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A TAXONOMIC REVISION OF THE FRESHWATER SNAILS REFERRED TO AS *ELIMIA CURVICOSTATA,* AND RELATED SPECIES

Elizabeth L. Mihalcik[1] and Fred G. Thompson[2]

ABSTRACT

This study involves the costate-shelled snail *Elimia curvicostata* (Reeve 1861) and species closely related to or previously referred to it. The group is found in the Gulf Coastal drainages of Alabama, Florida and Georgia, and to a limited extent includes some species found in the Altamaha River system of Georgia. By necessity some species not closely related to *E. curvicostata* are also discussed in order to clarify previous but erroneous taxonomic assignments, and to clarify biogeographic relationships.

The following 13 species and subspecies are recognized as valid: ***Elimia annae*** n.sp. (Escambia River system), ***Elimia buffyae*** n.sp. (Choctawhatchee River system), *Elimia curvicostata* (Reeve 1861) (Chipola River system and lower Apalachicola River tributaries), ***Elimia darwini*** n.sp. (middle Oconee River system), ***Elimia exusta*** n.sp. (Escambia River system), ***Elimia glarea*** n.sp. (upper Choctawhatchee River system) *Elimia induta* (Lea 1862) (middle Flint River system), *Elimia mutabilis* (Lea 1862) (upper Ocmulgee River system), *Elimia timida timida* (Goodrich 1942) (middle Ocmulgee River system), ***Elimia timida exul*** n.ssp. (middle Ocmulgee River system), ***Elimia timida nymphaea*** n.ssp. (middle Ocmulgee River system), *Elimia ucheensis* (Lea 1862) (Uchee Creek drainage, Chattahoochee River system) and *Elimia viennaensis* (Lea 1862) (upper Flint River system). Phylogenetic analysis based on mtDNA demonstrates the following relationships **((((((*catenaria-darwini*))) (((*viennaensis*) (*flava*)) ((*ucheensis-mutabilis)* (*buffyae*)))) ((((*curvicostata*))) (((*timida)* (*induta-glarea*))))) (((((*annae*))))) (((((*boykiniana*)))))).**

Key words: Gastropoda, Prosobranchia, Pleuroceridae, *Elimia,* freshwater snails, taxonomy, nomenclature, molecular genetics, phylogeny, biogeography, Alabama, Florida, Georgia.

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[1]Bainbridge College, 2500 East Shotwell St., Bainbridge, GA 31717, U.S.A. emihalci@catfish.bbc.peachnet.edu.

[2]Florida Museum of Natural History, P.O. Box 117800, Gainesville, FL 32611-7800, U.S.A. fgt@flmnh.ufl.edu.

INTRODUCTION

The objective of this study is to address the taxonomy and systematics of *Elimia curvicostata* (Reeve 1861) and those species of *Elimia* which at one time or other had been synonymized with, or which were subspecifically associated with, or which we find are closely related to *Elimia curvicostata* (Reeve 1861). These species are referred to herein as the *Elimia curvicostata* complex. The word *complex* is used in this case in the literary context, meaning a complicated situation, and not in the phylogenetic context implying close genetic relationships. Some species in the complex are closely allied genetically. Others are quite distant in their genetic relationships. The geographic study-area extends from the Escambia River system in Alabama and Florida east to the Altamaha River system in Georgia.

There are widely disparate opinions in the literature concerning morphological variation, geographic variation, geographic deployment and taxonomy of this widely distributed complex. The most recent taxonomic treatment (Chambers, 1990) recognizes a single species, *Elimia curvicostata*, distributed from the Escambia River system at the western border of Florida and Alabama eastward to the Apalachicola River system of Florida, Alabama and Georgia. Chambers recognized 10 names as synonyms of *E. curvicostata*. Earlier literature (Goodrich, 1942; Clench & Turner, 1956) recognized various of these names as distinct species or subspecies. Chambers acknowledged the extensive variation observed within the species. He attributed the variation to local ecological conditions, but he offered no experimental data to demonstrate this.

In 1965, an ongoing malacological survey of freshwater systems throughout Alabama, Georgia and Florida was initiated by F.G. Thompson. Since then we have visited on numerous occasions virtually all springs, small streams and rivers draining from these states into the Gulf of Mexico and the Atlantic Ocean. It soon became clear that the taxonomic interpretations put forth in previous literature did not adequately explain the morphological variation we observed. Our views on this matter are presented herein.

The taxonomic literature on *Elimia* is almost chaotic. Very few species have been described adequately enough to be recognizable from their descriptions or illustrations. Major ontogenetic changes take place in sculpture and shell shape, so that adults of a given species may have shells that are strikingly different from juveniles. Convergent evolution of adult shell forms has been rampant. Whereas local populations have diverged genetically and morphologically from others within their parent species, in many instances adults have converged in shell form with other species. Thus, there is in *Elimia* numerous examples of look-alike, but distinct species. Such is the case with the *Elimia curvicostata* complex, which in part explains it's confused taxonomic history.

Elimia is vast in its number of species. Approximately 450 species names have been applied to the genus (Tryon, 1873; Graf, 2001). The large number of names reflects the extensive morphological variation that exists throughout the range of the genus, and it is not just a consequence of overzealous Nineteenth Century taxonomists as has been suggested by some authors.

Current literature recognizes about 135 valid species or subspecies of *Elimia* (Burch, 1989; Thompson, 2000b; this study). Species tend to be restricted to particular rivers, to particular shoals within a river, to tributary rivers within a single river system and even to particular small streams or springs entering a river. As is typical of species that are highly restricted ecologically, populations in most streams are genetically isolated. Many have undergone considerable local evolution as a consequence of this isolation. Numerous morphologically distinct populations may exist even within a single river system.

Elimia contains multitudes of evolutionarily significant units or ESU's (Avise, 2000). Populations are isolated by seemingly minor ecological barriers. The barrier may be a large river habitat separating two small tributary streams, a quiet silt-bottom substrate separating rocky shoals, a short span of land separating adjacent streams, or a warmer more turbid stream habitat isolating clear cool springs along the bank of the stream. Populations of species that have such strict ecological parameters regulating habitat deployment undergo independent evolutionary trajectories. That is, populations are physically and ecologically isolated, they diverge genetically, they may diverge phenotypically, and their evolution is independent from other such populations. The identification of such populations requires careful analysis. It is not sufficient merely to identify them as a variation of a known taxon. Even in the restricted definition of *Elimia curvicostata* and *E. viennaensis* that we present below, we are aware of several ESU populations that leave us uncomfortable concerning their specific identities.

In some literature such populations have been referred as ecophenotypes, but that is a misuse of the term. Ecophenotypes are populations of a given genotype that differ phenotypically as a genetic expression to different environments. Such is not the case in *Elimia*. Populations of *Elimia* differ genetically as well as phenotypically from other closely related populations. Widely distributed species of *Elimia* have more evolutionarily significant populations (ETU's) than do narrowly distributed species. A concise taxonomic treatment of a given species is difficult to arrive at without extensive local field surveys and careful morphological analysis including data on various growth stages. We have tried to minimize the ambiguity inherent in dealing with locally variable populations. We are certain that other investigative techniques will require additional species to be recognized among those we discuss below.

Our taxonomic results differ in most respects from the results arrived at by previous authors. This is due in part to having at our disposal more extensive field samples than were available to previous authors, and incorporating juvenile shell morphology and data on mtDNA sequences into our analysis. We also have had the advantage of observing on many occasions each of these species in their natural habitats, which has given us an appreciation of the ecological and physiographic factors that have influenced and regulated their evolutions. We harbor no illusions that our results are definitive. We only hope to place *Elimia* systematics in a better framework than existed previously and to provide a clearer basis for future investigations. This data also will provide a better basis for issues related to environmental management and conservation.

Species of *Elimia* for the most part inhabit lotic bodies of water, and they tend to be habitat-restricted within epigene aquatic stations. We know of only two instances where species were found in subterranean habitats, *E. livescens* (Menke 1830) in Indiana (UF 292608) and *E. curvicostata* (Reeve 1861) in Florida (UF 93628). Ecologically, *Elimia* are divisible into two categories of species based on their habitat deployment. The categories are large-stream species and small-stream species. Large-stream species seldom enter small streams. When they do, the invasion usually is restricted to near the mouths of the small streams. Conversely small-stream species seldom enter large streams. Species of *Elimia* have limited vagility. Seldom are they uniformly distributed in a particular stream.

MATERIAL AND METHODS

Shell measurements. The term **adult shell** refers to specimens which appear to have reached definitive development. This determination is somewhat arbitrary because there is no feature that indicates definitive development other than the thickening of the outer lip of the aperture. Some species do not develop a thickened lip.

The **Whorls**. Most species of *Elimia* in the southeastern United States have approximately four functional whorls in the adult shell. The earliest remaining functional whorl is closed above by an **apical plug**. As the snail grows, new apical plugs are formed farther down the spire so that the total number of whorls below the apical plug tends to remain nearly constant. Whorls that are retained above the plug are non-functional because they are no longer part of the living organism. Figs. 2 and 3 represent one such specimen. Fig. 3 has had the dead whorls removed above the apical plug. The dead whorls represent fragments of juvenile growth stages, and they break off at variable rates and at variable places above the apical plug. Fragments continue to break or erode away until only small vestiges remain at definitive growth of the snail. For this reason shell measurements and whorl counts are based on the whorls below the apical plug, because that represents the actual living snail. The total number of whorls that the snail develops throughout its life can be quite accurately estimated by comparing different growth stages of shells from a given sample. The total number in some instances is useful for species comparisons.

The **standard length** (**SL**) of the shell is measured from the top of the apical plug to the base of the last whorl. Because of the extreme decollation of the apex and the variable point at which the apical plug develops in many species, the ratio of shell length to shell width has little comparative value other than as a general descriptor of the shell. This ratio varies significantly even between subadult and mature specimens from a single population sample. The species included in this study typically retain four or more whorls. We include two measurements of length: the length of the last four whorls and the length of the last whorl. The term **fourth whorl** (**4Wh**) refers to the fourth whorl above the insertion of the outer lip on the body whorl (Fig. 1). The length of the **last whorl** (**LWh**) is measured from the previous suture above the lip insertion to the base of the shell (Fig. 1). It includes one full whorl. Because of the extreme decollation of the apex in many species, the length of the last whorl may be the only remaining longitudinal measurement that reflects the dimension of shell length relative to other growth parameters.

The **shell width** (**SW**) is standard, and is measured across the last whorl perpendicular to the axis of the shell. The **aperture height** (**AH**) is measured from the posterior (upper) corner to the base of the aperture parallel to the shell axis. The **aperture width** (**AW**) is measured from the outside of the outer peristome to the outer edge of the columellar callus and is perpendicular to the shell axis. The number of whorls (**Wh**) is counted from the end of the apical plug to the base of the shell. Remnants of previous whorls above the apical plug may be present. Unless otherwise stated, these remnants are excluded from the data presented in this paper because of the variable number of whorls that may be retained and their incomplete condition. Some individuals may have two apical plugs, the uppermost of which encloses an unoccupied whorl. In such cases measurements were taken from whorls below the lower plug. The **angle of the spire** (**<Sp**) is measured by projecting the image of the shell through a camera lucida onto a sheet of paper and measuring the angle of divergence with a protractor.

Fred Thompson is primarily responsible for the taxonomic treatment presented herein. Elizabeth Mihalcik is primarily responsible for the genetic analysis and phylogeny. Both authors concur on the contents, interpretations and conclusions that are set forth. The authorships of new taxa are to be cited as Mihalcik and Thompson.

GENUS *ELIMIA* H. & A. Adams 1854

Elimia H. & A. Adams 1854, *Genera of Recent Mollusca,* I, p. 300. Type species designated by Pilsbry & Rhoads, 1896: *Melania acutocarinata* Lea 1841, p. 14 (= *Melania clavaeformis* Lea 1841, p. 12).

Melasma H. & A. Adams 1854, *Genera of Recent Mollusca,* I, p. 302. Type species designated by H.B. Baker, 1963: *Melania laqueata* (Say 1829).

Goniobasis Lea 1862, *Proceedings of the Academy of Natural Sciences of Philadelphia,* 14, p. 262. Type species designated by Hannibal, 1912, 179: *Goniobasis osculata* Lea 1862.

Macrolimen Lea 1863; *Journal of the Academy of Natural Sciences of Philadelphia,* 5, p. 221 (type species by monotypy: *Goniobasis showalterii* Lea 1861 = *Goniobasis* [=*Elimia*] *pilsbryi* Goodrich 1927, *non Lithasia* [=*Elimia*] *showalterii* Lea 1860).

Elimia is the oldest available name for this genus. It is also the first to have a valid type-species designation. As Lea (1862) pointed out, the genus *Elimia* of Adams & Adams 1854 included some species that Lea placed in *Goniobasis*.

Elimia is an immense genus that includes over 135 recognized species, and we have no doubt that many more remain to be recognized. The genus consists of several well-differentiated lineages, which eventually may be recognized as subgenera or even genera following further systematic studies of the numerous species-groups. Insufficient information on juvenile shell characters and opercular structure are available to sort out the numerous species according to apparent natural groups, and the information that is available on molecular-based genetic phylogeny is discordant because the various studies that have been performed employed different gene systems. At present it is not possible to clearly define subgeneric groups. However some divisions are apparent, and it may be fruitful to speculate on some of there groupings.

Elimia s.s. consists of those species with strongly carinate juvenile whorls that lack vertical or spiral sculpture. This group includes *Elimia clavaeformis* (Lea 1841), *Elimia aterina* (Lea 1863), *Elimia simplex* (Say 1825), *Elimia proxima* (Say 1825), *Elimia symmetrica* (Haldeman 1841) and *Elimia teretria* Thompson 2000.

Melasma includes species with a narrow juvenile shell that bears well developed axial and spiral sculpture. The group consists of species placed by Goodrich (1940, 1941, 1942) in the *laqueata* species-group and the *catenaria* species-group, as well as others.

Goniobasis includes those species related to *Elimia olivula* (Conrad 1834) and *Elimia alabamensis* (Lea 1841) which have a smooth or weakly plicate, broadly conical juvenile shell, such as occurs in *E. flava* (Lea 1862) (Figs. 153, 154). The operculum is neomelanian with a strongly eccentric nucleus (Figs. 200-201). This group seems to be confined to the Alabama River system.

Macrolimen may be a subjective junior synonym of *Goniobasis*. It has a broadly conical juvenile shell, but the operculum is unique (Figs. 204-205). It grows by increasing in size along the palatal margin. As it grows the muscle attachment scar migrates outward so as to abandon the nuclear region, which becomes free and projects outward beyond the columellar margin of the aperture (Fig. 206). At an early growth stage the nucleus usually becomes broken away so that only a tongue-like projection persists. Lea (1863, p. 121) and Goodrich (1936, p. 45) state that this condition is common to all individuals. The illustrated operculum of *Elimia pilsbryi* is from a juvenile 9.3 mm long, which still retains the nuclear whorl. This species apparently is extinct (Bogan & Pierson, 1993).

This is the extent in which the existing nomenclature accommodates the allocations of species to subgeneric groups. Most of the species discussed below fall outside of these subgeneric groups. It is not possible to assign better taxonomic subdivisions of *Elimia* until a phylogeny has been proposed that includes morphological studies based on many more species.

Some authors adhere to the taxonomy used by Goodrich (1920-1950), and revert to use of the generic name *Goniobasis* (Dillon & Keferl, 2000; Dillon & Reed, 2002). The name *Goniobasis* Lea 1862 is a subjective junior synonym of *Elimia* H. & A. Adams 1854. The most widely observed principal in systematic zoology is the recognition of name priority (ICZN Article 23). This is not simply an issue of which name one prefers. If the name *Goniobasis* is to be employed it would have to be for the Alabama River system species that comprise the *Elimia olivula* species-group and the *E. haysiana* species-group of Burch (1989) and it would exclude most other species. Even if *Elimia s.s.* is considered to be a separate genus, the name *Melasma* would apply to the majority of the remaining species. The continued use of the name *Goniobasis* for the genus only adds to the confusion that already characterizes the systematics of the Pleuroceridae.

For purposes of organization we list the species treated in this paper according to closest phylogenetic relationships as best as we are able to determine. It is clear that the phylogenetic relationships are disparate, and that there is no similarity to previous classifications that have been proposed. In most cases we are unable to reconcile the allocation of particular species to species-groups utilized by previous authors. To try to do so is equivalent to driving square pegs into round holes. It is obvious by now that the species-groups proposed by Goodrich, and employed by subsequent authors, are artificial in their composition and they serve little substantive purpose. The species-groups we adapt are, at the most, only small clusters of closely related species. The groups are unequal in differentiation and diversity. No higher classification is implied. We address *Elimia curvicostata* first because of the historical application of the name *curvicostata* to this and to the other species that are involved in the resolution of this systematic conundrum.

SPECIES ACCOUNTS

The *Elimia curvicostata* species-group

Earlier literature places *Elimia curvicostata* in the *carinocostata* species-group, which otherwise occurs in the Alabama River system (Goodrich,1940; Burch, 1989). The species that were assigned to the *carinocostata* species-group are diverse in relationships, and constituted an unnatural assemblage (Thompson, 2000b). We assign a singe species to this group, *E. curvicostata* (Reeve 1861). The group is differentiated as is diagnosed below for *E. curvicostata.*

Elimia curvicostata (Reeve 1861)

Vernacular name: Graphite Elimia

Melania curvicostata Reeve 1861, *Conchologica Iconica, Melania*, species 462, pl. LVIII, fig. 462; Thompson & Mihalcik, 2002, *Bulletin of Zoological Nomenclature,* in press.
Goniobasis curvicostata (Reeve 1861), in part; Tryon, 1873, *Smithsonian Miscellaneous Collections,* 253, p. 202, fig. 397; Goodrich, 1942, *Occasional Papers of the Museum of Zoology, University of Michigan,* (456), pp. 4-5; Clench & Turner, 1956, *Bulletin of the Florida State Museum,* 1, p. 136; Chambers, 1980, *Malacologia,* 20, p. 65.
Elimia curvicostata (Reeve 1861); Burch & Tottenham, 1980, *Walkerana*, 1(3), p. 136, fig. 358; Thompson, 1984, 26, fig. 48; Burch, 1989, *North American freshwater snails,* p. 137, fig. 358; Chambers, 1990, *Walkerana,* 4(12), pp. 262-264, fig. 4D; Thompson, 2000a, 22-23, figs. 51, 52.
Melania densicostata Reeve 1861, *Conchologica Iconica, Melania*, species 465, pl. LVIII, fig. 465; Thompson & Mihalcik, 2002, *Bulletin of Zoological Nomenclature,* in press.
Goniobasis doolyensis Lea 1862, *Proceedings Academy of Natural Sciences of Philadelphia,* 14, pp. 266; Lea, 1863, *Journal of the Academy of Natural Sciences of Philadelphia,* 5, p. 315, pl. 37, fig. 159.

Diagnosis. A moderate sized, moderately stout snail that has a conical, straight-sided spire. The sculpture consists of vertical ribs that tend to be synchronized. The ribs commence on the fourth juvenile whorl, and usually extend to the penultimate whorl or the last whorl. The juvenile shell is narrowly conical with 3-4 whorls that bear a strong peripheral carina. The carina forms slight knobs where it is crossed by the ribs on the following whorl or two. Spiral sculpture is absent on the lower shells. The aperture tends to be trapezoidal in shape.

Elimia curvicostata is similar to some specimens of *E. dickinsoni* (Clench & Turner, 1965), except that the latter species has raised spiral threads on the base of the body whorl, the outer lip is strongly recurved in lateral profile, and the juvenile shell has fine vertical ribs, a heavy peripheral spiral cord, and two basal cords (Thompson, 2000a, fig. 45). *Elimia dickinsoni* is remotely related to the species treated in this paper and is excluded from this study. *Elimia curvicostata* differs from *E. induta* and *E timida* by lacking a spiral thread below the suture. In the latter two species there is a spiral cord below the suture that forms small knobs at the top of the ribs.

Shell (Figs. 1-15). The shell is moderately obese with a straight-sided decollate spire that diverges at an angle of 22-35°, and is olive gray in color, although occasional specimens bear 1-2 rust-colored bands at the periphery. The shell is medium-sized, reaching about 22 mm in standard length. The last four whorls attain a length of up to 20.4 mm. There are 4.0-5.5 flat-sided whorls remaining below the apical plug. The growth rate of juveniles indicates that a total of about 10 whorls are formed. In juveniles the spire is narrow and straight-sided, with a deep suture (Figs. 7, 8). The suture may be exaggerated on the lower whorls by the rugose ribs. The first three whorls are button-shaped, smooth and have an acute peripheral carina, which extends to the fourth or fifth whorl. Occasional juvenile specimens have a weak spiral chord connecting the top of the ribs just below the suture (Fig. 8). Bold axial ribs begin on the third or fourth whorl, which form low knobs where they cross the peripheral carina. The ribs extend from the suture to the periphery of the whorls. They are synchronized or nearly so, and usually continue to the penultimate or last whorl. Usually there are 10-15 ribs on the penultimate whorl. The ribs are bold, nearly straight and vertical, and are as wide or wider than their interspaces. Weak incremental micro-striations occur on and between the ribs. The base of the whorls lack sculpture except for fine incremental striations. The aperture is trapezoidal in shape with a weakly canaliculate base, the aperture is about 0.38-0.47 times the length of the last four whorls and about 0.62-0.69 times the length of the last whorl. The columellar margin is moderately thick and is nearly uniformly wide. The outer lip is weakly recurved and nearly vertical in lateral profile. (Figs. 11, 16).

Measurements based on two population samples from the Chipola River system in Florida are given in Table 1.

Operculum (Figs. 177-178). Dark amber in color. Broadly ovate-rotund, consisting of two rapidly expanding whorls. Outer surface with moderately strong growth striations. Nucleus located about one third of the distance from the base to the apex and about one third of the distance from the columellar margin to the outer margin. Muscle attachment scar large, covering about half of the distance from the columellar margin, and most of the distance from the apex to the base, bordered along its base by a weak ridge.

Geographic variation. The description given above is based on specimens from the Chipola River system in Florida. The form from the Chipola River system (Figs. 10-15) is typical for the species throughout most of its range. Specimens from the Apalachicola River drainage in Florida and the Flint River drainage in Georgia conform closely to the description in most particulars. However, there is local variation in obesity and in the degree of the ribbed sculpture on the lower whorls.

Specimens from the Flint River drainage ("*doolyensis*") (Figs. 16-18) differ from typical *curvicostata* in that the aperture tends to be more rounded. This may be, in part, a matter of sampling error. Most of our samples from the Flint River system taken over a period of 30 years were collected during the summer and early fall, and the samples consist mostly of juveniles that have not achieved definitive growth. There is little else morphologically to distinguish these populations from typical *curvicostata*, although they show significant divergence

TABLE 1. *Elimia curvicostata* (Reeve 1861). Measurements of the neotype (UF 292208) and of ten specimens each from two population samples selected to show variation. UF 230569: Black Hole Spring, Spring Lake, Jackson Co., Florida. UF 230654: Waddell's Mill Creek, 0.8 mi. above confluence with Chipola River, Jackson Co., Florida. SL = standard length, 4Wh = length of last four whorls, LWh = length of last whorls, SW = standard width, AH = aperture height, AW = aperture width, Wh = whorls remaining, <Sp = angle of spire, StD = standard deviation.

