera mcclungi* (USNM 226395, figure 6), and the ANSP figured specimen of *G. p. mcclungi* from South Dakota (Pilsbry, 1948, fig. 493: 1–3) revealed that both fell well within the normal range of variation for the *Gastrocopta procera* complex. Thus, we concur with Leonard (1959) and Hubricht (1985) that this taxon should be regarded as a synonym of *G. procera*. However, the figured ANSP specimen of *G. p. mcclungi* from Rogers, Arkansas (Pilsbry, 1948, fig. 493: 4–5) conforms in all respects to *Gastrocopta rogersensis*. The reasons for the overlooking of the uniqueness of this specimen by Pilsbry are likely two-fold: first, the specimen fell within his concept of *G. p. mcclungi* as it has a very pronounced separation between the angulo-parietal lobes. Second, as no other *G. rogersensis* specimens exist in the ANSP collections, there was only limited opportunity for him to observe the other consistent differences that exist between it and *G. procera*.

Because of this confusion, *Gastrocopta rogersensis* has remained undescribed even though specimens have likely existed in collections for over 60 years. Baker (1939) referred to *Gastrocopta procera mcclungi* from Illinois, within the known range of *G. rogersensis*. His drawings of this taxon appear similar to *G. rogersensis*, but are too crude for definitive confirmation. Hutchison (1989) listed *G. p. mcclungi* from Fountain Bluff in Jackson County, Illinois, approximately 35 km to the SE of the southern-most known Illinois *G. rogersensis* population. Even though we have not been able to examine these specimens, the reported location and habitat make it likely that these also represent *G. rogersensis*. Theler (1997) encountered *G. rogersensis* in his survey of western Wisconsin bedrock glade land snail faunas, but identified all individuals as *G. procera*.

Preferred habitats: All known populations of *Gastrocopta rogersensis* are limited to xeric or dry-mesic calcareous rock outcrops. Ozark and southern Illinois populations were encountered on wooded cliffs or cliff crests, as at the type location. The Paleozoic Plateau populations are restricted to bedrock glades (see Theler, 1997 for images of the Brady Bluff site). In these habitats, individuals are limited to organic accumulations in xeric, sparsely vegetated microsites, where short-statured grasses and forbs such as *Agoseris cuspidata* (Pursh.) Raf., *Andropogon scoparius* Michx., *Artemesia caudata* Michx., *Carex abdita* Bickn., *Carex richardsonii* R.Br., *Castilleja sessiliflora* Pursh, *Muhlenbergia cuspidata* (Nutt.) Rydb., and *Viola pedata* L. occur.

CONSERVATION RECOMMENDATIONS

Because of its limited geographic range and habitat specificity, *Gastrocopta rogersensis* should be considered of conservation importance. Even within its distributional centers, populations are sporadic and tend to be limited to high-quality sites. Ironically, a further concern for its continued survival is the occurrence of many populations (including the type and most of the Wisconsin stations) within managed nature reserves. Prairie and bedrock glade habitats throughout the midwest USA are generally subjected to intense fire management, as it has been believed that reintroduction of fire will increase the vigor and diversity of the grassland biota (e.g. Curtis, 1959; Pauly, 1985). Because of this, Theler (1997) stated that fire management is essential to maintain the habitats used by *G. rogersensis* in Wisconsin. However, fire is known to be deleterious to many native prairie plant (Hill and Platt, 1975) and arthropod (Swengel, 1996; Harper et. al, 2000) species. Such negative impacts likely also exist for *G. rogersensis*, as individuals reside in thatch and organic duff layers that are removed through repeated fire episodes. As recovery of these layers takes over a dozen years in xeric grasslands (Gibson and Hulbert, 1987), the frequent use of fire management (<10 year return intervals) may limit the amount of appropriate habitat and significantly reduce the size of *G. rogersensis* populations. Suggestions of this can be seen in Theler (1997), as the most frequently burned sites (e.g. Rush Creek) also have the smallest *G. rogersensis* and *G. procera* populations. The number of recovered shells per unit volume of soil litter in these managed Wisconsin sites is 2–3 times smaller than that observed in nearby unburned Iowa sites (e.g. Maquoketa South and Roosevelt Road). Such trends should not be surprising, as land snails are highly sensitive to fire (Frest and Johannes, 1995). We have observed 50% reductions in richness and order-of-magnitude reductions in abundance of land snails between adjacent unmanaged and fire-managed grasslands in northwestern Minnesota (author's unpublished data). Thus, overuse of fire management by conservation groups may pose as great of a threat to the survival of *G. rogersensis* as habitat loss.

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Book Review

Catalogue and Bibliography of the Marine Shell-bearing Mollusca of Japan. Type Figures.

Shun'ichi Higo, Paul Callomon, and Yoshihiro Goto. 2001. Elle Scientific Publications, Osaka, 208 pp. $325.00.

This important work is now complete with the publication of the volume of figures. The text volume was reviewed in these pages (Petit, 1999) shortly after its publication. The book is unique in that all figured specimens are name-bearing types. As the authors state in the introduction, it became evident during the production of the text volume that the identity of many species was uncertain. As only type specimens are figured, readers may be assured that the figures match the names.

Almost 2000 type specimens are figured in color. Each page of figures comprises 16 excellent, informative illustrations. The arrangement of this data is, of course, explained in the introduction that should be read before the book is used. Data is arranged in five areas, the most important being the entry number that corresponds to the species number in the text volume. The suffix "s" on a number indicates that the name of the type figured is treated as a junior synonym in the text volume. As an example, there is a figure of the holotype of *Zafra mitriformis* A. Adams, 1860, and also three figures of type species of nomina that appear in most literature as synonyms of *Z. mitriformis*: *Z. zonata* (Gould, 1860), *Z. validicosta* (Habe, 1960), and *Z. subvitrea* (E. A. Smith, 1879). When viewed together it is clear that all four are not conspecific. On the other hand, the figures of *Buccinum midori* Habe and Ito, 1965, and *B. oedematum* Dall, 1907, appear to represent the same species. There are numerous examples to be found of both cases. This book dramatically illustrates the importance of having figures of type specimens.

The second bit of data is a scale bar used for specimens under 10 mm, and the third is a measurement in millimeters for larger specimens. Of little interest to the casual user is the fourth bit of information that is an indication used if the figure is a composite image. A composite image may be used for a shell whose shape precludes bringing the entire specimen into good focus at once, in which case two photographs are taken and combined.

The final bit of data is termed the "main data box" and contains the specific name and generic placement used in the text volume; the author and date of publication; type status; museum name and registration number. The rules for designation of type specimens have always been somewhat confusing and were recently made even more so by changes in the fourth edition of the ICZN. The authors list the various kinds of types recognized, the acronyms for which are used in the "main data box," and give a description of each.

The only negative aspect of this production is the fact that only some of the taxa listed in the text volume are represented by figures of type specimens. As explained by the authors, priority was given to species originally described from Japan as their limited resources precluded inclusion of all species. Many well-known Japanese species originally described from elsewhere by the earlier authors (Linnaeus, Gmelin, Lamarck, and others) are therefore absent.

An appendix lists additional species names for the Catalogue, errata for the Catalogue listings, errata and additions to the bibliography, and additional and emended Japanese names. There is a complete index. As with the first volume, this book of figures is superbly produced. It is A4 in size, the text printed on cream stock paper and the plates on heavy glossy stock, and bound in Damascene cloth with a gold-stamped leatherette spine. As is standard in Japan, it comes in a slipcase.

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