	SL	4Wh	LWh	SW	AH	AW	Wh	<Sp	SW/4Wh	AH/4Wh	AH/LWh	AW/AH	AH/SW
Neotype	22.3	20.0	12.8	8.9	8.2	5.7	4.8	30	0.45	0.41	0.64	0.70	0.92
UF 230569													
Min.	17.7	17.5	10.4	7.2	6.9	4.2	4.1	25	0.40	0.38	0.62	0.60	0.93
Max.	21.1	20.4	12.9	9.3	8.3	5.3	4.8	30	0.48	0.44	0.67	0.69	1.01
Avg.	18.8	18.47	11.58	7.92	7.47	4.78	4.36	27.50	0.43	0.40	0.67	0.64	0.96
StD	1.22	0.94	0.85	0.57	0.43	0.36	0.36	1.80	0.02	0.01	0.02	0.03	0.05
UF 230654													
Min.	16.3	15.8	10.6	7.2	6.6	4.8	4.3	25	0.40	0.40	0.62	0.61	0.88
Max.	21.4	19.9	12.7	8.6	8.7	5.3	5.4	33	0.49	0.47	0.69	0.73	1.01
Avg.	17.4	17.1	11.2	7.6	7.2	4.82	4.87	29.8	0.45	0.42	0.64	0.67	0.96
StD	1.52	1.34	0.63	0.45	0.61	0.25	0.40	2.30	0.02	0.02	0.03	0.05	0.05

genetically (Fig. 211, CUR-3).

Elimia curvicostata undergoes a great deal of geographic variation throughout its range. This is a consequence of isolated populations that have had independent evolutionary histories. Formal taxonomic recognition of them is withheld until a better knowledge of southeastern *Elimia* is achieved. Two such populations in particular deserve mention.

A population in Sawhatchee Creek, Early County, Georgia, contains two forms of *Elimia*, which are ecologically segregated within just a few meters of each other. One form is elongate, unicolor greenish-gray, the ribs occur only on the upper half of the shell, and the whorls are nearly flat in profile (Figs. 21, 22). The shell normally is free of surface deposits. It lives in quiet waters on a silty sand substrate. The second form is dark reddish-brown with bold yellow bands, it is stockier, the whorls are more rounded, and the shell is completely ribbed (Figs. 23-24). It is usually encrusted with a calcareous algae. It lives on gentle limestone shoals. Unfortunately, DNA was sequenced from neither form.

Another problematic population occurs in Mosquito Creek, Gadsden County, Florida. Specimens of this population have drastically truncate shells (Figs. 25-28). The ribs are synchronized, as is typical of *curvicostata*, but they are poorly defined and are usually restricted to the uppermost whorls. The contour of the whorls is more rounded, and traces of incised spiral microsculpture are present over the surface of the shell. Mitochondrial DNA sequences suggest a conspecific or very close relationship with *curvicostata* (Fig. 211).

Type localities. *Melania curvicostata* Reeve 1861: "Florida, United States." Three specimens from the Cuming Collection in the British Museum of Natural History are labeled syntypes [BM(NH) 1194056]. None is the specimen figured by Reeve (1861, pl. 85, fig. 462).

Melania densicostata Reeve 1861: "Florida, United States." Three specimens from the Cuming Collection in the British Museum of Natural History are labeled syntypes [BM(NH) 1194057]. None is the specimen figured by Reeve (1861, pl. 85, fig. 485).

Goniobasis doolyensis Lea 1862: In small streams tributary to the Flint River near Vienna, Dooly County, Georgia. Lectotype: USNM 119121 (Chambers, 1990: 262); collected by the Rev. G. White; paralectotypes: USNM 873108 (33 specimens). We restrict the type locality to Spring Creek, Dooly County, Georgia.

For over 140 years the name *Melania curvicostata* Reeve 1861 has been applied to the widely distributed species known as *Goniobasis curvicostata* (Reeve 1861) or *Elimia curvicostata* (Reeve 1861). The name *Melania curvicostata* has line priority (species 462) over the next available name applied to this species, *Melania densicostata* Reeve 1861 (species 465). Both look alike, as are depicted by Reeve's descriptions and illustrations. Until now there was little reason to doubt that the two names represented the same species. We have examined the syntype series of both. They represent two different species. Both species were reported to have come from "Florida." The syntypes of both came from the collection of John G. Anthony (1804-1877) who is known to have confused locality information of specimens from his collection (Goodrich, 1931). We have little assurance that either nominal species came from Florida. Furthermore, none of the syntypes are the specimens figured by Reeve. The questions raised by the specific identities and the provinces of the syntypes are best resolved by the designations of a neotype for each nominate species. We have petitioned the International Commission on Zoological Nomenclature to make the necessary designations in order to maintain the prevailing usage of the two names under Article 75.6 (ICZN Case 3232, Thompson & Mihalcik, *in press*). For the purposes of this paper Figs. 10 and 11 (UF 292208) represent a typical specimen of the snail known as *Elimia curvicostata.*

Distribution (Fig. 207). This snail is found in the lower part of the Choctawhatchee River system, the Chipola River and the Apalachicola River system in northwestern Florida, and in the lower Flint River and the Chattahoochee River systems in southwestern Georgia and southeastern Alabama.

Generally, *Elimia curvicostata* inhabits small streams tributary to larger rivers. In Houston County, Alabama, it has been found in headwaters of the Chipola River and in small creeks draining east into the Chattahoochee River. In Florida it is known from the Choctawhatchee, Chipola, and Apalachicola river systems. It is found in the main stream of the Chipola River, as well as small streams and springs that comprise the headwaters of the system. It is found in small creeks draining into the Apalachicola River, but it is seldom found in the main stream. Specimens from the Econfina River in Florida are referred tentatively to this species. In Georgia we have collected the species only as far north as Sawhatchee Creek, Kirkland Creek and Dry Creek in the Chattahoochee drainage. It has not been found in the Chattahoochee River. In the Flint River drainage *Elimia curvicostata* occurs as far north as Limestone Creek, Dooly County (Figs. 16-20). Large series of specimens were collected in the Flint River near Albany, Georgia by Robert Call around 1900 (UF collection). We have not found it in the Flint River during our surveys. We have collected it from Spring Creek, Chickasawhatchee Creek, and Kinchafoonee Creek, draining from the west to the Flint River, and from Mercer Mill Creek, Abrams Creek, Big Abrams Creek, Jones Creek, Cedar Creek, Swift Creek and Limestone Creek draining from the east to the Flint River.

Specimens examined. **ALABAMA. Houston Co.:** Cowart's Creek, nr. Cowart (UF 74207); Dry Creek, nr. Madrid (Chattahoochee drainage) (UF 74151); Golf Creek, nr. Smyrna; (UF 74152); Cowart's Creek, nr. Cottonwood (UF 74209); Big Creek, 7 mi. S of Dothan (UF 230668); Big Creek, nr. Taylor (Chattahoochee Drainage) (UF 74146); Big Creek, 3.2 mi. E of Madrid (UF 241079, UF 241080); Spring Creek, nr. Madrid (UF 74177); Spring Creek, nr. FL State Line (UF 74185); Howard Creek, 1 mi. S of Gordon (UF 210).

FLORIDA. Bay Co.: Econfina Creek at SR 20 (UF 263372, UF 271226); Econfina R., 6.8 mi. W of Youngstown (UF 231204); Gainer Springs (UF 244505). **Calhoun Co.:** Chipola River, Blountstown (UF 74181); Chipola River, 1 mi E of Chason (UF 230614); Dead Lake, Chipola River, Chipola Park (UF 1959); 9.2 km ENE of Kinard, 12.3 km NW of Lewis, 16.4 km N of Iona (UF 155940); Chipola River, 2 mi. E of Clarkesville (UF 1965); Chipola River, 1 mi. E of Clarksville at FL Hwy 20 bridge (UF 230619, UF 231177, UF 232047, UF 251645); Farley Creek, ca. 0.5 mi. W of FL Hwy 275 (UF 41077). **Gadsden Co.**: small creek W of Rosedale Glades (UF 230740); Aspalaga Bluff, E side of Apalachicola River (UF 271325); Aspalaga Landing Creek, N of Torreya State Park, Apalachicola River (UF 290376, UF 289983); Means Creek, on eastern edge of Apalachicola River, ca. 1.0 mi. S of I-10 (UF 272000); Mosquito Creek, 0.5 mi. E of Chattahoochee (UF 209, UF 30102); Mosquito Creek, between US 90 & hospital dam (UF 231183); North Mosquito Creek, 1 mi. E of Chattahoochee (UF 251634, UF 251635); North Mosquito Creek, 4 mi. NE Chattahoochee (UF 1961). **Gulf Co.:** W shore of Dead Lake, 3.0 mi. N of Weewahitchka Dam (UF 290417). **Holmes Co.:** Gully Creek at FL Hwy 177, ca. 9 mi. NNW of Bonifay (UF 270477); Limestone Branch, 30° 57.2' N, 85° 52.0'W (UF 270483, UF 291488); Holmes Creek at Jackson Co. line, FL Hwy 162 (UF231213); Ponce de Leon State Park, Ponce de Leon Springs (UF 290555); Ponce de Leon State Park, Sandy Creek, 0.5 mi. SE of Ponce de Leon (UF 290564). **Jackson Co.:** Spring Creek, 2.6 mi. N of Campbelltown (UF 290418, 230741); Holmes Creek, 9.3 mi. SSW of Graceville (UF 231182); Cowarts Creek, 5.6 mi. W of Malone (UF 230691); Waddell's Mill Creek, 0.8 mi. above Chipola River (UF 230654); cave at NW end of Waddell's Mill Pond (UF 230656); Waddell Spring Run, 0.5 mi. W of Chipola River (UF 231188); Blue Springs, Merritts Mill Pond ca. 3 mi. E of Marianna (UF 270503); Merritt's Mill Pond (UF 131424); Chipola River at Co. Rd 278, T3N, R9W, Sec. 30 (UF 263362); Chipola R, 5.2 mi. W of Greenwood (UF 230661); Chipola River, boat ramp on County Road 278 (UF 288681); Chipola River, at FL Hwy 167 bridge, N of Marianna (UF 231170); Chipola River, 0.3 mi. E Marianna (UF 231176); Chipola River, 1 mi. N of Marianna (UF 1963); Chipola River, Marianna (UF 3800, UF 4333, UF 4334, UF 4335); Chipola River, 0.6 mi. W of Sink Creek (UF 29620); Chipola River, 1.4 mi. N of Marianna off FL Hwy 167 (UF 224235, UF 231192, UF 281400); site of old mill on tributary of Chipola River, 2 mi. S of Marianna, FL Hwy 73 (UF 231927); creek, 2.4 mi. NW of Sink Creek (UF 4942); Gadsden Spring Run, trib. of Chipola River, via Dry Creek, Sec. 36, T4N, R11W) (UF 112272); Dry Creek, junction of FL Hwy 73, 5.8 mi. S of Marianna (UF 231180); Dry Creek, 6.4 mi. S, 2 mi. E of Marianna (UF 230611); Spring Creek, 3.6 mi. E of Marianna (UF 231929); Blue Springs, 5.4 mi. E of Marianna (UF 231928); small creek 1.5 mi NW of Florida Caverns State Park entrance, on SR 166 (UF 224229); Blue Hole Springs, Florida Caverns State Park (UF 224280, UF 231815, UF 290194, UF 291489); Marshall Creek, 8.4 mi. W of Malone, at Fla Hwy 2 (UF 230694); Reedy Creek, 6 mi. W of Malone (UF 1958); Big Creek, 8 mi. W Malone (UF 1960); creek, 2.4 mi. NW of Sink Creek Town (UF 4942); Baker Creek (UF 230664); Rocky Creek at FL Hwy 71, 2.6 mi. N of Sink Creek Town (UF 28349); stream 0.5 mi. N of Campbelltown (UF 74138); Spring Lake (UF 230551); Corner Spring, Spring Lake (UF 230535, UF 230531); W end of Spring Lake (UF 230539); Double Spring, Spring Lake (UF 230544); mouth of Mill Pond Spring Run, Spring Lake (UF 230561); Black Hole Spring, Spring Lake (UF 230569); E end of Spring Lake (UF 230570, UF 230600); Springboard Spring, Spring Lake (UF 230605). **Liberty Co.:** ravine S of campground, Torreya State Park (UF 232149); bridge on Rock Creek, Torreya State Park. (UF 232148); Apalachicola River, Camp Torreya (UF 4347). **Walton Co.:** Limestone Creek, N of Darlington (UF 281994); Limestone Creek, 7.3 km ENE of Gaskin, 5.0 km N of Darlington (UF 282277); Morrison Springs, 5 mi. SSE of Ponce de Leon (UF 231930). **Washington Co.:** Holmes Creek, Beckton Springs (UF 66008, UF 66013, UF 276625); Holmes Creek, Burnt-out Springs, 30°40.9'N, 85°38.8'W (UF 276598); small oxbow creek on NW side of Holmes Creek, 30°36.4'N, 85°45.2'W (UF 275119); Holmes Creek, 0.8 mi. N of Vernon (UF

224270); Holmes Creek, Vernon, boat landing (UF 28610); Holmes Creek, mossy rocks below Burnt Sock Landing, 30°40.1'N, 85°39.4'W (UF 276609); Holmes Creek, Mullet Springs, 30°40.2' N, 85°39.2'W (UF 276606); Blue Springs, Boy Scout Camp, NW 1/4, T1N, R13W, Sec. 27 (UF 231203); Blue Springs Cave (UF 93628); Econfina River, 1.5 mi. N of bridge at Fla RT 20 (UF 231931, UF 231933); Econfina River, Williford Spring Run, 1 mi N of FL Hwy 20 (UF 209076).

GEORGIA. Baker Co.: Chickasawhatchee Creek, Elmodel (UF 231175). **Calhoun Co.:** Chickasawhatchee Creek, 4 mi. E. of Leary (UF 231173); Chickasawhatchee Creek, 4.7 mi. E of Leary (UF 231831); Chickasawhatchee Creek, 2 mi. E of Leary (UF 231172). **Crisp Co.:** Cedar Creek, 5 mi. SW of Cordele (UF 1957, UF 74139); Big Abrams Creek, 4.2 mi. S of Oakfield (UF 280684, UF 251660, UF 251659, UF 251882); Jones Creek, 2 mi. SE of Oakfield (UF 251665); Swift Creek, ca. 4 mi. E of Warwick (UF 251656, UF 251663); Cordele Springs, Cordele (UF 79764); Gum Creek, 2 mi. N of Cordele (UF 74190). **Decatur Co.:** Spring Creek, near Brinson (UF 224); Spring Creek, 1.0 mi. WNW of Brinson (UF 278982); North Mosquito Creek, 2 mi. SW of Recovery (UF 1964, UF 4943). **Dooly Co.:** Limestone Creek, at McCay Rd., ca. 4 mi. S, 2 mi. E of Drayton (UF 277481, UF 279000, UF 280691). **Dougherty Co.:** Flint River, Albany (UF 74153; UF 74161, UF 74167, UF 74169, UF 277033). **Early Co.:** Sawhatchee Creek, at GA Hwy 370, 2.4 mi. NNW of Saffold (UF 276635); Sawhatchee Creek, at GA Hwy 273, 0.5 mi. W of Cedar Springs (UF 276641); Sawhatchee Creek, 14 mi. NW of Donaldsonville (UF 231184). Kirkland Creek, Howard's Mill, ca. 2.1 mi. E, 2.5 mi. S of Cedar Springs (UF 276645); Kirkland Creek, ca. 2.5 mi. NW of Jakin (UF 276647); Dry Creek (UF 74172). **Lee Co.:** Kinchafoonee Creek, 1 mi. W of Leesburg (UF 231187); Graves Spring, ca. 10 mi. NE of Albany (UF 278970); Muckalee Creek, 5.8 mi. SE of Leesburg (UF 231155). **Miller Co.:** Spring Creek, Colquitt (UF 211; UF 42576, UF 42577). **Seminole Co.:** Sawhatchee Creek, 10 mi. NW of Donaldsville (UF 209); Sawhatchee Creek, 14 mi. NW of Donalsonville (UF 206, UF 226, UF 231184); Kirkland Creek, 6 mi. NW of Donaldsville (UF 208, UF 223); Spring Creek, Brinson (UF 231179); Spring Creek, 7.5 mi. N of Brinson (UF 231194). **Terrell Co.:** creek, 1.0 mi. N of Bronwood (UF 231168); East Fork of Chickasawhatchee Creek, 5 mi. E of Dawson (UF 74189, UF 74184); Chickasawhatchee Creek, 5.2 mi. SE of Dawson (UF 232145); Chickasawatchee Creek, 5 mi. E of Dawson (UF 232173); creek, 1.0 mi. N of Bronwood (UF 231165). **Worth Co.:** creek, 12.4 mi. NNE of Albany (UF 231185); creek, 8.9 mi. NNE of Albany (UF 25463); Big Abrams Creek, at GA Hwy 300, 9.3 mi. SSW of Warwick (UF 278997, UF 279577, UF 279647); Abrams Creek, 5 mi. S of Oakfield (UF 74178); spring, 3 mi. W of Doles (UF 74206, UF 74216); Mercer Mill Creek at GA Hwy 300, ca. 10 mi. NE of Albany (UF 278963).

Conservation status. The species occurs in healthy populations throughout its range. No special conservation measures are needed by Federal or State agencies at the present time.

Habitat. *Elimia curvicostata* is primarily a small stream species that occupies quiet zones in clear low gradient smaller stream. It is most frequently found on silt or sand, and less commonly on tree rootlets, dead wood or rocks. At Blue Springs Cave, Washington County, Florida, this species was found in a subterranean stream, which discharged into the Econfina River approximately 100 meters away (UF 93628).

This is an annual species. Nidification usually commences in March and continues through July or August. Usually specimens reach their maximum size in June and July. By late August most populations consist of juvenile and subadult specimens. In some spring environments where the water temperature varies relatively little, the reproductive season and the annual growth cycle may be altered so that large adults persist into October and November.

Remarks. *Melania curvicostata* Reeve 1861 is the oldest available name for the Florida species. Clench & Turner (1956, p. 136) included as synonyms *Melania densicostata* Reeve 1861, *Goniobasis doolyensis* Lea 1862, *Goniobasis induta* Lea 1862, *Goniobasis ucheensis* Lea 1862, *Goniobasis elliotti* Lea 1862, *Goniobasis gesneri* Lea 1862, and *Goniobasis inclinans* Lea 1862. Chambers added to the synonymy *Goniobasis viennaensis* Lea 1862, *Goniobasis etowahensis* Lea 1862, *Goniobasis inosculata* Lea 1862, and *Goniobasis etowahensis* Lea 1862 (= *Goniobasis canbyi* Lea 1964).

Goniobasis (= *Elimia*) *viennaensis, Goniobasis* (= *Elimia*) *induta* and *Goniobasis* (= *Elimia*) *ucheensis*is are distinct species. They are discussed below. *Goniobasis elliotti*, *G. gesneri* and *G. inosculata* are synonyms of *Elimia ucheensis*, as is discussed below.

We have examined the lectotype (USNM 118420) and paralectotypes (USNM 873102) of *Goniobasis inclinans*. We agree with Goodrich (1942, p. 3) that *inclinans* is more closely related to *Elimia floridensis* (Reeve 1861) and not to *E. curvicostata.* The *Elimia floridensis* species-group is not included in this study.

We have examined the lectotype of *Goniobasis etowahensis* (= *Goniobasis canbyi*) (USNM 121479), and we consider it to be a synonym of *Elimia modesta* (Lea 1845) (see Thompson 2000b, p. 16).

We have examined the lectotype of *Goniobasis doolyensis* (USNM 119121) (Figs. 5, 6, 19, 20). We find that *Goniobasis doolyensis* is a subjective junior synonym of *Elimia curvicostata*. The lectotype is a large specimen that still retains two dead whorls at the top of the spire, and the ribs become obsolete on the penultimate whorl. The uppermost 1.5 whorls bear a single spiral carina that forms low knobs where it is crossed by the ribs (Fig. 6). An immature paralectotype (USNM 873108) retains all of the upper whorls (Fig. 9). The sculpture on the early whorls in both specimens is typical for *E. curvicostata*, and we find no morphological basis for recognizing *doolyensis* as distinct. The aperture of the lectotype is more rounded than usual, but this appears to be a factor reflecting the old growth-stage of the specimen. Except for its large size, the lectotype of *doolyensis* (Figs. 19, 20) is similar to specimens of *E. curvicostata* from Spring Creek, Dooly County, Georgia (Figs. 16-18), which is the restricted type locality of *doolyensis*.

In the Chipola River in Florida, *Elimia curvicostata* is found in association with *E. floridensis*, *E. athearni* and *E. dickinsoni*. In Limestone Creek, Walton County, Florida, *E. curvicostata* occurs with *E. buffyae*. In the Flint River drainage in Georgia, *E. curvicostata* is associated with *E. albanyensis*, *E. viennaensis* and *E. induta*. We found no instance in the field where *E. curvicostata* interbred or intergraded with any of these species. Other species from the Escambia River system, the Choctawhatchee River system and from Uchee Creek that were included in earlier taxonomic treatments as populations or as synonyms of *E.*

curvicostata are geographically disjunct, and morphologically distinct. No trends exist that suggest they may be conspecific with *E. curvicostata*.

Etymology. The name *curvicostata* is from the Latin *curvus*, meaning bent, and *costatus*, meaning ribbed. The name *densicostata* is from the Latin *densus*, thick or crowded, and *costatus*. The name *doolyensis* is a geographic patronym for Dooly County, Georgia.

The *Elimia induta* species-group

We recognize three species as belonging to the *Elimia induta* species-group: *E. induta* (Lea 1862), *E. timida* (Goodrich 1943), and a new species from the Choctawhatchee River system of Alabama. They are alike by having a slender-conical juvenile shell with *a pronounced peripheral carina on the middle of the early whorls*, and axial ribs that form knobs where they cross the carina. A second raised spiral thread is present just below the suture. *Elimia induta* is found in the middle section of the Flint River system, and *E. timida* is confined to small streams along the middle part of the Ocmulgee River system. A third species is found in small streams and springs in the upper Choctawhatchee River system in Barbour and Dale counties, Alabama.

Elimia induta (Lea 1862)

Vernacular name: Gem Elimia

Goniobasis induta Lea 1862, *Proceeding of the Academy of Natural Sciences of Philadelphia,* 14, p. 267; Lea, 1863, *Journal of Academy of Natural Sciences of Philadelphia,* 5, p. 319, pl. 37, fig. 166; Goodrich, 1942, *Occasional Papers of the Museum of Zoology, University of Michigan,* (256), p. 5.

Goniobasis doolyensis Lea 1862, in part; Tryon, 1873, *Smithsonian Miscellaneous Collections,* (253), p. 187, fig. 367.

Goniobasis curvicostata (Reeve 1861), in part; Clench & Turner, 1956, *Bulletin of the Florida State Museum,* 1, p. 136; Chambers, 1990, *Walkerana,* 4(12), p. 262, fig. 4E (lectotype).

Elimia induta (Lea 1862), Burch & Tottenham, 1980, *Walkerana,* 1(3), p. 136; Burch, 1989, *North American freshwater snails,* p. 136.

Diagnosis. A slender, medium-sized species up to about 20 mm in length with a straight-sided spire. The shell is densely sculptured with close bold vertical ribs that are ornamented by spiral series of knobs below the suture. The spiral series of knobs is situated below the upper ends of the ribs, giving the appearance of a double series of spiral knobs. A second strong spiral cord occurs along the periphery on all but the last two whorls. Four reddish spiral bands add to the ornamentation of the shell. *Elimia induta* is most similar to the following species, *E. timida*, because of subsutural knobby sculpture on the upper ends of the axial ribs.

The following description is based on specimens from small streams entering the east side of the Flint River in Dooly County and Crisp County, Georgia. A population from a stream entering the west side of the Flint River is discussed below.

Shell (Figs. 29-33, 34-39, 40-43). A medium-sized species that reaches a length of up to 20 mm when the apex is complete, and up to about 16 mm long in the decollate adult stage. Spire nearly straight-sided with an angle of 21-27º. Usually, the olive-colored shell has four reddish bands: a subsuture band, a peripheral band, a subperipheral band and a weak circum-umbilical band. Occasional shells have fewer or no bands. The growth rate indicates that about nine whorls are developed through maturity, of which 4-5 whorls normally are retained in the adult shell. The first two whorls of the juvenile shell are rounded and smooth (Figs. 30, 31). Strong, widely spaced axial ribs that are about as wide as their intervals begin on the fourth whorl. The ribs are not synchronized. There are 11-13 ribs on the fourth whorl of the adult spell. The ribs and their interspaces have parallel axial striations. Spiral striations are absent. A strong peripheral spiral cord begins on the third juvenile whorl and persists through about the sixth whorl creating an angular periphery and forming knobs where it crosses the ribs. A weaker subperipheral spiral cord is present on juvenile shells, but it is obliterated by the advancing peristome. A weaker subsutural spiral cord begins on the fourth juvenile whorl and persists through the last whorl. It forms a spiral row of knobs where it crosses the upper ends of the axial ribs. The aperture is ovate-elliptical in shape, 0.38-0.45 times the length of the last four whorls, and 0.62-0.69 times the length of the last whorl. The base of the peristome is slightly canaliculate. Columellar margin concave and relatively narrow. Measurements for the lectotype, seven paralectotypes and another sample of specimens are given in Table 2.

Operculum (Figs. 183-184). Amber colored. Broadly obovate in shape; parietal margin weakly concave. Nucleus rapidly expanding, located about one third of the distance from the base to the apex, and about one third of the distance from the columellar margin to the outer margin. Outer surface with a few coarse incremental striations. Inner surface smooth; muscle attachment scar about 0.4 times the width of the operculum; with a weak crest along the outer basal margin.

Type locality. Near Vienna, Dooly County, Georgia. Lectotype: USNM 119174 (Chamber, 1990); collected by the Rev. G. White. Paralectotypes: USNM 873111 (34); same data as the lectotype. We restrict the type locality to Limestone Creek, Dooly County, Georgia.

Distribution (Fig. 208). Small streams tributary to the Flint River in Dooly, Crisp, Lee and Worth counties in southwestern Georgia. There are numerous specimens of *Elimia induta* that were collected purportedly in the Flint River at

TABLE 2. *Elimia induta* (Lea 1862). Measurements of the lectotype (USNM 119174), seven paralectotypes (USNM 873111), eleven specimens from Limestone Creek, Dooly Co., Georgia (UF 251051) and ten specimens from a small creek in Lee Co., Georgia (UF 79765) selected for variations in size. SL = standard length, 4Wh = length of last four whorls, LWh = length of last whorls, SW = standard width, AH = aperture height, AW = aperture width, Wh = whorls remaining, <Sp = angle of spire, StD = standard deviation. The numbers of whorls in the lectotype and the paralectotypes were not determined in order to avoid damaging the specimens.

	SL	4Wh	LWh	SW	AH	AW	Wh	<Sp	SW/4Wh	AH/4Wh	AH/LWh	AW/AH
Lectotype	19.0	16.6	10.4	7.3	6.7	4.5	(6.0)	27	0.38	0.40	0.64	0.67
Paralectotypes												
Min.	14.7	12.5	5.3	5.3	5.0	3.2	4+	23	0.34	0.38	0.57	0.64
Max.	19.4	16.4	7.3	7.3	6.7	4.9	8.5	27	0.42	0.45	0.69	0.78
Avg.	17.2	14.6	9.26	6.53	5.93	4.21	-	24.9	0.38	0.41	0.64	0.71
StD	1.52	1.59	1.05	0.69	0.51	0.55	-	1.69	0.04	0.02	0.03	0.05
UF 251051												
Min.	11.9	11.5	7.3	5.0	4.6	3.0	4.0	21	0.36	0.38	0.62	0.60
Max.	15.8	14.1	9.8	6.6	6.1	3.8	5.0	27	0.48	0.45	0.69	0.72
Avg.	13.65	13.30	8.35	5.70	5.45	3.58	4.33	24.82	0.42	0.41	0.65	0.66
StD	1.30	0.96	0.68	0.46	0.43	0.28	0.38	2.12	0.03	0.02	0.02	0.03
UF 79765												
Min.	15.4	13.6	8.6	6.2	5.8	4.0	7.5	27	0.41	0.38	0.63	0.65
Max.	20.9	18.3	11.1	7.8	7.1	4.6	9.7	33	0.50	0.45	0.68	0.72
Avg.	17.91	15.55	19.85	6.96	6.43	4.37	8.66	29.90	0.45	0.42	0.60	0.68
StD	1.94	1.63	0.80	0.46	0.40	0.25	0.73	1.02	2.51	0.03	0.02	0.02

Albany by R.E. Call around 1900 (UF 79757, UF 79758, UF 79759 UF 79762, UF 79763, UF 279002). We have collected mollusks at the shoals of the Flint River at Albany on many occasions between 1969-2002 where the only pleurocerid we found was *Elimia albanyensis* (Lea 1862).

Specimens examined. **GEORGIA**. **Crisp Co.:** Swift Creek, 12 mi. SW of Cordele (UF 79760); Swift Creek, ca. 4 mi. E of Warwick (UF 277034); North Branch Swift Creek, 3.5 mi. W of Pateville (UF 251664); Cedar Creek, 5 mi. SW of Cordele (UF 277037); Cedar Creek, 6 mi. SW of Cordele (UF 79761); Limestone Creek, Drayton Rd., 4.7 mi. S, 1.1 mi. E of Drayton (UF 41459; UF 278994); Gum Creek, 0.5 mi. N of Cordele (UF 1967); Gum Creek, 6.5 mi. W of Cordele (UF 278998, UF 279008). **Dooly Co.:** Limestone Creek at McCoy Rd., ca. 4 mi S, 2 mi E of Drayton (UF 251651, UF 277480); spring 8 mi. NW of Vienna (UF 79763). **Lee Co**.: a small creek 7 mi. NW of Albany (UF 79756, UF 79765). **Terrell Co**.: small creek 1.0 mi. N of Bronwood (UF 280884). **Worth Co.:** Big Abram's Creek, at GA Hwy 300, 9.3 mi. SSW of Warwick, (UF 279006); Jones Creek, 12.4 mi. NNE of Albany (UF 277038).

Conservation status. This species should be listed as of special concern because of it's restricted geographic distribution to six small creeks. Extant populations are known only from Swift Creek, Cedar Creek, Limestone Creek, Gum Creek, Jones Creek, and Big Abram's Creek on the east side of the Flint River, and from a small stream in Terrell County on the west side of the Flint River. All are small streams entering the Flint River over a north-south distance of about 25 miles.

Habitat. *Elimia induta* is ecologically restricted to clear small-streams. Typically it is found in zones with a slow current where it occurs among tree rootlets, in clusters of aquatic mosses, and on slicks and limbs lying on the stream bottom.

Remarks. *Elimia induta* is most similar to *E. timida* because of the knobby subsutural spiral cord. It differs from *E. timida* by its larger size, its brightly color bands and its thicker shell.

Clench & Turner (1956) and Chambers (1990) treated *Elimia induta* as a junior synonym of *E. curvicostata*. This is not tenable for the following reasons. The juvenile shell of *E. induta* has a weak sub-peripheral spiral cord, a knobby subsutural spiral cord, and knobby peripheral spiral cords, all of which are lacking in *E. curvicostata*. The subperipheral cord is lost in adult *E. induta*, but the peripheral knobby cords persist onto the upper whorls of the adult shell, and the subsutural knobby cord persists through the length of the adult shell. These sculptural traits occur only on specimens from some small streams flowing into the Flint River in a small area in southwestern Georgia. *Elimia curvicostata* has a single peripheral spiral cord on the juvenile shell. It lacks a subsutural spiral cord and a subperipheral spiral cord. The axial ribs are simple in all stages of growth. *Elimia induta*, *E. curvicostata* and *E. viennaensis* co-inhabit Swift Creek and Gum Creek in Crisp County, Limestone Creek in Dooly and Crisp counties, and Big Abram's Creek in Worth County. We found no evidence of intergradation between any of these species where they co-occur. They tend to be ecologically segregated in such situations. *Elimia curvicostata* is found most commonly on the substrata and among tree rootlets. *Elimia induta* usually is confined primarily to tree rootlets and mosses, although occasionally it was found on submerged sticks and on silty sand. *Elimia viennaensis* is found primarily on submerged logs and rocks.

Elimia induta is a small-stream species. As is typical of ecologically restricted species, populations of some streams are genetically isolated and have undergone local and independent evolutions. Even though *E. induta* has a restricted geographic distribution, local variation in size, sculpture and whorl retention can be appreciable. Most specimens from small streams entering the east side of the Flint River in Dooly, Crisp and Worth counties are similar in size, color banding and sculpture (Figs. 34-39). A sample from a small stream in Lee County, 7 mi. NW of Albany (UF 79756) entering the west side of the Flint River are, on average, larger in size, they are more robust, the macrosculpture usually is weaker, the shells have distinct fine spiral microstriations, the reddish bands are less distinct and they have a conspicuous light subsutural zone (Figs. 40-43).

Etymology. The species name *induta* is from the Latin *indutus*, meaning covered. Apparently this is an allusion to the densely sculptured surface of the shell, although the original description does not say so.

Elimia timida (Goodrich 1942)

This is a graceful, slender species that occurs as isolated populations in small streams, springs and creeks entering the right side of the Ocmulgee River near Hawkinsville, Georgia. Each colony is distinguishable to varying degrees by its shell characters. We recognize three subspecies because of their distinct morphologies and their geographic isolation to separate creeks. They have in common medium-sized, slender shells and similar sculpture of the juvenile whorls; whorls 1-2 are rounded; whorls 3-5 have a strong peripheral cord. A strong subsutural cord begins on whorl 5 and may continue onto lower whorls. Bold axial ribs occur between the two cords beginning on the fifth whorl, and the ribs may extend below the periphery on the lower whorls. The spiral and axial sculpture may be completely lost on the adult shell, as is the case in the nominate subspecies. In the second subspecies the subsutural cord persists on the adult shell, but the axial sculpture is reduced or absent. In the third subspecies the subsutural cord and the vertical ribs are present on the lower whorls of the adult shell. We have not been able to locate an extant population of the nominate subspecies, and therefore we could not determine its DNA profile. The two other subspecies are abundantly represented by fresh specimens. Their mtDNA sequences are very similar, indicating their conspecific identity. It is presumptive to assume that *Elimia timida timida* is genetically very similar to the other two subspecies, although we strongly suspect that it is. *Elimia timida* is most similar to *E. induta* (Lea 1862) from the Flint River system. It differs from *E. induta* by its much thinner shell, as well as by the sculptural details characteristic of each its three subspecies.

Elimia timida timida (Goodrich 1942)

Vernacular name: Timid Elimia

Goniobasis mutabilis timidus Goodrich 1942, *Occasional Papers of the Museum of Zoology, University of Michigan,* (456), p. 5.
Elimia mutabilis timidus (Goodrich 1942), Burch & Tottenham, 1980, *Walkerana,* 1(3), p. 140; Burch, 1989, *North American freshwater snails,* p. 140.

Diagnosis. This is a medium-sized shell that is smooth and very slender. The sides of the spire diverge at 14-18°. Decollate adult shells are about 16-19 mm long and are 0.37-0.44 times as wide as the length of the last four whorls. The adult shell lacks vertical or axial sculpture on the last 4-5 whorls. The early juvenile shell and sculpture remain unknown. Several of the paralectotypes retain 1-2 juvenile whorls, and these have a bold rounded peripheral cord and some low wavy axial ribs similar to the sculpture occurring on equivalent whorls in the following two subspecies. Distinct spiral micro-striations are present over the surface of shell. Further comparisons between the subspecies are given below.

Shell (Figs. 44, 45, 48-51). Medium-sized with the last four whorls 15.0-18.1 mm in length in adult shells. Slender, 0.37-0.44 times as wide as high. Adult shell light brown in color and without any indication of spiral banding; shiny, smooth, with fine incremental striations and very fine but distinct incised spiral striations. Late juvenile whorls that are retained on some adult shells have a round peripheral cord and occasionally some very low, wide wavy ribs (Figs. 44, 45). The spire is very slightly convex in outline, being very nearly straight-sided. Suture deeply impressed; whorls uniformly arched between the sutures. Aperture broadly elliptical in outline, about 0.63-0.82 times as wide as high, about 0.38-0.44 times the length of the last four whorls, and about 0.52-0.64 times the length of the last whorl. Aperture slightly retrocline in lateral profile. Peristome protracted along baso-lateral margin and retracted along baso-columellar margin; columellar margin moderately thick at base and narrowing upward to the parietal margin. Measurements of the lectotype and 10 specimens are given in Table 3.

Operculum. None available.

Type Locality. A spring two miles southeast of Hawkinsville, Pulaski County, Georgia. Lectotype by present designation: UMMZ 49210, collected by William J. Clench and Peter Okkelberg, 5 July 1929, field station 489. Goodrich

TABLE 3. *Elimia timida*. Measurements of three subspecies. Specimens were selected for their large sizes. SL = standard length, 4Wh = length of last four whorls, LWh = length of last whorls, SW = standard width, AH = aperture height, AW = aperture width, Wh = whorls remaining, <Sp = angle of spire, StD = standard deviation.

Elimia timida timida (Goodrich 1942). Measurements of the lectotype (UMMZ 49122) and ten specimens (UMMZ 49211).

	SL	4Wh	LWh	SW	AH	AW	Wh	<Sp	SW/4Wh	AH/4Wh	AH/LWh	AW/AH
Lectotype	16.0	15.0	8.7	6.0	5.5	3.7	4.7	18	0.40	0.37	0.63	0.67
Paralectotypes												
Min.	16.0	15.1	9.4	6.1	5.1	3.7	4.0	14	0.37	0.30	0.52	0.63
Max.	19.4	18.1	11.2	7.5	6.5	4.4	4.8	17	0.44	0.38	0.64	0.82
Avg.	17.63	16.68	10.13	6.84	5.84	4.04	4.38	15.8	0.41	0.35	0.58	0.69
StD	1.16	0.94	0.65	0.49	0.43	0.26	0.35	1.03	0.02	0.02	0.04	0.05

Elimia timida exul new subspecies. Measurements of the holotype (UF 275841) and ten paratypes (UF 266283).

	SL	4Wh	LWh	SW	AH	AW	Wh	<Sp	SW/4Wh	AH/4Wh	AH/LWh	AW/AH
Holotype	12.3	11.0	6.6	4.9	4.4	2.9	5.1	22	0.45	0.40	0.66	0.67
Paratypes												
Min.	11.9	11.0	6.3	4.8	4.1	2.9	4.1	16	0.40	0.36	0.60	0.66
Max.	14.5	14.0	8.3	5.7	6.3	3.7	5.4	24	0.45	0.40	0.66	0.74
Avg.	13.07	12.18	7.33	5.10	4.65	2.44	4.88	20	0.42	0.38	0.63	0.69
StD	1.05	0.68	0.59	0.27	0.35	0.19	0.40	2.22	0.02	0.01	0.02	0.03

Elimia timida nymphaea new subspecies. Measurements of the holotype (UF 263347) and ten paratypes (UF 276084).

	SL	4Wh	LWh	SW	AH	AW	Wh	<Sp	SW/4Wh	AH/4Wh	AH/LWh	AW/AH
Holotype	14.3	12.4	8.2	5.5	5.3	3.2	8.6	32	0.38	0.43	0.65	0.60
Paratypes												
Min.	13.4	11.6	7.5	5.1	4.8	3.2	7.5	24	0.34	0.38	0.61	0.60
Max.	18.0	15.7	10.2	7.0	6.6	4.0	8.7	32	0.40	0.43	0.66	0.68
Avg.	14.8	12.8	8.2	5.6	5.3	3.4	8.3	27.7	0.38	0.42	0.64	0.64
StD	1.16	1.05	0.71	0.54	0.50	0.23	0.39	2.53	0.02	0.02	0.02	0.03

stated that the type locality is a spring two miles *northwest* of Hawkinsville. Clench's original field label (MCZ 91775) and his field notes on file at the Museum of Comparative Zoology indicate that the type locality is *southeast* of Hawkinsville.

Goodrich cited two specimens as "types." He did not designate a holotype. He does not cite other material, but specimens in the Museum of Zoology, University of Michigan, and in the Museum of Comparative Zoology, are marked "paratypes." We recognize the second "type" of Goodrich as a paralectotype (UMMZ 266708). It is an old worn adult shell consisting of four whorls. Other specimens that comprised parts of the original field sample are UMMZ 49211 (23) and MCZ 91775 (25).

Distribution (Fig. 208). This snail was discovered near Hawkinsville, Georgia. The type locality is uncertain because of discrepancies between the published account by Goodrich and by Clench's field notes. We have not been able to relocate the type locality. We have not found any populations of *Elimia* in the Hawkinsville area that have the morphological characteristics of *E. timida timida*. The type population may be extinct.

Conservation status. This species may be extinct.

Habitat. Unknown. Clench's field notes do not record habitat information.

Remarks. *Elimia timida timida* is a small, slender snail with a smooth thin shell. It has gone almost unnoticed in the scientific literature since its original description except for being listed in Burch & Tottenham (1980) and Burch (1989). It was described as a subspecies of *Elimia mutabilis* (Lee 1862), which occurs in headwater creeks and small streams of the upper Ocmulgee basin in Georgia. The two taxa are disjunct in their distributions, and they differ greatly in morphology and genetics. Mitochondrial DNA indicates that two subspecies of *E. timida* are most closely related to *E. induta* (Lea 1862) from the Flint River systems, and to a lesser extent, to the following new species from the Choctawhatchee River system. The genetic analysis indicates that *E. mutabilis* is related to the *E. alabamensis* species-group of the Alabama River system. Much of the obscurity and misconception surrounding *E. mutabilis* and *E. timida* is due to the facts that *E. timida* was never illustrated until now, and Goodrich's description is too brief and misleading to identify this snail.

The nominate subspecies, *Elimia timida timida,* is closely related to the following two taxa. The two differ rather strikingly in adult shell morphology. We recognize them as distinct subspecies because of their genetic similarities, similar sized slender shells with similar juvenile sculpture, and their geographic proximity.

Etymology. The name *timida* is from the Latin *timidus*, meaning timid or fearful of. Goodrich does not explain the basis for his choice of name. The choice was prophetic because of the apparent extinction of this subspecies.

Elimia timida exul new subspecies

Vernacular name: Mockspring Elimia

Diagnosis. This is a medium-sized, slender subspecies that has a strong peripheral cord on whorls 3-5 of the juvenile shell, and a strong subsutural spiral cord that begins on whorl-5 and extends to the last whorl of the adult shell. Weak axial ribs begin on the fifth whorl and may also be present on the upper whorls of the adult shell, or the axial sculpture may be indicated only by the presence of nodes on the subsutural spiral cord.

Shell (Figs. 32, 46, 52-55). Very small sized, adults about 12-15 mm long. Spire slender, nearly straight-sided; sides of spire diverging at about 16-24°. Width of shell about 0.40-0.45 times length of last four whorls. Suture moderately impressed. Rate of growth of juvenile shell indicates that specimens develop about nine whorls, of which 4.1-5.4 are retained in adult specimens. The first two whorls of the juvenile shell are smooth and rounded (Fig. 32). The third whorl develops a peripheral carina which persists to the fifth or sixth whorl, and thereafter becomes obsolete. A subsutural carina begins on the fifth whorl and becomes progressively stronger and persists through the body whorl of the adult shell (Figs. 52-55). Strong, widely spaced axial ribs begin on the fifth whorl and are confined between the subsutural carina and the peripheral carina. The ribs may persist only as nodes on the subsutural cord along the lower whorls. Usually they are absent on the last 2-3 adult whorls. There are 15-18 ribs on the fourth whorl of adult shells. Distinct spiral micro-striations are absent. The aperture is elliptical, 0.36-0.45 times the length of the last four whorls and 0.60-0.63 times the length of the last whorl. The parietal callus is very thin. The outer lip is retracted above the periphery and projects forward at the base. The columella margin is widest below and tapers above. Measurements are given in Table 3.

Operculum (Figs. 181-182). Oblong-ovate in shape with a convex parietal margin; thin, light amber colored. Nucleus large and slowly expanding; located in the lower left third of the face. Outer surface with a few weak incremental striations. Muscle attachment scar about half the width of the operculum and almost 0.9 times the length; smooth; base and inner margin only slightly thickened.

Type Locality. Georgia, Pulaski County, Mock Springs, about 10.5 miles WSW of Hawkinsville (32°12.3' N, 83°35.0'W). Holotype: UF 275841, collected October 12, 1996, by Elizabeth Mihalcik and Fred G. Thompson. Paratypes: UF 266246, UF 266283, UF 275839, UF 275840, USNM (10), UMMZ 300044 (10), ANSP 410591, same data as the holotype; UF 296274 (16), topotypes, collected 16 February, 2002.

Distribution (Fig. 208). *Elimia timida exul* is endemic to the type locality.

We have not found other populations of *E. timida* in Cedar Creek. Another species of *Elimia*, apparently related to *E. catenaria*, occurs in the lower section of Cedar Creek.

Conservation status. No protective measures are in place to protect this subspecies. We recommend that it be classified as endangered because a single catastrophic event in the spring pool could cause its extinction. Such threats regularly occur, because the spring pool is treated chemically for the removal of aquatic vegetation. We last visited the spring on February 16, 2002. The spring pool had been treated recently with copper sulfate ($CuSO_4$), and was devoid of live mollusks. The spring run below the pool was nearly devoid of mollusks.

Habitat. Mock Springs has been dredged to form a circular recreational swimming pool that is approximately 50 meters wide and two meters deep. The spring source is enclosed in a rectangular concrete box within the pool. The pool is sand bottomed. A steel culvert drains the pool along its south side. The outlet forms a small creek that flows for about 100 meters before entering Cedar Creek. At the time of our visit on October 12, 1996, the pool was bordered by a narrow fringe of filamentous algae mats, but was devoid of other aquatic vegetation. *Elimia timida exul* is abundant on rooted vegetation, algae mats and the substrata for a short distance of a few meters in the run below the pool outlet. It was found with *Helisoma anceps* (Menke 1830), *Physella h. hendersoni* (Clench 1926) and *Campeloma rufum* (Haldeman 1841). *Elimia timida exul*, as well as other snails, were absent in the pool, except along a very narrow section of the bank near the concrete enclosure at the spring source. On February 16, 2002, we found no live mollusks in the pool, and only a few *Elimia timida exul* and a single *Campeloma* in the spring run.

Remarks. This subspecies is readily recognized by it's bold subsutural cord that extends to the last whorl of the adult shell. Axial sculpture usually is absent or poorly developed on the last 2-3 adult whorls.

Etymology. The name *exul* is from the Latin *exilium*, an exile. It alludes to the isolation of this subspecies in the uppermost tributary of Cedar Creek.

Elimia timida nymphaea new subspecies

Vernacular name: Nymph Elimia

Diagnosis. This is a medium-sized, relatively slender subspecies. It differs from the two other subspecies of *Elimia timida* by retaining all of the earlier whorls and by having moderately distinct axial ribs that are present from the fourth whorl to the last whorl.

Shell (Figs. 33, 47, 56-59). Shell complete, retaining 7.5-8.7 whorls; uniformly light grayish-green. Medium-sized, relatively slender, width of shell about 0.34-0.40 times the length of the last four whorls. Sides of spire diverging at 24-32°, spire nearly straight-sided. Suture strongly impressed. Juvenile shell similar in sculpture to that of the previous subspecies (Fig. 33). The second whorl develops a strong peripheral carina that persists through the sixth or seventh whorl. The last whorl is rounded at the periphery. A subsutural carina begins on the fifth whorl and persists to the last whorl. Moderate, straight, vertical axial ribs are present over most of the lower five whorls. There are 11-14 ribs on the penultimate whorl. The peripheral and subsutural spiral cords develop nodes where they are crossed by the axial ribs. The surface of the shell on and between the ribs bears rather coarse vertical striations and vague spiral micro-striations. The aperture is broadly elliptical, 0.38-0.43 times the length of the last four whorls, 0.61-0.66 times the length of the last whorl, and 0.60-0.68 times as wide as high. The columellar margin is widest at the base and is only slightly tapered above. Measurements are given in Table 3.

Operculum (Figs. 179-180). Ovate in shape with a weakly pointed apex. Parietal margin convex. Thin, very light amber colored. Nucleus slowly expanding, with about 2.5 whorls; located in the lower left third of the face. Muscle attachment scar very thin, slightly less than half the width of the operculum and about 0.85 times of the length.

Type locality. Georgia, Pulaski County, One-Mile Creek, ca. 200-300 m upstream from the Ocmulgee River, and about 1.0 mi. southeast of Hawkinsville (32°16.0' N, 83° 27.7' W). Holotype: UF 263347; collected 15 September, 1996 by Elizabeth L. Mihalcik and Fred G. Thompson. Paratypes UF 276082, 276083 (figured), UF 276084 (measured); same data as the holotype; UF 266247, collected at type locality 12 October, 1996, by Elizabeth L. Mihalcik and Fred G. Thompson.

Distribution (Fig. 208). *Elimia timida nymphaea* is known only from One-Mile Creek, on the south edge of Hawkinsville, Pulaski County, Georgia. One-Mile Creek is a very small stream. The upper half of it passes through residential lawns and gardens. We found *E. t. nymphaea* only in the lower half of the creek near where it enters the Ocmulgee River.

Conservation status. We recommend that this subspecies be given Endangered Species Status because of its very limited distribution in a very small creek that passes through a municipal area. The stream is subject to intense and adverse environmental impact because of residential and municipal developments and rain run-off within its watershed. A single pollution event or other adverse event could exterminate the only known population.

Habitat. One-Mile Creek is a small sand-bottomed brook that is about a meter wide and 5-10 cm deep with occasional broader and deeper pools. The creek originates in a residential area on the south side of Hawkinsville. The lower half of the creek flows through a mixed hardwood forest behind a city park along the Ocmulgee River where it consists of gentle shallow pools and riffles. The sand substrata overlays a dense limestone which occasionally outcrops in the stream. No herbaceous vegetation was found in the section of the creek inhabited by *Elimia timida nymphaea*. Specimens were very sparse on the two occasions when we collected this subspecies. They were found crawling on sand, dead tree limbs and leaves.

Apparently *Elimia timida nymphaea* reproduces during the mid-summer or early fall. Mostly newly hatched and half-grown juveniles were collected on September 15, 1996. Specimens collected on October 12, 1996, (UF 266247) consist mostly of half-grown juveniles and young adults.

Remarks. *Elimia timida nymphaea* is strikingly different from *E. t. timida* and *E. t. exul* by retaining the early whorls of the spire through definitive growth, and by having strong, clearly defined ribs present from the fourth whorl to the first whorl. It differs from *E. t. timida*, and is similar to *E. t. exul*, by having a strong, nodose subsutural spiral cord.

A similar subspecies of *Elimia timida* occurs in Tucsawhatchee Creek, Pulaski County, Georgia (UF 266328). It has bolder ribs, a more obese shell, and the apex loses some of the uppermost whorls. This subspecies is left undescribed because we have not determined the extent of its geographic deployment or its population variation within the creek.

Etymology. The subspecies name *nymphaea* is derived from the Classical Greek νυμφε, a nymph, and alludes to its diminutive size and graceful form.

Elimia glarea new species

Vernacular name: Gravel Elimia

Diagnosis. The species is characterized by its plane, nearly featureless, drab, unicolor adult shell. The adult shell is about 15-18 mm in standard length. It is elongate-conical with a slightly convex spire consisting of 5.0-6.5 weakly arched whorls that are separated by a moderately impressed suture and are nearly devoid of any prominent sculptural features. The upper-most whorl is usually angular at the periphery, and in occasional specimens some weak plica may persist. In contrast, the juvenile shell consists of a narrow straight-sided spire with distinct plica beginning on the fourth or fifth whorl. A strong peripheral spiral cord, and a weaker subperipheral cord lying just above the suture begin on the third or fourth whorl. A third supra-peripheral spiral cord located near the upper suture begins on the fifth whorl and usually persists for the following 3-4 whorls. The peripheral cord and the supra-peripheral cord usually are knobbed where they intersect the plica. By the ninth whorl the spiral cords and the plicate sculpture become obsolete, leading to the nearly featureless adult shell.

Shell (Figs. 167-172). The shell is unicolor with two color phases. The dominant form is light green; less commonly it is dark ebony-colored. The narrow, weakly convex spire diverges at an angle of about 21-33°. The standard length is up to 18-19 mm. The shell is about 0.41-0.49 times as wide as long, and retains 5.0-6.5 whorls. The rate of growth of the juvenile shell indicated that a total of about 11-12 whorls are formed. The uppermost whorl of the adult shell usually is weakly angular at the periphery (Fig. 169-172) as a remnant of the juvenile peripheral cord. The following whorls are weakly arched with a moderately impressed suture. The adult shell usually lacks distinctive sculpture, which in itself is a distinctive feature of the species. The whorls are crossed by weak incremental growth striations with occasional finer irregular spiral micro-striations. Occasional specimens may bear a few obsolete plicae on the upper whorls. The juvenile shell is narrowly conical. The first two whorls are rounded and button-shaped. The following whorl develops a prominent peripheral cord that continues to about the seventh whorl where it becomes obsolete (Figs. 168, 169, 170, 172, arrows). The peripheral cord is close to the lower suture so that the whorls are scalariform. A second, weaker spiral cord lies just below the peripheral cord and borders the suture. A third spiral cord lies near the upper suture. It begins on the fifth whorl and usually persists for only 3-4 whorls (Figs. 168, 172, lines, Fig. 189). The juvenile shell bears low, but distinct, evenly spaced plicae that are about as wide as their interspaces. They begin on the third or fourth whorl and extend from the upper suture to the periphery. The upper cord, and to a lesser extent the peripheral cord, are scalloped or knobbed where they intersect the plica. The lower cord is smooth and rounded throughout its length. The aperture is irregularly elliptical in shape; about 0.60-0.64 times as wide as high, about 0.38-0.44 times the length of the last whorls, and about 0.63-0.67 times the length of the last whorl. The columella is moderately wide and weakly concave. The baso-columellar corner is slightly but noticeably canaliculate. The outer lip is strongly receded at and above the periphery in lateral view. Measurements are given in Table 4.

The holotype (Figs. 167-168) is an immature specimen that bears most of the juvenile sculpture characteristic of the species. The figured paratypes (Figs. 169-172) are representative of most adult specimens.

Operculum (Figs. 185-186). Obovate in shape; parietal margin weakly convex. Nucleus located at about 0.25 of distance from the columellar margin to the outer margin, and at about 0.25 of the distance from base to apex. Outer surface with sparse but relatively strong growth striations. Thin, hyaline, amber-colored. Muscle attachment scar about half the width of operculum, and about 0.85 times the length of the operculum; smooth and without prominent thickening along its lower edge.

Type locality. Alabama, Barbour County, Blue Springs State Park, Blue Springs. Holotype: UF 296260; collected 12 April, 2002, by Fred G. Thompson. Paratypes: UF 296259 (10 measured), UF 296261 (six figured), UF 296081

TABLE 4. *Elimia glarea* new species. Measurements of the holotype (UF 296259) and ten paratypes (UF 296259) selected for variations in size. SL = standard length, 4Wh = length of last four whorls, LWh = length of last whorls, SW = standard width, AH = aperture height, AW = aperture width, Wh = whorls remaining, <Sp = angle of spire, StD = standard deviation. The numbers of whorls in the lectotype and the paralectotypes were not determined in order to avoid damaging the specimens.

	SL	4Wh	LWh	SW	AH	AW	Wh	<Sp	SW/4Wh	AH/4Wh	AH/LWh	AW/AH
Holotype	13.2	12.5	8.3	6.2	5.7	3.4	5.2	30	0.50	0.46	0.69	0.60
Paratypes												
Min.	15.0	14.1	9.0	6.3	5.8	3.6	5.0	21	0.41	0.38	0.63	0.60
Max.	18.3	17.6	10.8	7.4	7.0	4.4	6.5	33	0.49	0.44	0.67	0.64
Avg.	16.07	15.03	9.52	6.70	6.19	3.83	5.60	26.56	0.45	0.41	0.65	0.62
StD	0.89	0.99	0.51	0.37	0.37	0.23	0.56	3.50	0.02	0.02	0.02	0.02

TABLE 5. *Elimia darwini* new species. Measurements of the holotype (UF 41450) and fifteen paratypes (UF 274097). The paratypes were selected for their large sizes, and were the largest specimens in UF 274097. SL = standard length, SW = standard width, AH = aperture height, AW = aperture width, Wh = whorls remaining, <Sp = angle of adult spire, StD = standard deviation; WPB = length of shell below apical plug.

	SL	WPB	SW	AH	AW	<Sp	Wh	SW/SL	AH/SL	AW/AH
Holotype	19.6	18.5	8.6	8.7	5.5	32	5.0	0.44	0.44	0.63
Paratypes										
Min.	18.3	17.6	8.6	8.3	5.5	26	3.2	0.46	0.43	0.60
Max.	22.4	21.9	11.6	10.2	6.7	34	4.1	0.53	0.50	0.70
Avg.	19.7	19.0	9.9	9.15	5.92	29.7	3.85	0.50	0.47	0.65
StD	1.10	1.45	0.72	0.54	0.32	2.26	0.61	0.03	0.02	0.03

(141); same data as the holotype; UF 296258 (76), UMMZ 300043 (10), USNM (10), ANSP 410590, same locality, collected 25 November, 2000, by Fred G. Thompson; UF 71009 (84), same locality, collected 25 November, 1930, by William J. Clench (186).

Blue Springs, enclosed within a concrete retainer wall, is a recreation spa. The spring discharges into a short run that flows for about 25 m into the West Fork of the Choctawhatchee River. The water in the run, and immediately within the river, is less than a meter deep and flows over a sand and gravel substrate. *Elimia glarea* was common generally within the spring run and near its mouth in the river, but it was particularly abundant on submerged tree rootlets. The snail was associated with *Somatogyrus* sp., *Notogillia* sp. and *E. buffyae* (which is described below).

Distribution (Fig. 208). This species is found in springs and small streams tributary to the Pea River, and the Choctawhatchee River in southeastern Alabama.

Specimens examined. **ALABAMA.** **Barbour Co.**: a spring near Pea River (UF 64168); branch of Pea River W of Elamville (UF 74213); Blue Springs, Blue Springs State Park (UF 76166, UF 74165, UF 131417); Big Lime Spring on Pea River, W of Elamville (UF 74162); creek 4 mi. N of Elamville (UF 74212); Spring Branch, affluent of Pea River, near Elamville (UF 74157, UF 74159); Limestone Branch of Pea River, 4 mi. W of Elamville (UF 74140, UF 74142, UF 74200); Limestone Branch near mouth with Pea River (UF 74196); McCoy's Mill Creek, 5 mi. E of Clio (UF 74154, UF 75300); Sikes Creek (UF 74163, UF 74201). **Dale Co.**: Little Choctawhatchee River, Golden Bridge, Newton (UF 74204); East Choctawhatchee River, at Bevert's Bridge (UF 74176, UF 75220); East Choctawhatchee River, 9 mi. N of Pinckard (UF 74158); Little Choctawhatchee River, near Pinckard (UF 74141); Hurricane Creek, near Newton (UF 74192, UF 75289); Little Choctawhatchee River near Pinckard (UF 75295); Mount Pleasant Mineral Spring, near Pinckard (UF 74164); McCheasan Spring, near Pinckard (UF 75223); Palmer Branch, near Midland City (UF 75253); Klondyke Spring, near Ozark (UF 72213). **Henry Co.**: East Choctawhatchee River (UF 74194); East Fork Choctawhatchee River at AL Hwy 27 (UF 296458); East Choctawhatchee River, W of Abbeville (UF 74188); Indian Creek (UF 74182). **Pike Co.**: Barefoot Spring, 6.5 mi. SE of Brundidge, 31°40.4' N, 85°44.7' W (UF 296261).

Conservation status. *Elimia glarea* is abundant at most stations where it is found. No adverse environmental factors effecting the populations were observed. No special protective measures are required at present.

Habitat. This species inhabits gentle flowing small streams and springs with a firm sand or gravel bottom. It occurs primarily on the substrate, but it is also found on dead logs and aquatic vegetation.

Remarks. The plain looking, nearly featureless adult shell could be confused with any of a number of similar appearing species found from the southern coastal plains north to the Great Lake region, including such diversely related species as *E. laqueata castanea* (Lea 1841), *E. livescens* (Menke 1830) and *E. dislocata* (Reeve 1861).

Within the *Elimia induta* species-group this is a well differentiated species. *Elimia glarea* has in common with *E. induta* and *E. timida* a prominent supra-peripheral spiral cord and distinct plicate sculpture on the early whorls. In contrast with the other two species, *E. glarea* loses the axial and spiral sculpture on most adult whorls. Most specimens retain an angular periphery on the uppermost whorl, which is the obsolescent termination of the peripheral cord of the juvenile whorls. Otherwise the adult snail retains little indication of the striking sculpture found on juveniles. There is considerable local variation in shell characters. Most populations consist of specimens that are slender and devoid of any axial sculpture on the adult shell. In some populations adults tend to be more obese and retain axial plicae on the upper two or three whorls. Such populations are more frequent in the East Choctawhatchee River system, but they also occur elsewhere.

At some stations *Elimia glarea* occurs with *E. buffyae* n.sp., described below. Both species usually are heavily encrusted with mineral deposits, and they may be difficult to distinguish until their shells are cleaned. Specimens of *E. buffyae* from the upper Pea River and the upper Choctawhatchee River systems almost always are brightly banded, which can be detected from within the aperture. At Blue Springs State Park the shell of *E. buffyae* is light green in color with bold rust-colored spiral bands, in contract to the unicolor shell of *E. glarea*. The species are strongly divergent in the sculpture of the juvenile whorls.

Etymology. The name *glarea,* from Latin, means of gravel, or located in gravel, alluding to the appearance of this snail in its natural habitat.

The *Elimia catenaria* species-group

Three species of this group are recognized within the study area: *Elimia viennaensis* (Lea 1862), a new species from the Oconee River system (a tributary of the Altamaha River in central Georgia), and an undescribed species from the upper Tallapoosa River system in western Georgia (voucher specimens *Elimia* FLA-2, Distance matrix, Table 12). The species from the Oconee system is described because of its adult-shell similarity to *Elimia mutabilis*, but it differs in its juvenile shell and its genetic affinities.

Elimia darwini new species

Vernacular name: Pup Elimia

Diagnosis. This is a moderately large stocky shell that is about 19-21 mm long and about 0.46-0.53 times as wide as high. The adult spire tapers at about 26-32° and usually has fewer than four remaining whorls at definitive growth. The shell usually has four strong reddish bands on a rusty-tan background. The juvenile shell is narrow and bears two strong spiral cords, one at the periphery, and a weaker cord below that is covered by the advancing peristome. Weak, low axial plicae usually are present between the suture and the periphery. The axial plicae and spiral cords become obsolete on the lower whorls of the adult shell, which are sculptured with coarse irregular incremental striations. The aperture is broadly auriculate in shape with a narrowly constricted columellar margin that causes the baso-columellar corner of the aperture to project laterally.

Shell (Figs. 60, 61, 73-78). The shell usually has four prominent spiral bands. These include an upper band lying just below the suture, a peripheral band that overlies the peripheral cord, a third band that lays below the periphery and is covered by the advancing peristome, and a strong band on the base of the body whorl. The banding is very prominent on juvenile shells and becomes less distinct on older specimens. Occasional specimens have fewer bands or may be unicolor. The juvenile spire tends to be weakly concave in outline, and initially it diverges at an angle of 35-43° (Fig. 61). The adult spire tapers at 26-34°. The first juvenile whorl is higher than wide and is smooth. Subsequent whorls have a strong peripheral cord that forms a prominent keel above the suture, causing the whorls to be scalariform. A weaker subperipheral cord is overlaid by the advancing insertion of the peristome, which forms a deeply channeled suture. The base may bear two or three very weak low spiral threads (Fig. 78). Beginning on the fifth whorl, broad, low, wavy, nearly obsolete axial plicae usually are present, extending downward from the shoulder of the suture to the peripheral cord where they tend to form weak knobs. One or two weak spiral cords also may be present between the suture and the periphery and form nodes where they intersect the plicae. The axial plicae and spiral cords become obsolete or absent on the lower whorls of adult shells, which bear irregular, coarse, incremental striations. The adult shell is robust and retains about three or four whorls, which are moderately arched and separated by a moderately impressed suture. The rate of growth of the juvenile shell indicates that a total of about nine whorls are developed throughout the life of the snail. Seldom are the adult whorls scalariform, in contrast to the whorls of juvenile shells. In adult specimens, the aperture is broadly auriculate with a very narrow columellar margin, which usually causes the basal lip to project laterally and slightly forward. The narrow columellar margin is emphasized by the parietal callus, which is broadly reflected over the umbilical region and then abruptly narrows along the columellar margin.

Measurements are given in Table 5. The holotype is a sub-adult with five whorls remaining from a total of eight, judging by the rates of growth of juvenile shells. The specimen was selected as the holotype because it shows most traits that characterize the species throughout its growth. The measured paratypes were selected for their large sizes.

Operculum (Figs. 175-176). Broadly lanceolate in shape; parietal margin weakly but uniformly convex. Outer surface coarsely sculptured with incremental striations. Nucleus slowly expanding, located at about 0.6 of distance from the apex, and at about 0.4 of distance from the columellar margin. Muscle attachment scar thick, bounded by a conspicuous ridge, and bearing a small, oval, granular field over the nucleus; the scar is about 0.75 times the length of operculum and about half its width.

Type locality. Georgia, Laurens County, Rocky Creek, 5.1 miles southwest of Dudley, at County Road 338. Holotype: UF 41450; collected 11 October, 1996, by Elizabeth L. Mihalcik and Fred G. Thompson. Paratypes: UF 274097 (120), ANSP 410588 (10), UMMZ 300041 (10), USNM (10); same data as the holotype. Additional paratypes are listed under specimens examined.

Distribution (Fig. 209). This species is known only from the middle and upper regions of Rocky Creek, Laurens County, Georgia. Lower down-stream, near the confluence of the Oconee River, Rocky Creek is inhabited by an undetermined but different species of *Elimia* belonging to another species group.

Specimens examined. **GEORGIA.** **Laurens Co.:** Rocky Creek, 6 mi. W of Dudley (UMMZ 49195) (Paratypes); Rocky Creek, 6 mi. W of Dudley (UF 75265); Rocky Creek, nr. Dudley (UMMZ 49996); Rocky Creek at Co. Rd. 338, NW of Dexter, 1.3 mi. SW of Dudley (UF 41452); Rocky Creek at Co. Rd. 338, 6.7 mi. SW, 2.9 mi. NW of Dudley (UF 41451).

Conservation status. *Elimia darwini* has a restricted distribution within a single creek. No adverse environmental impact has been noticed at any of the stations where the species was collected. We recommend that the snail be listed as a species of special concern because of its limited distribution within a single creek.

Habitat. *Elimia darwini* inhabits small streams with a slight current flowing over a hard sand-gravel substrate. It is most commonly found on submerged logs and tree roots. No aquatic angiosperms occurred at any of the stations where we found it. At most times of the year the water is turbid because of light siltation from agricultural run-off. Other species found associated with *E. darwini* are *Campeloma limum* (Anthony 1860), *Spilochlamys turgida* Thompson 1968, *Notogillia sathon* Thompson 1968, *Planorbella trivolvis* (Say 1817) and *Physella hendersoni* (Clench 1925).

Remarks. *Elimia darwini* is most similar morphologically to *E. mutabilis* from the upper Ocmulgee drainage system. *Elimia darwini* has more brightly colored bands on the shell, and its juvenile shell is narrower and more strongly sculptured. The adult shell has moderately arched whorls. It's aperture is characterized by its broadly auriculate shape, its very narrow columellar margin and the secondary lateral extension of the basal lip. *Elimia mutabilis* generally has a uniform gray shell, its juvenile shell is more broadly conical with finer axial ribs and spiral cords. The adult shell has nearly flat-sided whorls.

No single morphological trait consistently separates adult *Elimia darwini* from *E. mutabilis* because there is some minor overlap between the two species in each of these shell differences. The strong morphological similarity between the two caused William Clench, Herbert Smith and Calvin Goodrich to identify specimens of *E. darwini* in various museum collections as *E. mutabilis*. However, the morphology of the juvenile shells and the genetic differences between the two species require that *E. darwini* be recognized as a distinct species. Phylogenetic affinities are with *E. caelatura* (Conrad 1849) from the Savannah River and to a lesser extent with *E. catenaria* (Say 1822) from the Santee River system. *Elimia darwini* differs from both by its relatively simple sculpture. The other two species bear rugose axial ribs that are crossed by raised spiral lirations (Thompson, 2000b).

Etymology. We name this species for a Pembroke Welsh Corgi named Darwin (1995–), which accompanied the authors on field trips to the Oconee River system and most other areas in the South during the course of this study.

Elimia viennaensis (Lea 1862)

Common name: Squat Elimia

Goniobasis viennaensis Lea 1862, *Proceedings of the Academy of Natural Sciences of Philadelphia,* 14, p. 267; Lea, 1863, *Journal of the Academy of Natural Sciences of Philadelphia,* 5, p. 137, pl. 37, fig. 160; Tryon, 1873, *Smithsonian Miscellaneous Collections,* (253), p. 184; Clench & Turner, 1956, *Bulletin of the Florida State Museum,* 1, p. 135, pl. 5, figs. 708; Graf, 2001, *Walkerana,* 12(27), p. 112.

Goniobasis boykiniana viennaensis Lea 1862, Goodrich, 1942, *Occasional Papers of the Museum of Zoology, University of Michigan,* (456), p. 4.

Elimia boykinina viennaensis (Lea 1862), Burch, 1989, *North American freshwater snails,* p. 131.

Elimia boykiniana (Lea 1840), in part, Chambers, 1990, *Walkerana,* 4(12), pp. 254-262, fig. 1.

Elimia curvicostata (Reeve 1861), in part, Chambers, 1990, *Walkerana,* 4(12), p. 262, fig. 4C.

Diagnosis. The large robust decollate adult shell consists of 3.0-4.5 whorls. The dominant sculpture consists of rugose ribs, which tend to become obsolete on the last whorl. Spiral sculpture is weak or absent on the adult shell. The juvenile shell has scalariform whorls marked by strong peripheral keels and bold axial ribs. The peripheral cord and a weaker subsutural cord form scalloped nodes where they intersect the ribs.

Shell (Figs. 125-128, 133-138, 139-144). This is a large robust species in which the decollated adult shell attains a length of up to 24 mm and a width up to 12 mm. Adult shells are 0.45-0.51 times as wide as long. The development rate of juveniles indicates that nine whorls are formed, of which 3.0-4.5 are retained in adult shells. The whorls are flat above the periphery. The suture is moderately impressed and is exaggerated by the nodular base on the ribs of the whorl above. The spire is straight-sided or slightly convex and diverges at an angle of 21-32°. The periostracum is yellowish-green and may be marked with three or four darker green bands which are discernable through the interior of the aperture. The aperture is narrowly elliptical in shape, and is 0.55-0.67 times as wide as high. It is weakly canaliculate at the base and has a conspicuously projecting baso-columellar lip below the narrow columella. The sculpture undergoes striking ontogenetic change. In the juvenile shell the first two whorls are button-shaped and rounded at the periphery (Figs. 126-128). The next three whorls are strongly scalariform with a bold peripheral keel. The following three or four whorls have bold broad ribs that are crossed by the peripheral keel, as well as by a poorly defined subsutural cord. The keel and cord form scalloped nodes where they intersect the ribs. A weak subperipheral cord, present on earlier stages of development, is subsumed by the advancing peristome. The adult shell is sculptured with rugose, bold ribs, with coarse axial striations on and between the ribs (Figs. 133-138). The ribs becomes reduced and may be completely absent on the last whorl or two (Figs. 125, 135, 141). There is little indication of spiral sculpture. An inconspicuous peripheral cord may be indicated only by nodes on the ribs of the upper-most whorl or two. There is little or no indication of the subsutural cord. The base of the last whorl is nearly smooth with two or three faintly discernable spiral cords. Measurements are given in Table 6.

Variation. *Elimia viennaensis* is a variable species, which has caused much confusion about its identity. The variation is both ontogenetic and geographic.

The appearance of the shell is complicated by ontogenetic changes. This is an annual species that reproduces in May through August. The reproductive season differs between populations, so that some specimen-samples collected from then through September may be dominated by juvenile shells, whereas specimen-samples collected at other localities at the same time may be dominated by large adults. Immature sub-adult shells may be rugosely sculptured with a nearly complete conical spire (Fig. 142). Adult shells have reduced sculpture consisting of bold axial ribs with little indication of spiral threads or cords, and the spire is decollate (Figs. 133-135). The juvenile and the adult forms differ so strikingly that pure samples of the two forms from the same locality would hardly be recognizable as the same species. This has caused considerable confusion in the past as authors had attempted to assign names to the upper Flint River populations (Goodrich, 1942).

This species also shows some significant geographic variation. Specimens from streams draining into the Flint River in Dooly, Crisp and Worth counties are more robust and less rugosely sculptured than are specimens from the Flint River and from tributaries farther upstream. Populations from the Flint River above Thomaston, Upson County, Georgia, become increasingly paedomorphic in shell shape and in sculpture. This is strongly manifested in snails from Flat Shoals southeast of Gay, Meriwether County, Georgia, where the snail formerly was abundant. Specimens from there are more conical in outline (Figs. 142-

TABLE 6. *Elimia viennaensis* (Lea 1862). Shell measurements of specimens from two population samples selected to show variation. The samples are from streams tributary to the Flint River in Dooly Co., Georgia: Pennahatchee Creek, 4.0 mi. NW of Vienna (UF 71700, n=10); Limestone Creek, 4.0 mi. S, 2.0 mi. E of Drayton (UF 266250, n=15). SL = standard length, 4Wh = length of last four whorls, LWh = length of last whorls, SW = standard width, AH = aperture height, AW = aperture width, Wh = whorls remaining, <Sp = angle of spire, StD = standard deviation.

	SL	4Wh	LWh	SW	AH	AW	Wh	<Sp	SW/4Wh	AH/4Wh	AH/LWh	AW/AH
(UF 71700)												
Min.	19.8	19.8	14.0	9.8	9.0	5.4	3.7	21	0.49	0.43	0.62	0.60
Max.	23.2	22.6	16.4	11.2	10.4	6.3	4.6	32	0.51	0.47	0.69	0.64
Avg.	21.8	22.2	14.8	10.5	9.6	5.9	4.1	27.3	0.49	0.45	0.65	0.62
StD	1.37	2.50	0.71	0.58	0.53	0.29	0.24	3.03	0.01	0.01	0.02	0.02
(UF 266250)												
Min.	18.8	19.0	13.3	9.0	8.3	5.0	3.0	23	0.45	0.43	0.60	0.55
Max.	23.8	22.8	15.7	11.9	10.8	6.3	4.3	30	0.51	0.51	0.70	0.67
Avg.	19.2	20.5	13.6	9.43	8.89	5.36	3.49	24.8	0.48	0.46	0.61	0.57
StD	1.26	1.25	0.63	0.75	0.67	0.29	0.41	2.67	0.02	0.03	0.03	0.03

144), the spiral and axial sculpture is retained on the lower whorls of adult shells more often, producing a more rugose appearance, and large specimens seldom exceed 18 mm in length. Some populations in Potato Creek, Upson County, also are dominated by paedomorphic adults (Figs. 139-141). The upper Flint River populations differ by 2% in the mtDNA sequences from populations farther downstream (Fig. 211). We have not determined if the differences are clinal or disjunct.

Operculum (Figs. 198-199). Broadly obovate in shape; parietal margin straight along the upper half; convex along the lower section. Outer surface with numerous coarse incremental striations. Nucleus rapidly expanding; located at about 0.7 times distance from apex to base, and at about a third of the distance from the columellar margin. Muscle attachment scar sub-elliptical in shape; short, about 0.7 times the length of the operculum; about half as wide as the operculum at the center of the attachment scar; attachment scar bearing a relatively large oblong field of fine granules.

Type locality. Georgia, Dooly County, in a small stream near Vienna. Lectotype: USNM 118743 (Chambers, 1990, p. 262); collected by Rev. G. White. Paralectotype: USNM 873110 (2). Clench & Turner (1956, p. 135) restrict the type locality to the North Fork of Pennahatchee Creek. Chambers (*loc. cit.*) repeated this restriction.

Distribution (Fig. 209). *Elimia viennaensis* is endemic to the upper half of the Flint River system in Georgia from near Albany, north to Pike County and Meriwether County.

Specimens examined. GEORGIA. Baker Co.: Chickasawhatchee Creek, Elmodel (UF 31237, UF 258081). **Crisp Co.:** Swift Creek (UF 1604); Swift Creek, 12 mi. SW of Cordele (UF 71690, UF 71692); Swift Creek, ca. 4 mi. E of Warwick (UF 251657, UF 251658, UF 280687, UF 280693); Cedar Creek, 5 mi. SW of Cordele (UF 1991); Gum Creek, 6.5 mi. W of Cordele, 31°57.7' N, 83°53.0' W (UF 279009); Limestone Creek, at Drayton Rd., 4.7 mi. S, 1.1 mi. E of Drayton , 32°01'08"N, 83°54'39"W (UF 251650); Limestone Creek at Drayton Rd. ca. 9.0 mi. SSE of Drayton, 32°01.3' N, 83°55.4' (UF 278993); Limestone Creek, at Cannon Rd., 4.7 mi. S of Drayton, 33°02'02"N, 83°55'34"W (UF 251643, UF 251644, UF 280704). **Dooly Co.:** Limestone Creek at McCay Rd, 0.8 mi. NW of Drayton Rd., 32°01.9' N, 83°54.5' W (UF 279001); Limestone Creek, at McCay Rd., ca. 4 mi. S, 2 mi. E of Drayton, 32°02'00"N, 83°54'33"W (UF 251654, UF 266250, UF 280689, UF 280690). North Fork Pennahatchee Creek, 4.0 mi. NW of Vienna (UF 71700); Little Pennahatchee Creek at AL Hwy 90, 3.5 mi. NW of Vienna (UF 230728, UF 241054, UF 241055); Turkey Creek, 4.4 mi. NNE, 0.8 mi. E of Drayton (UF 251648, UF 251649). **Dougherty Co.:** Flint River, Albany (UF 71699). **Macon Co.:** Flint River, 4 mi. E of Garden Valley (UF 231841). **Meriwether Co.:** White Oak Creek, 3.8 mi. NE of Gay (UF 29610); Flint River, 3.5 mi. SE of Gay (UF 231844, UF 289524); Flint River, 5.0 mi. SE of Gay (UF 29613, UF 231852, UF 231842, UF 231843, UF 231156); Flint River, 5.6 mi. SE of Gay (UF 230376, UF 289523); Flint River, Flat Shoal, 3 mi. SE of Gay (UF 231845, UF 231851); Flint River, 1.5 mi. E of Gay (UF 231849, UF 231850); Flint River, old bridge 2.0 mi. NE of Gay (UF 231853); Flint River, 1.6 mi. E of Gay, 0.4 mi. S of Birch Creek (UF 231854); Flint River, 1.7 mi. NE of Gay, 0.2 mi. N of Birch Creek (UF 231855); Flint River bridge 4.6 mi. E of Gay on SR 109 (UF 251617, UF 251618); Flint River, 2.0 mi. SE of Alvaton (UF 231846, UF 231848); Flint River, 2.1 mi. E of Alvaton (UF 231847). **Pike Co.:** Eklins Creek, 3.6

mi. ESE of Woodbury (UF 31235); Flint River, 2.6 mi. W of Hollonville (UF 231856). **Talbot Co.:** Flint River, 3.2 mi. NW of Carsonville (UF 231861, UF 231862, UF 231863); Flint River, shoals 2.2 mi. NNW of Fickling Mill (UF 231858, UF 231859); Flint River, shoal 3.6 mi. NW of Fickling Mill (UF 231860); Flint River, 4.0 mi. E of Prattsburg (UF 231864, UF 231865). **Terrell Co.:** creek, 1.0 mi. N of Bronwood (UF 231165, UF 231168). **Upson Co.:** Potato Creek at AL Hwy 36, 7.1 mi. W of Thomaston (UF 251612, UF 251611, UF 251613); Potato Creek, 5.7 mi. SW of Lincoln Park (UF 29611, UF 231866, UF 231871); Potato Creek, 3.0 mi. W of Thomaston (UF 231868); Potato Creek, 2.3 mi. W of Thomaston, Adams Ferry Rd. and Po Biddy Rd. (UF 251614, UF 251615); Potato Creek, 2.3 mi. WNW of Thomaston (UF 231869, UF 231872, UF 231867, UF 231874); Flint River., 5.3 mi. SW of Lincoln Park, RM252 (UF 31231); Flint River, Snipes Shoals, ca. 7.0 mi. S of Lincoln Park, (UF 31232, UF 31233); Flint River, Spewell Bluff, River Mile 266 (UF 31234); Flint River, Yellow Jacket Shoals, ca. 6.0 mi. SW of Thomaston (UF 31242); Flint River, Pasley Shoals (UF 230510); Flint River, Seven Islands Shoals (UF 230514); Flint River, Seven Islands Shoal area, 2.0 mi. S of Spewell Bluff (UF 230525); Flint River, 7.4 mi. WSW of Thomaston (UF 231870, UF 231873, UF 231876); Flint River, 6.0 mi. SW of Lincoln Park (UF 231875, UF 231877, UF 231878, UF 231879, UF 231880); Flint River at AL Hwy 36, shoal downstream from bridge, 5.8 mi. SW of Lincoln Park (UF 241056, UF 241057, UF 241058, UF 241059); Flint River, Po Biddy Rd. Bridge (UF 251616). **Worth Co.:** Jones Creek, 2 mi. S of Oakfield (UF 71691); Mill Creek, 8.0 mi. S of Oakfield (UF 71702); Abram's Creek, 5.0 mi. S of Oakfield (UF 71703); Big Abram's Creek, 4.2 mi. S of Oakfield (UF 251661, UF 251662, UF 251881, UF 280705); Jones Creek, 2 mi. SE of Oakfield (UF 251666, UF280703); Jones Creek, 1.0 mi. S of Oakfield (UF 231154); creek, 8.9 mi. NNE of Albany (UF 231166); creek, 12.4 mi. NNE of Albany (UF 231191); Mercer Mill Creek at Ga. Hwy 300, ca 10 mi. NE of Albany, 31°40.1' N, 83°59.8' (UF 279341); Big Abram's Creek at AL Hwy 300, 9.3 mi. SSW of Warwick, 31°43.1' N, 83°58.3' (UF 278996, UF 279005, UF 279570, UF 279576, UF 279922).

Conservation status. This species persists throughout most of its known former range. However, populations in the Flint River and tributaries above Thomaston, Georgia, have had severe impact from municipal and industrial affluent since 1981 (personal observation). The snail has been extirpated from most of Potato Creek, and from much of the Flint River. Prior to 1981 *Elimia viennaensis*, as well as *Somatogyrus rheophilus* Thompson 1984, were extremely abundant at Flat Shoals on the Flint River east of Gay, Meriweather–Pike counties. Both species no longer occur there. In this regard it should be noted that Watson (2000, p. 235, fig. 2) failed to find *S. rheophilus* at several sites in the upper Flint River from where it had previously been recorded by Thompson (1984). The current status of *E. viennaensis* populations throughout the upper Flint River system needs to be documented with new field surveys.

Habitat. Below Montezuma, Macon County, Georgia *Elimia viennaensis* is found primarily in smaller streams tributary to the Flint River, but it also occurs sparsely in the river. Further up-stream, at localities from which it has not been extirpated, *E. viennaensis* is generally present in the Flint River as well as in tributaries. It is generally distributed on the substrate in slower flowing water.

Elimia viennaensis is found commonly with *E. curvicostata* and *E. induta* in small streams in Dooly, Crisp and Worth counties. It is found occasionally with *E. albanyensis* in the Flint River and the lower parts of smaller streams in the same region.

Remarks. *Elimia viennaensis* is related to *E. "flava"* from the Tallapoosa River system and to the *E. catenaria* species-group as is indicated by mtDNA sequences.

Chambers (1990, p. 254) synonymized *Elimia viennaensis* with *E. curvicostata* on the basis of similarities of their adult shell sculpture. The costate shells of some large adults of *Elimia viennaensis* are similar superficially to *E. curvicostata*. *Elimia viennaensis* is a larger, more robust species than is *E. curvicostata*, and its juvenile shell differs by being broadly conical and differently sculptured. The lectotype of *E. viennaensis* is a large adult shell sculptured with bold ribs (Fig. 125). It lacks spiral cords on the last four whorls, and on the last whorl the ribs become obsolete. The shell retains seven whorls, of which the upper three are dead but have not been eroded away. The upper three whorls bear a scalloped peripheral spiral cord that crosses well-defined ribs. A weak, scalloped, subsutural cord is also present. These traits of the lectotype are consistent with adult *E. viennaensis* and distinguish it from *E. curvicostata*. The two species coexisting on the same logs in small creeks in Worth County and Crisp County, Georgia, where adults of the two species differ strikingly and show no indication of hybridizing or intergradation. There they differ by the large robust size and rugose appearance of *E. viennaensis* and the smaller size and more graceful appearance of *E. curvicostata*.

Chambers (1990, p. 254) synonymized *Elimia albanyensis* with *E. boykiniana* (Lea 1840), a species occurring in the Chattahoochee River system. His description of *E. boykiniana* is a composite of several species. The distribution he gives for *E. boykiniana* in the Flint River system is based primarily on *E. viennaensis*, but also on *E. albanyensis*. It is beyond the scope of this paper to resolve the taxonomic status of the names that Chambers synonymized with *boykiniana,* except that we continue to recognize *E. albanyensis* and *E. boykiniana* as distinct species because of genetic and morphological differences and because of the co-occurrence of *E. albanyensis* with *E. viennaensis*. The genetic relationship of *E. boykiniana* to *E. viennaensis* is quite remote. We illustrate for comparison four specimens of *E. albanyensis* from the Flint River at Albany, Georgia (Figs. 145-147, 151), and four specimens of *E. boykiniana* from the Chattahoochee River below the dam at Phenix City, Alabama (Figs. 148-150, 152). The figured specimens of *E. boykiniana* were collected on 4 September, 2000 (UF 289697). *Elimia boykiniana* has a larger, more fusiform-shaped shell with weaker spiral sculpture than does *E albanyensis* and its juvenile shell is more robust, the sculpture is weaker, the whorls are not scalariform, and they lack a peripheral keel.

In *Elimia albanyensis* (Fig. 156) the juvenile whorls have a shallow suture and are not scalariform. The peripheral keel is weak and is located just above the suture. The first whorls are smooth, as in *E. viennaensis*, but the following whorls are sculptured with weaker spiral cords that cross low, wide plica. This sculpture persists in adult *E. albanyensis*, which seldom exceeds 12 mm in length, they have a shallower suture separating the whorls, and the shell is elongate-elliptical in shape. It is found in the lower Flint River system in Georgia and in the Apalachicola River in Florida. We have found no intergrading populations of the two species.

Etymology. *Elimia viennaensis* was named for the City of Vienna, Dooly County, Georgia, because of its proximity to the type locality.

The *Elimia mutabilis* species-group

We recognize three species belonging to this group: *Elimia mutabilis* (Lea 1862) from the upper Ocmulgee River system of Georgia, *Elimia ucheensis* (Lea 1862) from the middle Chattahoochee River system in eastern Alabama, and a new species from the lower Choctawhatchee River system in Alabama and Florida. The group is characterized by the broadly conical juvenile shell that is smooth or is weakly plicate (Figs. 190-191). The *mutabilis* species-group shows phylogenetic affinities with *Elimia olivula* from the Alabama River system, although the relationship does not seem to be close.

Elimia mutabilis (Lea 1862)

Common name: Oak Elimia

Goniobasis mutabilis Lea 1862, *Proceedings of the Academy of Natural Sciences of Philadelphia,* 14, p. 270; Lea, 1863, *Journal of the Academy of Natural Sciences of Philadelphia,* 5, p. 331, pl. 38, fig. 180; Goodrich, 1942, *Occasional Papers of the Museum of Zoology, University of Michigan,* (456), p. 5.

Goniobasis suturalis (Haldman 1840), in part, Tryon, 1873, *Smithsonian Miscellaneous Collections,* (253), pp. 183-184, fig. 357.

Oxytrema suturalis (Haldeman 1840), Krieger & Burbanck, 1976, *American Midland Naturalist,* 95, pp. 49-63.

Elimia mutabilis mutabilis (Lea 1862), Burch & Tottenham, 1980, *Walkerana,* 1(3), p. 140; Burch, 1989, *North America Freshwater snails*, p. 140.

Goniobasis catenaria postelli (Lea 1858), Dillon & Reed, 2002, *Malacologia,* 44, pp. 23-29, fig. 2, right.

Diagnosis. In general appearance this is a medium-sized species with a moderately stocky scalariform shell that is greenish-gray in color and is nearly devoid of axial and spiral sculpture on the lower adult whorls. The whorls are nearly flat between the sutures. The spire is weakly convex in outline. The juvenile shell is stocky and diverges initially at about 43-50°, which rapidly changes to 27-36° in adults. The juvenile shell bears two prominent spiral cords, one at the periphery, and one below the periphery. The lower cord usually is covered by the insertion of the lip during shell growth so that it no longer remains visible. Two or three additional very weak spiral cords may be present on the base of the body whorl. The juvenile shell also may have low, weak, undulating plicae, which end at the peripheral cord and do not form conspicuous knobs. The plicae usually are obsolete or absent on the lower whorls of the adult shell.

Shell (Figs. 62, 63-66, 67-72). The juvenile spire diverges at an angle of 43-50° and tends to be slightly convex in outline. A strong peripheral cord begins on the second whorl. A weaker subperipheral cord may be present just below the peripheral cord, or it may be overlaid by the insertion of the peristome. The base may have an additional two or three very low weak spiral cords, or it may be smooth. Weak, low, vertical plicae usually extend from the suture to the peripheral cord, where they may form very weak knobs. An additional very weak spiral cord may be present between the suture and the periphery (Figs. 63-66). Most specimens from Snapping Shoals also have on the upper whorls a few rather distinct spiral striations between the suture and the periphery (Figs. 69-70). Distinct spiral striations are absent from the type specimens, which in turn have more distinct vertical striation on the lower whorls than do more recently collected samples. The rates of growth indicate that adults acquire a total of about 10 whorls, and lose 4-5 juvenile whorls above the apical plug, leaving about 4.5-6.0 weakly scalariform whorls in decollate adults. The adult spire diverges at about 27-36°. Adults are about 15.6-22.3 mm in length below the decollated apex. The shell is moderately stout; the length of the last four whorls is about 0.45-0.51 times the standard width. Most specimens are greenish-gray in color. Occasional shells may have up to five rust-colored spiral bands. The sculpture of adult shells is best described as indistinct and irregular. Vaguely differentiated ribs may be present on the upper whorls or the axial sculpture may consist of only coarse incremental striations (Figs. 67-72). A few poorly differentiated spiral threads also may be present. The aperture is broadly obovate in shape, 0.62-0.76 times as wide as high and 0.41-0.52 times the height of last whorl. The lower margin is rounded, and is slightly canaliculate at the base of the columella. Measurements of 12 adult specimens from four population samples are given in Table 7.

Operculum (Figs. 173-174). Broadly ovate in shape; parietal margin convex. Outer surface covered by numerous coarse incremental striations. Nucleus consisting of about 2.5 slowly expanding whorls; it is located at about 0.65 of the distance from the apex to the base and about 0.3 of the distance from the columellar margin. Muscle attachment scar about 0.85 times the length of the operculum, and about 0.5 its width; bordered along the lower 0.3 with a heavy rounded ridge, and having a small elliptical granular field near its base.

Type Locality. Butts County, Georgia. Lectotype by present designation: USNM 118443; collected by the Rev. G. White. Paralectotypes: USNM 905413

TABLE 7. *Elimia mutabilis* (Lea 1862). Measurements of adult specimens from two field stations. Butts Co. Georgia: lectotype and paralectotypes. South River at Snapping Shoals, Newton Co., Georgia: UF 251609, UF 251667, UF 271307. SL = standard length, 4Wh = length of last four whorls, SW = standard width, AH = aperture height, AW = aperture width, Wh = whorls remaining, <Sp = angle of adult spire, std = standard deviation. Statistical analyses are not provided because the samples are small and each was collected on different occasions and at different seasons.

	SL	4Wh	SW	AH	AW	<Sp	Wh	SW/4W	AH/4W	AW/AH
Lectotype	15.6	15.0	7.3	6.9	4.5	30	5.0	0.49	0.46	0.65
Paralecto.	18.6	18.1	9.1	8.7	5.6	28	4.5	0.50	0.48	0.64
Paralecto.	15.8	15.7	7.9	7.1	5.4	36	5.3	0.50	0.45	0.76
Paralecto.	15.9	16.3	7.9	7.1	4.9	27	4.8	0.48	0.44	0.69
UF 251609	22.7	22.0	10.5	11	6.8	32	5.0	0.48	0.50	0.62
UF 251609	21.5	20.9	10.2	10	6.6	32	4.8	0.49	0.48	0.66
UF 251609	22.3	-	11.1	10.2	7.5	28	3.9	-	-	0.74
UF 251609	20.5	20.0	10.0	10.3	6.8	30	4.7	0.50	0.52	0.66
UF 251667	21.3	19.6	8.90	9.6	6	31	4.7	0.45	0.49	0.63
UF 251667	18.2	17.6	9.0	7.3	5.5	30	5.0	0.51	0.41	0.75
UF 271307	19	17.8	8.6	8.6	5.3	32	6.0	0.48	0.48	0.62

(21). The lectotype is the specimen figured by Lea (1863). We restrict the type locality to the South River, which forms the northeastern border of Butts County. Butts County has the same boundaries now as it did in 1862 when the species was described (Kimberly Ball, *personal communication*). The county is bounded on the east by the Ocmulgee River, and on the north by the South River. Specimens collected further upstream in the South River at Snapping Shoals, Newton County, are very similar in shell traits to the type series.

Distribution (Fig. 209). Populations that are identifiable as this species occur in the South River and in the Yellow River in Newton County, Georgia. We have surveyed numerous small streams in Butts County. We have not found any populations of *Elimia* in streams within Butts County, and we know of no museum specimens that originated from streams within the county. We assume that *Elimia* was extirpated from there due to adverse environmental impact factors, if indeed the snail had ever occurred within the county.

Specimens examined. **GEORGIA.** "Atlanta" (UMMZ 134018). **Newton Co.**: South River, Snapping Shoals (UF 251609, 271307, 251667); Yellow River, Cedar Shoals, 0.5 mi. S of Porterdale (UF 31262); Yellow River, Porterdale (UF 271306). **Rucksdale Co.**: Yellow river 1.5 mi. N of Conyers (UF 230494). **Gwinnett Co.:** Yellow River, Anniston Rd. Bridge, 2 mi. S of US Hwy 78 (UMMZ 249127).

Habitat. *Elimia mutabilis* is a large-river species found on granite shoals in clear silt-free habitats. In the South River and in the Yellow River it is found on the down-stream sides of granite boulders and outcrops in moderate to fast currents. We did not find it in quiet pools or backwaters at these localities nor in quieter sections of the rivers where silt deposition takes place.

Conservation status. *Elimia mutabilis* is endangered, although it is not listed by the State of Georgia or United States governmental agencies. The Alcovy River, the Yellow River and the South River are heavily impacted by siltation due to urban development upstream from within the southeast environs of the City of Atlanta. We found *E. mutabilis* only at the stations listed above during surveys in 1981, 1995 and 1999. During our most recent survey on 19 March, 1999, we found only a single juvenile specimen in the Yellow River at Porterdale, and only eight specimens at Snapping Shoals, South River. We found no specimens elsewhere in the Yellow River.

Remarks. *Elimia mutabilis* has a generalized shell with sculpture features that occur frequently throughout the genus. This has caused the species to be neglected and misunderstood in the scientific literature since it was described. Lea (1862) gave a brief description of the shell. In 1863 he repeated his earlier description and figured a specimen which we designate here as the lectotype. Tryon (1873) treated *mutabilis* as a junior synonym of *Melania suturalis* Haldeman 1840. Haldeman did not give a type locality for *M. suturalis* other than "Ohio." Tryon (1873, p. 183) expressed doubt that *suturalis* was found in Ohio. The "type" of *suturalis* (USNM 12115) is an adult shell that lacks juvenile sculpture traits. It is not identifiable with *E. mutabilis* because it has a subsutural spiral cord and another cord midway between it and the peripheral cord. Goodrich (1940) made no mention of the name *suturalis* in his synoptic list of the Pleuroceridae in the Ohio River drainage. Later Goodrich (1942, p. 4) treated *suturalis* as a questionable senior synonym of *Goniobasis viennaensis* Lea 1862. Krieger & Burbanck (1976) continued to use the name *suturalis* for this species. The name *Melania suturalis* Haldeman 1840 is a *nomum dubium* because it is not identifiable with any know population of *Elimia*.

Goodrich (1942, p. 5) treated *Elimia mutabilis* as a distinct species and stated that it occurs in streams in western Georgia and Florida west to the Alabama River system. This large geographic area contains numerous populations of *Elimia* with shells that are superficially similar to *E. mutabilis*. Goodrich provided no morphological criteria shared by these various populations, nor did he provide additional information concerning the taxon. Burch (1989, p. 141, fig. 394) quoted the distribution given by Goodrich, and he provided a new figure. The illustration does not agree with the lectotype and other specimens from populations we identify as *E. mutabilis*.

Dillon & Reed (2002) provide valuable information concerning genetic variation of *Elimia* in the Atlantic coastal plains based on allozyme analysis. The taxonomic interpretations of their data require re-examination. They discuss four taxa: *Elimia catenaria catenaria*, *E. c. dislocata*, *E. c. "postelli"* and *E. proxima*. They consider all populations of *Goniobasis* (= *Elimia*) from the Altamaha River drainage to consist of a single taxon, *E. catenaria postelli* (Lea 1858). Their study population is *E. mutabilis*, and not *E. c. postelli*, which is a very different species (Burch, 1989, p. fig. 337). They do not address data presented by Mihalcik (1998) demonstrating the presence of two additional species in the river system, *E. timida* (Goodrich 1942) and a new species described above, *E. darwini*. Dillon & Reed's fig. 5 depicts both *E. c. catenaria* and *E. c. dislocata* as being polyphyletic, and that *E. c. postelli* (= *mutablis*) differs from *E. catenaria* almost to the same degree as does *E. proxima*, which they regard as a separate species. Their polyphyletic phylogeny is untenable by modern systematic methodologies.

Numerous populations of *Elimia* occur in Georgia, which are identified in museum collections as *E. mutabilis*. Only populations in the South River and the Yellow River of the upper Ocmulgee system are this species. Specimens from the adjacent Alcovy River and the Ocmulgee River, Georgia, are much more rugosely sculptured than is typical for *Elimia mutabilis*. Although they inhabit immediately adjacent rivers, we tentatively exclude them from this taxon. *Elimia darwini* from Rocky Creek, Laurens County, a tributary of the Oconee River, is superficially similar to typical *E. mutabilis*, and it has been identified in museum collections as such. When we first encountered *E. darwini* in the field we though it was a local variation of *E. mutabilis*. Close examination of juvenile shell characters and mtDNA analysis indicate that it is a different species related to *E. catenaria* and not to *E. mutabilis*.

Etymology. The name *mutabilis* is from the Latin, meaning changeable, and alludes to the shells variable sculpture.

Elimia ucheensis (Lea 1862)

Vernacular name: Creek Elimia

Goniobasis ucheensis Lea 1862, *Proceedings of the Academy of Natural Sciences of Philadelphia,* 14, p. 270; Lea, 1863, *Journal of the Academy of Natural Sciences of Philadelphia,* 5, p. 334, pl. 38, fig. 195; Goodrich, 1942, *Occasional Papers of the Museum of Zoology, University of Michigan,* (456), p. 4.

Goniobasis inosculata Lea 1862, *Proceedings of the Academy of Natural Sciences of Philadelphia,* 14, p. 270; Lea, 1863, *Journal of the Academy of Natural Sciences of Philadelphia,* 5, p. 334, pl. 38, fig. 195.

Goniobasis elliotti Lea 1862, *Proceedings of the Academy of Natural Sciences of Philadelphia,* 14, p. 271; Lea, 1863, *Journal of the Academy of Natural Sciences of Philadelphia,* 5, p. 338, pl. 38, fig. 201; Tryon, 1873, pp. 265-266, fig. 509.

Goniobasis gesneri Lea 1868a, *Proceedings of the Academy of Natural Sciences of Philadelphia,* 20, p. 151; Lea, 1868b, *Journal of the Academy of Natural Sciences of Philadelphia,* 6, p. 330, pl. 54, fig. 5.

Goniobasis curvicostata (Reeve 1861), in part, Clench & Turner, 1956, *Bulletin of the Florida State Museum,* 1, p. 136.

Elimia ucheensis (Lea 1862), Burch, 1989, *North American freshwater snails*, p. 121, fig. 346.

Elimia curvicostata (Reeve 1861), in part; Chambers, 1990, *Walkerana,* 4(12), p. 262.

Diagnosis. This is a moderately large species that generally has a straight-sided, truncate spire consisting of about 4-5 whorls. The early whorls are scalariform with a prominent peripheral spiral keel that lies just above the suture. The sculpture consists of coarse posteriorly arched incremental striations and usually very fine spiral striations that give the shell a satiny luster. The vertical striations frequently occur on an undulating obsolete-plicate background, but axial ribs are absent at all growth stages.

Shell (Figs. 155-158, 159-166). The shell is moderately large, up to about 22 mm long, and is 0.44-0.48 times as wide as high. It is glossy, light brown or grayish brown in color with a livid-white aperture and a white columella. The shell is elongate-conical in shape with a truncate apex. The sides of the spire are straight and diverge at an angle of about 25-37°. The spire becomes weakly convex at terminal growth. Adult shells retain about 4-5 whorls. The growth rate of juvenile shells indicate that 9-10 whorls are developed through the life of the snail. The whorls are flat-sided, or nearly so, between the sutures. The early whorls have a strong peripheral keel that lies just above the suture. The suture is weakly impressed, but is accentuated above by the tendency of the earlier whorls to be weakly scalariform due to the peripheral keel. The keel begins on the second juvenile whorl and may persist to the sixth or seventh whorl (upper 2-3 whorls of adult). A weak rounded spiral cord is present on the base of the juvenile body whorl just below the periphery (Figs. 157, 158). This cord begins on the second whorl and persists through the next 4-5 whorls. It is covered and obscured by the advancing parietal callus. On the upper whorls another weak spiral cord occasionally is present just below the suture. The sculpture consists of coarse posteriorly arched incremental striations that are nearly equal in intensity over the surface of the shell. Very fine spiral micro-striations also may be present. Frequently the surface of the lower whorls may be weakly undulating. The aperture is narrowly elliptical to nearly trapezoidal in shape and is about 0.58-0.66 times as wide as high. The aperture is about 0.42-0.48 times the length of the last four whorls, and about 0.65-0.72 times the length of the last whorl. The columellar margin is strong, nearly straight, weakly inclined, and partially reflected over the umbilical area. The outer lip is nearly straight above the periphery, rounded below and projecting forward in lateral profile. Measurements are given in Table 8.

Variation. In general appearance this snail is drab-colored and coarse in appearance. The shell is glossy with a satiny appearance when clean, but usually it is covered by mineral deposits. The measurements given in Table 8 encompass most of the size variation found in this species. There is very little geographic variation in other shell features. As with other species of *Elimia, E. ucheensis* is an annual species. Specimens from samples collected at a single station but at different seasons may differ dramatically in appearance because of the different growth stages they represent.

This seasonal variation, coupled with small sample-sizes, caused Lea to recognize four nominate species in the Uchee Creek system that we treat as synonyms. They represent different growth stages and are typical for specimens found in many large samples from there. The lectotype of *Goniobasis ucheensis* (Fig. 156) is a juvenile with scalariform whorls on the upper spire. The whorls bear a strong peripheral keel and a weaker keel located between the upper suture and the periphery. The lectotype of *Goniobasis inosculta* (Fig. 155) represents a more advanced growth stage, but it is still immature. The lectotype of *Goniobasis elliotti* (Fig. 165) is an older, gerontic shell, which still retains the peripheral carinae. Specimens of this size are uncommon because they represent terminal growth at old age, and usually they survive for only a brief period during the summer. The lectotype of *Goniobasis gesneri* (Fig. 166) is typical for the species in sculpture and other structural traits, except that it is unusually obese, but not uniquely so. Many large specimen-samples have individuals that encompass the range of variation demonstrated by the four nominate types.

Operculum (Figs. 187-188). Broadly ovate in shape with a weakly indented

TABLE 8. *Elimia ucheensis* (Lea 1862). Measurements of lectotypes of four nominate species and ten specimens from a single population sample (UF 279856) selected to show variation. The lectotypes are *Goniobasis ucheensis* (USNM 119259), *Goniobasis inosculatus* (USNM 119177), *Goniobasis elliotti* (USNM 119122) and *Goniobasis gesneri* (USNM 119134). The sample UF 279856 is from Little Uchee Creek, 8.0 mi. NE of Seale, Russell Co., Alabama. SL = standard length, 4Wh = length of last four whorls, LWh = length of last whorls, SW = standard width, AH = aperture height, AW = aperture width, Wh = whorls remaining, <Sp = angle of spire, StD = standard deviation. The numbers of remaining whorls in the lectotype and the paralectotypes were not determined in order to avoid damaging the specimens.

	SL	4Wh	LWh	SW	AH	AW	Wh	<Sp	SW/4Wh	AH/4Wh	AH/LWh	AW/AH
UF 279856												
Min.	16.0	16.0	10.8	8.0	7.0	4.5	3.9	25	0.44	0.42	0.65	0.58
Max.	22.0	21.7	14.0	10.4	9.1	4.9	5.3	37	0.48	0.48	0.72	0.66
Avg.	17.37	18.18	12.06	8.35	8.07	4.95	4.26	28.9	0.46	0.44	0.67	0.61
StD	2.65	1.90	1.12	0.90	0.70	0.43	0.42	3.24	0.01	0.02	0.02	0.02
ucheensis	13.1	12.9	8.7	6.3	5.7	3.8	4.2	32	0.49	0.44	0.66	0.67
inosculatus	17.2	15.7	10.3	7.3	6.9	4.2	5.3	28	0.46	0.44	0.67	0.61
elliotti	21.3	21	13.6	10.8	9.6	6.0	4.5	31	0.51	0.46	0.71	0.63
gesneri	19.5	19.1	14.0	9.5	9.1	6.1	5.3	38	0.50	0.48	0.65	0.67

parietal margin. Thin, delicate, hyaline in color. Nucleus located at about a third of the distance from the base to the apex and about a third of the distance from the columellar margin. Nucleus consisting of 2.5 rapidly expanding whorls. Outer surface with a few delicate incremental striations. Muscle attachment scar smooth; about 0.7 times the length of the operculum, and about half its width.

Type localities. *Goniobasis ucheensis*: Little Uchee Creek, "Georgia" [Alabama], lectotype USNM 119259 (Chambers, 1990, p. 263), collected by George Hallenbeck; paralectotypes USNM 873114 (26), same data as the lectotype. *Goniobasis inosculata*: Little Uchee Creek, Alabama, lectotype USNM 119177 (Chambers, 1990, p. 263), collected by George Hallenbeck; paralectotypes USNM 873115 (7), same data as the lectotype. *Goniobasis elliotti*: Little Uchee River, Alabama; lectotype USNM 119122 (Chambers, 1990, p. 263), collected by George Hallenbeck; paralectotypes USNM 873113 (10), same data as the lectotype. *Goniobasis gesneri*: Uchee River, Alabama, holotype USNM 119134, collected by William Gesner.

The name *Goniobasis elliotti* Lea 1862 is based on specimens collected by Bishop Elliott in Fannin County, Georgia, which is in the Hiawassee drainage system of the Tennessee River. Lea (1862, p. 271) also cited specimens from Little Uchee Creek collected by George Hallenbeck. Chambers (1990, p. 262) selected the specimens from the latter locality as the lectotype, which circumvents Lea's original intention as is implied by Lea's choice of the name *elliotti*. This action conveniently disposes of the name *elliotti* because the Little Uchee Creek specimens unquestionable are old adult *Elimia ucheensis*, but it leaves unanswered the question regarding the identity of the Fannin County specimens for which Lea intended the name *elliotti* to be applied.

Distribution (Fig. 209). This species occurs in the Uchee Creek system, a tributary of the Chattahoochee River in eastern Alabama.

Specimens examined. **ALABAMA. Russell Co.:** Uchee Creek (UF 61677, UF 76318, UF 71707,UF 76321, UF 76322); Uchee Creek, Fort Mitchell (UF 76315); Uchee Creek, nr. Ft. Mitchell (UF 71695, UF 76314); Big Uchee Creek, 6.0 mi. NE of Seale (UF 76319); Uchee Creek, 4.7 mi. NE of Seale (UF 231792); Uchee Creek, 3.0 mi. W of Ft. Mitchell (UF 231795); Uchee Creek, 3.0 mi. W of Ft. Mitchell (UF 279899); Uchee Creek, 4.2 mi. N of Seale (UF 231797); Uchee Creek at U.S. Hwy 431 (UF 251461); Uchee Creek at Co. Rd 39 (UF 251462); Uchee Creek at AL Hwy 165, 1.0 mi. N of Ft. Mitchell (UF 279851, UF 279853); Uchee Creek, 6.1 mi. NE of Seale (UF 279854, UF 279855); Uchee Creek at AL Hwy 169, 6.7 mi. N of Seale (UF 279858-279860); Little Uchee Creek, 7.5 mi. WSW of Phenix City (UF 231794, UF 231798, UF 279894, UF 279895-279897); Little Uchee Creek, 16.2 mi. SW of Phenix City (UF 251623, UF 251623, UF 41470); Little Uchee Creek at U.S. Hwy 431, 8.0 mi. NE of Seale (UF 41462, UF 41465, UF 251466, UF 279856, UF 279856, UF 279857); small creek on U.S. Hwy 431, 6.2 mi. NE of Seale (UF 41468, UF 41469).

Conservation status. This species is widely distributed with the Uchee Creek system, and it is common at most places where it occurs. No special protective measures are warranted.

Habitat. *Elimia ucheensis* inhabits small, shallow, clear streams, which form intermittent pools and riffles, and which lack aquatic vegetation. It is generally found on the substrata on silt, sand, gravel, rocks and logs. We have not detected a substrate preference.

Remarks. *Elimia ucheensis* is most closely related to *E. mutabilis* and the following species as is indicated by the strong similarities in their mtDNA, their juvenile shell morphology and their opercula.

Chambers (1990, p. 263) placed *Goniobasis ucheenis* in the synonymy of *Elimia curvicostata. Elimia curvicostata* consistently differs from *E. ucheensis* by having a single strong spiral carina on the middle of the juvenile whorls. The carina is strongly scalloped by strong ribs located between the upper suture and the periphery. The juvenile whorls of *E. ucheensis* have two prominent carinae and lack axial ribs so that the carinae are simple smooth crests. The sculpture of adult shells also are strikingly different. *Elimia curvicostata* has bold axial ribs that lack any spiral sculpture features, in contrast to *E ucheensis*, which lacks bold axial ribs but retains the spiral carina on the upper whorls. The two species also differ in mtDNA sequences.

Etymology. Three names associated with *Elimia ucheensis* are geographic or personal patronymics. *Goniobasis ucheensis* was named for Uchee Creek. *Goniobasis elliotti* was named for The Right Reverend Stephen Elliott. *Goniobasis gesneri* was named for George Gesner. The species name *inosculta* refers to an open, broadly rhombic (not puckered) mouth or aperture.

Elimia buffyae new species

Vernacular name: Iris Elimia

Goniobasis curvicostata (Reeve 1861), in part, Clench & Turner, 1956, *Bulletin of the Florida State Museum,* 1, p. 136-138.
Elimia curvicostata (Reeve 1831), in part, Thompson, 1984, *Freshwater snails of Florida,* pp. 26-27, fig. 49; Chambers, 1990, *Walkerana,* 4(12), pp. 262-264.
Elimia sp., Thompson, 2000a, *Walkerana,* 10(23), p. 24, fig. 54.

Diagnosis. The elegant shell is moderately large, up to about 22 mm in standard length. The spire is slightly convex, diverging at 25-33°. The shell is decollate with 3.5-4.5 whorls remaining in the adult shell. The shell usually is smooth, shiny, and frequently has one to four rust-colored bands. The sculpture on the adult shell, when present, is confined to the early whorls of the spire and consists of low, poorly defined, undulating plicae. Juvenile shells are broadly conical, straight-sided in outline, and have two peripheral carinae. The advancing lip is deposited between the two carinae so that the upper whorls have a single carina that lies just above the suture. The carina is smooth and not knobbed by intersecting ribs.

Shell (Figs. 81-85, 92-97, 98-105, 106-109). The shell is medium to large in size, measuring up to 22 mm in standard length. The periostracum is yellowish-gray in color with up to four rust-colored bands. When present, one band lies below the suture, two bands are peripheral and a fourth band is located about midway around the base. The shell vairies in shape from conical to ovate-conical. The shell is moderately stout, and in outline the spire is slightly convex, diverging at an angle of 25-33°. Adult shells have 3.0-4.5 whorls remaining below the apical plug. The rate of growth of the juvenile shell indicates that a total of about 10-11 whorls are formed. The juvenile shell is narrowly conical with flat-sided whorls bounded by a peripheral carina located just above the suture (Figs. 80-81, 83-85). A weaker subperipheral carina is present on the juvenile shell, but it is overlaid and obliterated by the advancing peristome. The peripheral carina is located just above the suture and is smooth throughout its course. It continues on the adult shell, causing the upper whorls to be slightly scalariform; the suture of the last whorl is more deeply impressed, causing the last whorl to be slightly pinched from the preceding whorl. The first three to four juvenile whorls are smooth. The following whorls are usually smooth also, but may have poorly defined, widely spaced plicae that may persist on the uppermost whorl or two of the adult shell as low irregular wavy undulations. Adult shells have rather coarse incremental striation. The aperture is irregularly elliptical in shape, about 0.52-0.67 times as wide as high, and 0.59-0.70 times the length of the last whorl. The columellar margin is narrow and weakly concave. In lateral profile the outer peristome is nearly vertical and recurved in the middle (Fig. 97). Measurements are given in Table 9.

Variation. *Elimia buffyae* demonstrates considerable geographic variation within the Choctawhatchee River system and to a lesser extent in the Yellow River. Populations may differ by the size of the adult shells, relative obesity, intensity of the plicate sculpture, and by the color pattern. The variations do not correlate with stream size. All population samples that we have examined include some specimens that are banded, and in some populations nearly all of the individuals are banded. Populations from Double Bridge Creek in Geneva County, Alabama, are short, squat and coarsely plicate. Specimens from upstream tributaries in Dale and Barbour Counties, Alabama, also tend be more rugosely plicate than normal. Specimens from a small stream, Limestone Creek, Walton County, Florida (Figs. 102-105), essentially do not differ from those from the Choctawhatchee River. Specimens from tributaries to the Choctawhatchee River farther south tend to be smaller and more cylindrical (see Remarks). Specimens from the Yellow River are typical in most respects, except that the columellar margin of the aperture tends to be thicker (Figs. 98-101).

Operculum (Figs. 194-195). Hyaline, dark amber colored. Broadly elliptical; parietal margin straight or weakly convex. Nucleus located near the lower

TABLE 9. *Elimia buffyae* new species. Measurements of the holotype (UF 268735, n=15), and fifteen paratypes (UF 270485) from the Choctawhatchee River, 0.1 mi. E of Geneva, Geneva Co, Alabama, and ten specimens (UF 281536, n=10) from Limestone Creek, N of Darlington, Walton Co., Florida. SL = standard length, 4Wh = length of last four whorls, LWh = length of last whorls, SW = standard width, AH = aperture height, AW = aperture width, Wh = whorls remaining, <Sp = angle of spire, StD = standard deviation.

	SL	4Wh	LWh	SW	AH	AW	Wh	<Sp	SW/4Wh	AH/4Wh	AH/LWh	AW/AH	AH/SW
Holotype	20.7	20.7	13.7	8.6	9.0	4.9	4.5	28	0.42	0.43	0.66	0.54	1.05
Paratypes													
Min.	18.1	18.9	13.1	8.0	8.8	4.6	3.0	23	0.43	0.44	0.59	0.52	0.96
Max.	22.2	22.2	15.3	10.4	10.2	6.6	4.5	32	0.48	0.48	0.69	0.66	1.10
Avg.	20.21	20.23	14.41	9.11	9.48	5.59	3.69	28.3	0.45	0.46	0.66	0.59	1.04
StD	1.16	1.06	0.61	0.59	0.46	0.45	0.54	2.79	0.02	0.01	0.02	0.04	0.07
UF 281536													
Min.	18.3	18.2	12.5	8.2	8.4	4.6	4.0	24	0.45	0.42	0.64	0.55	0.90
Max.	20.6	20.6	14.3	9.9	9.6	5.8	4.5	35	0.49	0.50	0.70	0.63	1.05
Avg.	19.69	19.36	13.46	9.06	9.04	5.17	4.21	30.7	0.47	0.47	0.67	0.57	1.00
StD	0.70	0.82	0.60	0.49	0.44	0.33	0.20	3.44	0.02	0.02	0.02	0.02	0.04

left 1/3 of the columellar margin. Outer surface rugose with coarse incremental striations. Inner surface smooth. Muscle attachment scar elliptical in shape, about 0.75 times length of operculum and about 0.5 its width; a strong ridge runs along its basal and columellar margin; a small granular patch is present over the nucleus

Type locality. Choctawhatchee River, 1.0 mi. E of Geneva, Geneva County, Alabama. Holotype: UF 268735, collected 8 October, 1997, by Fred G. Thompson. Paratypes: UF 270485 (130), UMMZ 300040 (10), ANSP 410587 (10), USNM (10); same data as the holotype. Topotypes: UF 231919 (155), UF 231921 (105), collected 21 April, 1970.

Distribution (Fig. 210). Known from the Choctawhatchee River system and the Yellow River system in Alabama and Florida. This species enters the headwaters of the Chipola River in Cowart's Creek, Houston County, Alabama.

Specimens examined. ALABAMA. **Barbour Co.**: West Fork Choctawhatchee River Blue Springs State Park (UF 25462, UF 74160, UF 75305); Blue Springs, Blue Springs State Park (UF 231912, UF 282443); McCoy's Mill Creek, 5 mi. E of Clio (UF 74154, UF 75300); Campbell's Creek, Clio (UF 75230); Campbell's Creek, near Clio (UF 74214): Limestone Branch of Pea River, 4 mi W of Elamville (UF 74200, UF 74140); creek, 7.5 mi. E, 4.1 mi. S of Texasville (UF 25461). **Coffee Co.**: Pea River, Flemings Mill (UF 76323, UF 75218); Pea River, at Ala. Hwy167 (UF 231157); Pea River, 2.5 mi. E of Perry Store (UF 231196, UF 231209); Pea River, 0.4 mi. SW of Elba on AL Hwy189 (UF 241077, UF 241078); Whitewater Creek, at Lowry Mill, 22 mi S of Troy (UF 222568); Whitewater River, 2.6 mi. NNW of Victoria (UF 231189). **Covington Co.**: artesian spring along Five Runs Creek, ca. 2 mi S of Co. Rd 24 (UF 208003); Watkins Mill Creek (UF 74045, UF 75268); Watkins Mills Creek, Florala, Rte. A, Yellow River drainage (UF 71055); Yellow River, near Opp (UF 75260); Yellow River, 4.4 mi. ESE of Wing (UF 231942). **Dale Co.**: Choctawhatchee River, near Newton (UF 75258); Choctawhatchee River, 0.8 mi. NW of Newton (UF 231917, UF 231914); Choctawhatchee River, near Pinckard (UF 75275); Choctawhatchee River at Mckinley's Shoals, near Pinckard (UF 74180, UF 75283); Choctawhatchee River, below Dam (UF 131416); Choctawhatchee River, 3 mi. N of Midland City (UF 231916); Choctawhatchee River, 2.8 mi. SE of Daleville (UF 231956); Choctawhatchee River, Waterford (UF 296473); Choctawhatchee River, ca. 0,5 mi. NE of Waterford (UF 269466); Choctawhatchee River ca. 0.5 mi. NE of Waterford (UF 296470); East Fork of Choctawhatchee River, 9 mi. N of Pinckard (UF 74158, UF 75238); East Fork of Choctawhatchee River, 10 mi. E of Ozark (UF 74179, UF 75243); East Fork of Choctawhatchee River, at Bevert's Bridge (UF 74176, UF 75220); East Fork Choctawhatchee River, 1.4 mi. S of Brown's Crossroads (UF296480); West Fork Choctawhatchee River at Al Hwy 105, 4 mi E of Skipperville (UF 222567); West Fork Choctawhatchee River, 3.1 mi. NNE of Skipperville (UF 231915); West Fork of Choctawhatchee River, 2.8 mi. SE of Daleville (UF 231955); West Fork of Choctawhatchee River, T6N, R25E, Sec. 23 (UF 207950); West Fork of Choctawhatchee River, 7 mi. E of Ozark (UF 75285); West Fork Choctawhatchee River, at AL Hwy 27, 0.5 mi. SE of Brown's Crossroads; Little Choctawhatchee River, near Pinckard (UF 74141, UF 74204); Pea Creek, Rte 231, 11 mi. NW of Ozark (UF 46988); Pea River, 12.2mi N of Ozark (UF 296478); Pea River., US Hwy 231 (UF 231913); Pea River, Fleming's Mill, near Ariton (UF 75234); Calloway Spring, near Newton (UF 75226); Spring Grove (UF 75264); Claybank Creek, 7 mi. E of Enterprise (UF 75225); Creek near Daleville (UF 74197). **Geneva Co.**: Choctawhatchee River, 0.3 mi. E of Geneva (UF 231919, UF 231921); Choctawhatchee River, 0.5 mi. E of Geneva (UF 251669); Choctawhatchee River, ca. 2 mi. NE of Geneva (UF 1962, UF 258437); Choctawhatchee River, 4 mi. NE of Geneva (UF 29615, UF231960); Choctawhatchee River, 4 mi. S of Bellwood (UF 231961, UF 231920): Choctawhatchee River, 7 mi NW of Hartford (UF 75241, UF 75293); Choctawhatchee River, near

Mouth of Gilley's Mill Creek (UF 75296); Choctawhatchee River, near High Bluff (UF 75244); Corner Creek, at AL Hwy 54, 8.7 mi. WSW of Samson (UF 224297); Double Bridges Creek (UF 74193); Double Bridges Creek, near Geneva (UF 76905); Double Bridges Creek, N of Geneva (UF 74195, UF 74143, UF 74150); Double Bridges Creek, 1.0 mi. NW of Geneva (UF 74211); Double Bridge Creek, 0.5 mi. NE of Geneva (UF 231922); Flat Creek, 8 mi SW of Samson, near Mouth of Pea River (UF 74198); Pea River, 3 mi. ENE of Lowery (UF 231962); Pea River, 4.0 mi. W of Samson (UF 231911, UF 231918); Pea River, 2.8 RM upstream of confluence with Choctawhatchee River (UF 270826); Pea River, about 0.5 mi. SW of Geneva (UF 1992); Pea River, at Steam Ferry, 8 mi. W of Geneva (UF 75273); Pea River, near Pera (UF 74170). **Henry Co**.: Choctawhatchee River, 9.1 mi. SW of Abbeville (UF 231924). **Houston Co**.: tributary of Cowart's Creek at Co. Rd 55, 5.2 mi. NE of Cottonwood (UF 282276); Little Choctawhatchee Creek near Pinckard (UF 75310); Little Choctawhatchee Creek, near Dale Co. (UF 74145, UF UF 74155, UF 75229). **Pike Co.**: Pea River, 6.4 mi. E of Brundidge (UF231949).

FLORIDA. Holmes-Washington Cos.: Beckton Springs, 2 mi. NW of Vernon (UF 291590); Holmes Creek, Clemmons Spring, along left side of creek (UF 276631); Cypress Springs, 2.5 mi. NE of Vernon (UF 66002); High Tower Springs, 3 mi. SW of Vernon (UF 66023); Holmes Creek, small spring on SE side of river, 30°36.5' N, 85°44.2' W (UF 275193); Holmes Creek, 30°36.6' N, 85°48.6' W (UF 275174); Holmes Creek, below Big Pine Landing, 30°39.0' N, 85°41.5' W (UF 277485); Holmes Creek, 30°36.4' N, 85°47.7' W (UF 275169); Holmes Cr., 6.5 mi. NE of Vernon (UF 65990);; Holmes Creek, 4 mi. NE of Vernon (UF 65998); Holmes Creek, Vernon (UF 65986). **Jackson Co.**: Marshall Creek at FL Hwy 2, 8.4 mi. W of Malone **Okaloosa Co.**: Yellow River, Milligan (UF 1994); Yellow River, 0.3 mi. E of Oak Grove (UF 29616); Yellow River, ca. 5 mi. S of AL Hwy 4 (UF 208000); Murder Creek, tributary to Yellow River at FL Hwy 2, 4.5 mi. W of FL Hwy 85 (UF 241132, 241133). **Walton Co.**: Limestone Creek, Bridge, 7.3 km ENE of Gaskin, 5.0 km N of Darlington, 9.5 km NNW of Leonia (UF 155939); Limestone Creek, N of Darlington (UF 281535); Limestone Creek, N part Walton County (UF 4338, UF 4351, UF 4352, UF 231205, UF 282280); Sandy Creek (UF 4337). **Washington Co.**: 1.2 mi. W of Ebro on Washington Co. line, FL Hwy 20 (UF 224264), Choctawhatchee River; Choctawhatchee River, 1.6 mi. W of Ebro (UF 231932).

Conservation status. The species is widely distributed within the Choctawhatchee River system and the Yellow River system. It inhabits many streams and it usually occurs in dense populations. No conservation measures are needed.

Habitat. This species inhabits the substrata in clear streams with a moderate current where it is found on rock, gravel and sand bottoms. We have not found it on submerged wood or tree rootlets. For the most part, the rivers and streams throughout its range lack rapids and shoals, and rooted herbaceous vegetation is absent. In the lower part of the Choctawhatchee River system, *Elimia buffyae* is found with *E. curvicostata* and *E. dickinsoni*, as well as other prosobranchs. It is the only species of *Elimia* that is known from the Yellow River system.

Remarks. *Elimia buffyae* is a large-river species throughout most of its range. In Alabama it is found in the Choctawhatchee and Pea Rivers and their larger tributaries. Populations from smaller tributaries, both in Alabama and in Florida, may differ morphologically to the extent that they are questionably assigned to this species. Some of these populations are mentioned above under Variation. Throughout most of its range, *Elimia buffyae* is readily distinguished by its large, nearly smooth shell and its color pattern. However, in some tributaries of the Choctawhatchee River in Florida individuals are more slender in shape, and may be confused with *E. curvicostata* with which it occurs in the lower Choctawhatchee River system. The two species differ in the sculpture of the juvenile shell as well as adult sculpture. The juvenile shell of *E. buffyae* has a single smooth peripheral carina that lies just above the suture and it is not nodose, whereas *E. curvicostata* has a single carina located in the middle of the whorl, and the carina is nodose where it intersects ribs.

Typical *Elimia buffyae* (Figs. 102-105) and *E. curvicostata* occur together in Limestone Creek, Walton County, Florida, without any indication of interbreeding. In Holmes Creek, Florida, *Elimia buffyae* coexists with *E. curvicostata*, where the two species are more similar. However, the periostracum of *E. buffyae* is light yellow in color, the shell is almost cylindrical in adults, lacks costate sculpture below the upper spire, the ribs when present have poorly defined plicae which are not synchronized, and the outer lip is noticeably indented in lateral profile (Figs. 106-109). The periostracum of *E. curvicostata* is darker in color, the shell is more broadly conical, retains synchronized ribs onto the last whorl or the penultimate whorl, and the outer lip is more nearly straight in lateral profile (Figs. 110-113).

Etymology. In *An Identification Manual for the Freshwater Snails of Florida*, Thompson (2000a, p. 23) proposed for this species the vernacular name "Choctawhatchee Elimia." The illustration was inadvertently switched with that of *E. annae*. We propose that henceforth *E. buffyae* be known as the Iris Elimia, alluding to its bright shiny appearance, and also the fact that it is more widely distributed than just the Choctawhatchee River. We name this species *Elimia buffyae* for an Australian shepherd named Buffy (1985-2001), which accompanied the first author on field trips to the Choctawhatchee River system.

Elimia from the Escambia River system

The following two species had been referred to *Elimia curvicostata* in previous literature (Clench & Turner, 1956, pp. 136-138; Thompson, 1984, p. 126; Chambers, 1990). Their phylogenetic relationships approach *E. olivula* (Conrad 1834) and other species in the Alabama River system more than they do to *E. curvicostata*. The two species occur in the Escambia River system in southern Alabama. One has a double peripheral carina on the juvenile shell, similar to that described above for *Elimia buffyae*. The advancing peristome is deposited in the sulcus between the two carina so that a single peripheral carina is left behind just above the suture, producing weakly scalariform early whorls. The adult shells are smooth, or nearly so, with poorly defined, low, wavy plicae on the earlier whorls. The second species has a single peripheral carina on the juvenile shell with poorly defined, low, close ribs. The two species are not closely related, nor are they particularly close to *E. olivula*, but their affinities are closer to *E. olivula* than to other *Elimia* from the east.

The operculum of *Elimia olivula* is figured for comparison (Figs. 200-201). The operculum is neomelanian in structure, *i.e.*, it has a very eccentric nucleus located near the basal margin. The parietal-columellar margin is very long and nearly straight. The outer surface bears coarse incremental striations and folds. The muscle attachment scar is elongate-elliptical with a small oblong granular field. The scar is about 0.8 times the length of the operculum and is about 0.5 its width. The operculum is similar to that of *Elimia modesta* (Lea 1945), *E. godwini* Thompson 2000, *E. carinocostata leidyana* (Lea 1862), *E. carinocostata scabrella* (Lea 1862) and *E. lecontiana decorata* (Anthony 1860), all from the Alabama-Coosa river system (Thompson, 2000b). *Elimia buffyae*, described above from the Choctawhatchee River system, has an operculum that is similar to this group.

The *Elimia annae* species-group

The following species is isolated within the genus *Elimia*. It is confined to Patsiliga Creek and headwaters of adjacent steams tributary of the Conecuh River in south-central Alabama. The species-group is characterized by having an attenuate juvenile shell that bears a strong peripheral carina and a weaker subperipheral carina. The juvenile shell lacks plicae or ribs.

Elimia annae new species

Vernacular name: Rainbow Elimia

Goniobasis curvicostata (Reeve 1861), in part, Clench & Turner, 1956, *Bulletin of the Florida State Museum,* 1, pp. 136-138.

Elimia curvicostata (Reeve 1861), in part, Thompson, 1984, *Freshwater snails of Florida*, pp. 26-27.

Elimia sp., Thompson, 2000a, *Walkerana,* 10(23), p. 24, fig. 53.

Diagnosis. This is a large, elegant species with a slender straight-sided spire. The glossy shell usually bears up to five rust-colored bands on a light green background. The juvenile shell is elongate with a peripheral carina and a weaker subperipheral carina, both of which become obsolete or lost on adults. Low wavy weak plicae are present on the upper spire of adults.

Shell (Figs. 79, 80, 86-91). The shell is large, up to 27 mm long in standard length. It is slender with a straight-sided spire, which diverges at an angle of 21-29° at maturity. The periostracum is glossy and light green, with up to five rust-colored bands present on the last whorl. The interior of aperture has a slight whitish glaze that does not obscure the external banding. Adult shells are decollate, with 3.9-5.6 whorls remaining below the apical plug. The rates of growth of juvenile shells indicate that a total of about 10 whorls are formed. Juvenile shells are slender with flat-sided scalariform whorls that bear a low peripheral carina located just above the suture (Fig. 80). A weaker subperipheral carina is present on the last whorl and is obscured by the advancing peristome, which inserts in the sulcus between the two carinae. The carinae become obsolete or are absent on the adult shell. The suture of the adult shell is weak to moderately impressed. The upper whorls have wavy, poorly defined plicae. The lower whorls usually are smooth with sinuous incremental striation. The aperture is elongate-trapezoidal or broadly elliptical in shape, and is about 0.59-0.65 times as wide and high. The aperture is 0.41-0.45 times the length of the last four whorls, and is about 0.59-0.66 times the length of the last whorl. The columellar margin is nearly vertical, narrow and slightly concave. The basal lip is thin and moderately produced. This species shows little variation throughout its range. Measurements are given in Table 10.

Operculum (Figs. 192-193). Hyaline, dark amber in color, broadly elliptical; parietal margin straight or very slightly convex. Nucleus located very close to the base and about a third of the distance from the columellar margin. Outer surface sculptured with coarse incremental striations. Attachment scar elliptical, about 0.7 times the length of operculum; with a strong ridge along its basal and outer margin.

Type locality. Alabama, Crenshaw County, Patsaliga Creek, 1.5 miles west of Rutledge. Holotype: UF 291581; collected 9 October, 1997. Paratypes: UF 270490 (105), UF 268734 (1), UF 291580 (5), UMMZ 300039 (10), ANSP 410586 (10), USNM (10); same data as the holotype.

Distribution (Fig. 210). This species occurs in Patsaliga Creek and some headwater tributaries of the Sepulga River in the Escambia River system in southcentral Alabama.

Specimens examined. ALABAMA. **Butler Co.:** Pigeon Creek, 7.7 mi ESE of Greenville (UF 123280); Pigeon Creek, 10.7 mi E of Georgiana (UF 224280); Pigeon Creek, 14.2 mi. NE of McKenzie (UF231935); Persimmon Creek at AL Hwy 106 (UF 251452); Persimmon Creek at Co. Rd 8 (UF 251467). **Conecuh Co.:** Oldtown Creek (UF 73520); Old Town Creek at US Hwy 31 (UF 251451); Beaver Creek, near Evergreen (UF 75287); Pigeon Creek at US Hwy 84, ca. 19 mi E of Evergreen (UF 224286); Pigeon Creek, about 7.5 mi. E Herbert (UF 231212). **Covington Co.:** Pigeon Creek, at AL Hwy 55, 11 mi. SE of Mackenzie (UF 47020); Cattle Creek, near Crenshaw Co. line (UF 75219); Pigeon Creek, 6.7 mi. NW of Red Level (UF 231941); Patsiliga River, 4.4 mi. W of Red Level, 3.3 mi. W of Gantt Dam (UF 270486). **Crenshaw Co.:** Conecuh River, 0.5 mi. SE of Dozier (UF 231945); Batts Creek, near Searight (UF 71078); Horse Creek, near Luverne (UF 74208, UF 75224); Horse Creek at Co. Rd 77, 4.1 mi. SW of AL Hwy 10 (UF 251469, UF 260029); Horse Creek, dirt rd 0.7 mi. SE of Co. Rd 77 crossing (UF 260021); Horse Creek, T8N, R17E, Sec. 28 (UF 207952); Hornet Creek, near Dozier (UF 75329); Dry Creek, near Brantley (UF 75228, UF 75269); Patsaliga Creek, 1 mi W of Luverne (UF 75284); Patsaliga River at Lang's Bridge, near Searight (UF 75299); Patsaliga Creek, near Rutledge (UF 75311); Patsaliga Creek, 0.8 mi. SE of Patsburg (UF 231943); Patsaliga Creek, 7.6 mi. NNW of Dozier (UF 231944); Little ga Creek at AL Hwy 10, 3.5 mi. W of Rutledge (UF 41071, UF 241072); Little Patsiliga Creek, 1.5 mi. W of Rutledge (UF 70490, UF 268734, UF 280682, UF 280701, UF 291580, UF 291581); Patsaliga Creek at AL Hwy 106, 11.8 mi. W of Brantley (UF 241075); Patsiliga River at AL Hwy 77, 8.6 mi. SSW of Rutledge (UF 270487); small creek on W side of Patsiliga Creek, ca. 3 mi. S of Rutledge (UF 270489, UF

Table 10. *Elimia annae* new species. Measurements of the holotype (UF 291581), and ten paratypes (UF 270490) selected for variation from Patsaliga Creek, 1.5 mi. W of Rutledge, Crenshaw Co., Alabama. SL = standard length, 4Wh = length of last four whorls, LWh = length of last whorls, SW = standard width, AH = aperture height, AW = aperture width, Wh = whorls remaining, <Sp = angle of spire, StD = standard deviation.

	SL	4Wh	LWh	SW	AH	AW	Wh	<Sp	SW/4Wh	AH/4Wh	AH/LWh	AW/AH
Holotype	27.9	25.4	16.5	10.6	11.0	6.3	5.9	23	0.42	0.43	0.67	0.57
Paratypes												
Min.	23.4	22.8	15.3	10.3	9.8	6.1	3.9	21	0.41	0.40	0.62	0.59
Max.	26.8	26.3	18.2	11.3	12.9	7.1	5.6	32	0.45	0.44	0.66	0.65
Avg.	25.2	24.4	16.2	10.6	10.5	6.5	4.9	24.8	0.44	0.42	0.64	0.62
StD	0.99	1.09	0.92	0.32	0.18	0.28	0.53	2.20	0.01	0.01	0.02	0.02

280700); west branch of Patsaliga Creek, at AL Hwy 106, 23.7 mi. W of Brantley (UF 241073, UF 241074).

Conservation status. *Elimia annae* is a common species throughout its range, and no adverse ecological changes appear to be taking place. No protective measures are recommended.

Habitat. This species is found in small rivers and streams with a gentle current, and a sand or gravel substrate. At the type locality specimens were generally distribute on the bottom of the stream, but were not found on tree rootlets of on submerged dead logs.

Remarks. *Elimia annae* bears no close relationship to any other species of the genus that we have examined. It is isolated genetically as far as we have determined, although it has distant affinities to *E. flava* and other species from the Alabama River system. *Elimia flava* is discussed below.

This very large and elegant appearing snail cannot be confused with any other in the genus. Specimens received from the Alabama Museum of Natural History collected in 1910 by Herbert Smith were identified by Smith as a new species but were never described. Clench & Turner (1956) misidentified this species as *Elimia curvicostata*. They had very little material from the Escambia River system, and virtually any snail with ribs or plica from the Escambia River east to the Flint River they attributed to *E. curvicostata*. The juvenile shell morphology of *E. annae* is very different from that of *E. curvicostata*. In *E. annae* the juvenile whorls are flat with a peripheral carina located just above the suture, and they lack costate sculpture, in contrast to *E. curvicostata*, which has inflated juvenile whorls with a peripheral carina located in the middle of the whorl and the carina is nodose where it intersects distinct axial ribs. The adult shell of *E. annae* is smooth and glossy with weak plicae confined to the upper whorls of the spire, whereas *E. curvicostata* has bold synchronized ribs throughout the spire.

Etymology. In *An identification manual for the freshwater snails of Florida,* Thompson (2000a, p. 23-24) called this the "Escambia Elimia." The illustration was inadvertently switched with another species. We propose that henceforth it be known as the Rainbow Elimia because of its banded color pattern, its limited distribution and the fact that there are additional species in the Escambia River system. We name this species for a Pembroke Welsh Corgi named Anne (1984-1995), which accompanied the first author on field trips to the Escambia River system.

The *Elimia exusta* species-group

The following species is isolated within the genus *Elimia*. Its juvenile shell differs by having a weak peripheral keel that becomes a rounded fold lying above the suture on the fourth or fifth whorl, and by having weakly differentiated riblets that extend from the upper suture to the peripheral fold. This species is confined to Burnt Corn Creek, a tributary of the Escambia River system in southern Alabama.

Elimia exusta new species

Vernacular name: Fire Elimia

Goniobasis mutabilis Lea 1862, in part, Goodrich, 1942, *Occasional Papers of the Museum of Zoology, University of Michigan,* (456), p. 5.

Goniobasis curvicostata (Reeve 1861), in part, Clench & Turner, 1956, *Bulletin of the Florida State Museum,* 1, pp. 136-138.

Elimia curvicostata (Reeve 1831), in part, Thompson, 1984, *Freshwater snails of Florida,* pp. 26-27, fig. 49; Chambers, 1990, *Walkerana,* 4(12): 262-264.

Diagnosis. This is a moderately large-sized species that normally attains a length of up to 23 mm. The spire is straight-sided and slender, diverging at an angle of 20-33°. Juvenile shells have a single weak peripheral keel or fold located just above the suture, and bear weak poorly discerned riblets located between the suture and the periphery. The adult spire has irregular, poorly developed and unsynchronized plicate ribs that generally are confined to the upper whorls. The adult shell retains 5-6 whorls. Outer lip of peristome strongly receded at the periphery. Baso-columellar lip canaliculate.

Shell (Figs. 114-121, 122-124, 129-132). The shell is moderately large, normally attaining a standard length of up to 23 mm. It is moderately slender, being 0.42-0.46 times as wide as long. The spire is straight-sided and diverges at an angle of about 20-33°. The periostracum is variable in color, but generally is uniformly light green or with 1-4 reddish spiral bands on a light green background. The juvenile shell is conical, diverging at 40-50°, and consists of weakly scalariform whorls that bear a single weak peripheral keel. By the fourth or fifth whorl, the keel becomes a rounded fold and then a peripheral bulge lying just above the suture. The first whorl or so is smooth. Beginning on the third or fourth whorl, the shell is sculpted with weakly differentiated riblets that extend from the upper suture to the peripheral fold (Figs. 129-132). The adult shell has poorly differentiated plicate ribs that are irregularly spaced and are not synchronized (Figs. 114-121). These usually are confined to the upper whorls. The periostracum is smooth and shiny with fine incremental growth-striations on and between the ribs. The suture is moderately impressed. Usually 5.1-6.0 whorls remain below the apical plug. The upper whorls have a weak peripheral bulge continuing from the condition of the juvenile shell, but the last whorl or two tends to be rotund. The aperture is ovate-elliptical in shape with a conspicuously canaliculate baso-columellar lip. It is 0.55-0.66 times as wide as high. The aperture is about 0.39-0.46 times the length of last four whorls and is about 0.64-0.69 times the length of the last whorl. The columellar margin of the peristome is narrow, nearly straight and nearly vertical. The outer lip is strongly recurved at the periphery when viewed in lateral profile (Fig. 115). Measure-

TABLE 11. *Elimia exusta* new species. Shell measurements of the HOLOTYPE (UF 219265) and ten PARATYPES (UF 291266) selected to show variation at the type locality: Burnt Corn Creek, 2.2 mi. NW of Brewton, Escambia Co., Alabama. Five large specimens from a second locality are also given to show inter-population variation: Burnt Corn Creek, Co. Rd. 40, 1.3 mi. W of Appleton, Escambia Co., Alabama (UF 292176). Both samples were collected on January 19, 2002. Values in bold provide instant comparisons between the two population samples. SL = standard length, 4Wh = length of last four whorls, LWh = length of last whorls, SW = standard width, AH = aperture height, AW = aperture width, Wh = whorls remaining, <Sp = angle of spire, StD = standard deviation.

	SL	4Wh	LWh	SW	AH	AW	Wh	<Sp	SW/4Wh	AH/4Wh	AH/LWh	AW/AH
Holotype	21.1	19.0	13.6	8.7	8.7	5.1	5.6	25	0.46	0.46	0.64	0.59
Paratypes												
Min.	19.9	18.6	12.0	8.1	8.1	4.4	**4.6**	20	0.42	0.39	0.64	0.55
Max.	**22.6**	**21.7**	**14.3**	**9.9**	**9.2**	**5.4**	**5.9**	33	0.44	0.46	0.69	0.66
Avg.	21.99	20.06	12.88	8.70	8.54	5.06	5.12	**25.5**	**0.43**	**0.43**	**0.66**	**0.59**
StD	0.97	0.85	0.70	0.52	0.53	0.46	0.53	3.85	0.01	0.02	0.02	0.04
UF 292176												
Min.	**23.1**	**22.2**	**14.3**	**9.8**	**9.2**	**5.3**	**4.8**	22	0.40	0.40	0.64	0.57
Max.	30.7	28.3	17.3	11.2	11.4	6.6	**6.0**	27	0.46	0.46	0.69	0.62
Avg.	25.4	23.8	15.3	10.2	10.0	5.9	5.6	**24.6**	**0.43**	**0.42**	**0.66**	**0.59**
StD.	2.69	2.29	1.05	0.57	0.79	0.41	0.47	1.85	0.03	0.02	0.02	0.02

ments are given in Table 11.

No significant population variation is apparent other than with color. Population samples from the lower part of Burnt Corn Creek tend to be uniformly yellowish-green (Figs. 114-121), whereas specimens from up-stream localities usually are banded (Figs. 122-124). A specimen-sample from 1.3 mi. west of Appleton (UF 292176) contains a few unusually large gerontic adults that are up to 30 mm in length. They are typical in all other respect (Table 11).

Operculum (Figs. 196-197). Ovate-elliptical in shape, consisting of about 2.5 rapidly expanding whorls. Nucleus located about 1/4 of the distance from the base to the apex, and about 1/3 of the distance from the columella margin. Outer surface with a few strong growth striations. Muscle attachment scar about 0.5 the width of the operculum and about 0.8 times the length; surface over the nucleus slightly thickened and granular.

Type locality. Alabama, Escambia County, Burnt Corn Creek, 2.2 miles northwest of Brewton. Holotype: UF 292165; collected 19 January, 2002 by Fred G. Thompson. Paratypes: UF 292166 (200+), UF 292276 (5), UMMZ 300042 (10), ANSP 410859 (10), USNM (10); same data as the holotype; UF 224276 (200+), collected 5 November, 1993 by Elizabeth L. Mihalcik.

Distribution (Fig. 210). This species is known only from Burnt Corn Creek in Conecuh and Escambia counties, Alabama.

Specimens examined. **ALABAMA. Conecuh Co.:** Burnt Corn Creek (UF 73593, UF 75252); unnamed tributary SW of Burnt Corn Creek on US Hwy 84 (UF 251481); branch of Burnt Corn Creek, 2 mi. W of Belleville (UF 73581, UF 75307); Burnt Corn Creek at Co. Rd. 6, 1.6 mi. E of Lenox (UF 297733); Burnt Corn Creek, 2.3 mi. W of Belleville (UF 260023, UF 292178); Burnt Corn Creek at Janes Mill Rd., ca. 4 mi. NW of Appleton, 31°16.3' N, 87°10.1'W (UF 292177). **Escambia Co.:** Burnt Corn Creek, 0.5 mi. SW of Brewton at US Hwy 31 (UF 292169); Burnt Corn Creek, 2.2 mi. NW of Brewton on Ala. Hwy 41 (UF 224276); Burnt Corn Creek, at Co. Rd. 77, ca. 9 mi. N of Brewton (UF 292175); Burnt Corn Creek, at Co. Rd 40, 1.3 mi. W of Appleton (UF 292176).

Conservation status. No protective measures are needed for this species. It exists in healthy populations throughout its known range.

Habitat. Burnt Corn Creek is a clear low-gradient shallow stream that flows over a sand and gravel bottom alternating between pools and gentle riffles. *Elimia exusta* is found primarily in quiet shallow backwaters with little or no current on silt or fine sand substrates. Our data indicate that this species is a late summer-fall breeder. Specimen samples collected in October and November consist mostly of juveniles or sub-adults.

Remarks. Attempts to obtain a mtDNA sequence for this species have been unsuccessful. The morphology of the juvenile shell is unique compared to that of any other species we have examined. A second unusual morphological feature is the large number of functional whorls retained by adults, five to six. Many other species retain up to five live whorls, but seldom do they have more than five.

Elimia exusta is similar to *E. buffyae* in shell shape. The adult shell differs from *E. buffyae* by having more rugosely plicate ribs on the upper spire, by the more produced tongue-like canaliculate extension of the basal lip of the aperture and by its more deeply impressed suture. The operculum of *E. exusta* is less rugose, and the nucleus is located closer to the base and not as near the columellar margin.

Four species of *Elimia* occur within the Escambia River system. *Elimia exusta* is endemic to Burnt Corn Creek. *Elimia annae* is confined to Patsaliga Creek and nearby tributaries. A small, slender, smooth species of *Elimia* occurs in small spring-fed creeks draining into the Sepulga River near Brooklyn, Escambia County. It is left undescribed because it has no close relationship to *E. curvicostata*, nor has it been referred to that species in the literature. A fourth species of *Elimia* is rather widely distributed in the Escambia River and the Sepulga River, and in the lower part of tributary streams. It is also omitted from this study for the same reasons.

Etymology. The name *exusta* is derived from the Latin *exustus*, meaning burned out, and alludes to the name of the type locality, Burnt Corn Creek.

Other species of Elimia

Elimia flava (Lea 1862)

Vernacular name: Yellow Elimia

Goniobasis flava Lea 1862, *Proceedings of the Academy of Natural Sciences of Philadelphia,* 14, p. 264; Lea, 1863, *Journal of the Academy of Natural Sciences of Philadelphia,* 5, p. 303, pl. 37, fig. 139.

Elimia flava (Lea 1862), Burch & Tottenham, 1980, *Walkerana,* 1(3), p. 136, fig. 372; Burch, 1989, *North American Freshwater snails*, p. 136, fig. 372; Thompson, 2000b, *Walkerana,* 11(25), p. 19, figs. 31-34.

Elimia flava is included in this study for comparisons to other species. Typically, *Elimia flava* is a large-river species found primarily in the lower and middle sections of the Tallapoosa River, although it enters some tributaries and headwater streams for a short distance. It has a robust shell that usually reaches a length of 17-18 mm (Thompson, 2000: 18; figs. 33, 34). The growth rate indicates that about 10 whorls are formed, of which 2-3 usually remain in adult shells, an unusually small number of whorls for a species of *Elimia*. Usually the shell has two bold rust-colored spiral bands on a light yellow background. Occasional specimens lack bands. The juvenile shell is broadly conical with a pronounced spiral ridge at the periphery (Figs. 153-154). The suture usually lies on top of the ridge, which causes the spire to be perfectly conical, or the suture may insert immediately beneath the ridge causing the spire to be weakly scalariform. The juvenile shell may bear two peripheral bands, one along the suture (periphery) and one just below the sutures. An additional band may circumscribe the base near the umbilical region.

Elimia flava is the only species of *Elimia* recognized currently from the Tallapoosa River system (Goodrich, 1941; Burch, 1989). Our data indicate that there are two or more species of *Elimia* in the Tallapoosa River. We sequenced mtDNA from samples from Chewacla Creek, at the Lee County Rd. 159 bridge, Lee County, Alabama (UF 288997), FLA-1 (Fig. 211), and from the Tallapoosa River, 4.8 mi. N of Buchanan, Haralson County, Georgia (UF 291381), FLA-2 (Fig. 221). Genetic analysis indicates that the two populations are different species. We are uncertain that either of these populations is *E. flava*. Specimens from neither sample are typical morphologically of *E. flava* from the lower part of the Tallapoosa River. Neither species has been confused in the literature with *E. curvicostata*. Each is phylogentically related to different species groups within the *Elimia curvicostata* species-complex. The species FLA-1 has affinities with the *Elimia boykinana* species-group. The species FLA-2 is more closely allied to the *Elimia catenaria* species-group.

GENETIC ANALYSIS

Methods. Thirty-six population samples were collected by hand and dip net for the purpose of DNA analysis from the southeastern river drainages of the Escambia, Choctawhatchee, Apalachicola, and the Altamaha river systems. Tissues were either stored frozen in a –80°C ultrafreezer or preserved in 90% ethanol. Samples of *Elimia* from the Alabama River system and the Savannah River system were collected for comparisons. A dried specimen of *Elimia c. catenaria* collected by William Clench at the type locality in the Santee River system was also sequenced. The sister outgroup chosen for the phylogenetic analysis was *Pachychilus obeliscus*.

Isolations of total genomic DNA were performed by two different methodologies. The first method used the phenol-chloroform methodology (Hillis & Moritz 1990) that was modified by Mihalcik (1998). The second method used the Qiagen DNeasy Tissue Kit. All samples were examined for isolated DNA using an agarose gel (1 g agar with 100 ml of TBE containing 3 ul of ethidium bromide). Gels were then visually inspected for template DNA using UV light.

A 385 base-pair segment of cytochrome oxidase subunit I of the mitochondria was amplified using the polymerase chain reaction (PCR) (Mullis & Faloona, 1987). Modified versions of the primers developed by Folmer *et al.* (1994) were used for amplying the DNA sequence. Primers developed for this study were CO5 (5'-GGTCAACAAATCATAAAGATATTGG-3') and CO6 (5'-TAAACTTCAGGGTGACCAAAAAATCA-3'). Samples were run for 36 cycles in a thermocycler at 50°C for annealing, 72°C for extension, and 94°C for denaturing. Negative controls for establishing the purity of the PCR products were run with each set of samples. A mass ladder was used as a size standard. Fragments of DNA were visualized using ethidium bromide staining. The gels were run at 115 V for approximately 30 minutes.

Polymerase chain reaction results from earlier sequences were purified with an agarose gel (Mihalcik, 1998). Latter methods of purification for the PCR products include the 30,000 MW Millipore filters and the Qiagen QIAquick PCR Purification Kits.

Sequencing reactions of the PCR products were conducted at the DNA Sequencing Core of the University of Florida. An automated sequencer (Applied Biosystems models 373A and 377) was used to sequence double-stranded DNA with the same primers as used with the initial PCR. A modified Sanger Method was used for the DNA Sequencing (Sanger *et al.,* 1977).

DNA sequences were aligned with *Sequencher software*, version 3.0 (Gene Code Corporation).

Genetic distances between sequences were determined with the Kimura 2-parameter model of PAUP version 4.08a (Kimura, 1980). The number of bootstrap replicates were 100 to support the nodes at the parsimony tree. Dendrograms were generated using the branch and bound and neighbor-joining method algorithm of PAUP (Swofford, 2000). The phylogenetic tree was rooted with the sister taxa *Pachychilus obeliscus* as the outgroup.

Blast searches were done with several of the samples on GenBank to insure that the sequences we were reviewing were the cytochrome oxidase subunit I gene. Also, multiple specimens were used to determine sequence validity at the sites of Chipola River, Mile Spring, Rocky Creek, Snapping Shoals, Little Uchee Creek, and Honduras. Mitochondrial DNA sequences found within this paper were sent to GenBank.

Voucher specimens for DNA analysis. Voucher specimens for DNA sequence data are deposited in the Florida Museum of Natural History. These are listed below with their respective catalog numbers and data.

Elimia annae n.sp.: UF 280701; Alabama, Crenshaw Co., Patsiliga Creek, 1.5 mi. W of Rutledge; October 9, 1997; Fred G. Thompson. **ANN-1**.

Elimia boykiniana (Lea 1840): UF 279838; Alabama, Russell Co., Phenix City, Chattahoochee River, below dam; collected September 4, 2000, by Fred G Thompson. **BOY-1**.

Elimia buffyae n.sp.: UF 251669; Alabama, Geneva Co., Choctawhatchee River, 0.5 mi. E of Geneva; September 4, 1995; Fred G. Thompson. **BUF-1**.

Elimia buffyae n.sp. UF 281535; Florida, Walton Co., Limestone Creek, 3 mi. north of Darlington; November 26, 2000; Fred G. Thompson. **BUF-4**.

Elimia catenaria catenaria (Say 1822): UF 73909; South Carolina, Burke Co., Eutaw Springs; 1931, Clench. **CAT-1**.

Elimia curvicostata (Reeve 1861): UF 271226; Florida, ,Jackson Co., Chipola R. at CR 167, Florida Caverns State Park, June 6, 1996; Paul Mohler. **CUR-1**.

Elimia curvicostata (Reeve 1861): UF 270503; Florida, Jackson Co., Blue Springs, Merritts Mill Pond; ca. 3 mi. NE of Marriana; September 11, 1997; Fred G. Thompson. **CUR-2**.

Elimia curvicostata (Reeve 1861): UF 251655; Georgia, Crisp Co., Swift Creek, ca. 4 mi. E of Warwick; August 26, 1995; Elizabeth L. Mihalcik and Fred G. Thompson. **CUR-3**.

Elimia curvicostata (Reeve 1861): UF 281400; Florida, Jackson Co., Chipola River 1.4 mi. N of Marianna, on Fla. Hwy 167; October 22, 2000; Elizabeth L. Mihalcik. **CUR-4**.

Elimia curvicostata (Reeve 1861): UF 251634; Florida, Gadsden Co., Mosquito Creek, 1 mi. E of Chattahoochee; June 18, 1995; Elizabeth L. Mihalcik. **CUR-5**.

Elimia curvicostata (Reeve 1861): UF 290555; Florida, Holmes Co., Ponce de Leon State Park, Ponce de Leon Springs; November 4, 2001; Fred G. Thompson, FGT 6121. **CUR-6**.

Elimia darwini n.sp.: UF 41451; Georgia, Laurens Co., Rocky Creek 6.7 mi. SW, 2.9 mi. NW of Dudley at Laurens Co. Rd. 338 (32°28.5'N, 83°02.4'W); October 11, 1996; Elizabeth L. Mihalcik and Fred G. Thompson. **DAR-1**.

Elimia "flava" (Lea 1862): UF 288997; Alabama, Lee Co., Chewacla Creek, at Lee Co. Rd. 159 bridge crossing (Tallapoosa Drainage); May 3, 2001; Kristin Lenertz. **FLA-1**.

Elimia "flava" (Lea 1862): UF 291381; Georgia, Haralson Co., Tallapoosa River, 4.8 mi. N of Buchanan, at US Hwy 27; November 25, 2001; Fred G. Thompson. **FLA-2**.

Elimia glarea n. sp.: UF 281529; Alabama, Barbour Co., Blue Springs State Park, Blue Springs; November 26, 2000; Fred G. Thompson. **GLA-1**.

Elimia induta (Lea 1862): UF 251651; Georgia, Dooly Co., Limestone Creek at McRay Rd, ca. 4 mi. S, 2 mi. E of Drayton (32°02'00"N, 83°54'33"W); 26 November, 1995; Elizabeth L. Mihalcik and Fred G. Thompson. **IND-1**.

Elimia mutabilis (Lea 1862): UF 251667; Georgia, Newton Co., South River, Snapping Shoals; August 24, 1995; Elizabeth L. Mihalcik and Fred G. Thompson. **MUT-1**.

Elimia olivula (Conrad 1834): UF 267737; Alabama, Monroe Co., Alabama River ca. 1.5 mi. downstream of US Hwy 84; February 10, 1991, M. Pierson and W. Holznagel. **OLI-1**.

Elimia timida exul n.ssp.: UF 275841 (holotype); Georgia, Dooly Co., Mock Springs, 10.5 mi. WSW of Hawkinsville (32°12.3' N, 83°35.0'W); October 12, 1966; Elizabeth L. Mihalcik and Fred G. Thompson. **TIM-1**.

Elimia timida nymphaea n.ssp.: UF 263347 (holotype); Georgia, Pulaski Co., One-Mile Creek, 1.0 mi. SE of Hawkinsville (32°16.0'N, 83°27.7'W); September 11, 1996; Elizabeth L. Mihalcik and Fred G. Thompson. **TIM-2**.

Elimia ucheensis (Lea 1862): UF 290208; Alabama, Russell Co., Uchee Creek, 7 mi. N of Seale; collected October 20, 2001 by Fred G. Thompson. **UCH-2**.

Elimia viennaensis (Lea 1862): UF 251653; Georgia, Dooly Co., Limestone Creek at McRay Rd., ca. 4 mi. S, 2 mi. E of Drayton (28°37'18.7"N, 81°19'48.1"W); August 26, 1995; Fred G. Thompson. **VIE-1**.

Elimia viennaensis (Lea 1862): UF 41459; Georgia, Crisp Co, Limestone Cr., Drayton Rd., 4.7 mi. S, 1.1 mi. E of Drayton (32°01'08"N, 83°54'39"W); October 13, 1996; Elizabeth L. Mihalcik and Fred G. Thompson. **VIE-2**.

Elimia viennaensis (Lea 1862): UF 290218; Georgia, Upson Co., Potato Creek, 3.4 mi. WSW of Thomaston; collected October 25, 2001, by Fred G. Thompson. **VIE-3**.

Pachychilus obeliscus: UF 239528, Honduras, Dept. Santa Cruz de Yahoa, limestone peninsula on NW shore of Lago de Yahoa (14°55.8'N, 88°02.1'W); FGT 5516, May 30, 1994, Fred G. Thompson and J. Polisar. **POB-1**.

Results. Sequence alignment for the mitochondrial CO1 gene produced 385 base pairs. For the best consensus tree when all characters were weighted equally and applying the bootstrap 50% majority rule, refer to Fig. 211. Parsimony analysis of the data yielded 79 variable characters and 294 informative characters (CI = 0.687, RI = 0.664, TL = 1061).

Interspecific variation between the taxa described in the *Elimia curvicostata* complex range from 2-21%. Interspecific variation within the *Elimia* of the southeastern drainages range from 2-62% sequence divergence because of *E. boykinnia* from the Chattahoochee River.

Phylogeny. A detailed study of all growth stages of shell morphology and the analysis of mtDNA differentiate 12 species that previous authors at one time or another considered to be synonyms of a single species, *Elimia curvicostata*. Additional species are described for comparative purposes. The phylogenetic relationships of the species are very disparate within the genus. They do not cluster as a tightly related clade, but instead they form three very distinct clades that have only remote relationships within *Elimia*.

Mitochondrial DNA analysis indicates that the species included in the *Elimia curvicostata* species-complex consist of three major and three minor clades. The first major clade is composed of species identified as *E. buffyae* (BUF-1, BUF-4), *E. mutabilis* (MUT-1), *E. ucheensis* (UCH-1), and *E. olivula* (OLI-1). This clade is partitioned from the rest of the tree by a high bootstrap value of 93. *Elimia buffyae* is found in the upper Choctawhatchee River system, which drains into the Gulf of Mexico. *Elimia mutabilis* occupies the upper Ocmulgee River of the Altamaha River within the Atlantic coastal plain. *Elimia ucheensis* occu-

TABLE 12. Distance matrix for mtDNA CO1 sequences. This table provides the distances generated by kimura 2-parameter of PAUP that created the parsimony tree.

Kimura 2-parameter distance matrix

	ANN-1	BOY-1	BUF-1	BUF-4	CAT-1	CUR-2	CUR-3	CUR-4
ANN-1	-							
BOY-1	0.58242	-						
BUF-1	0.20875	0.57525	-					
BUF-4	0.21741	0.57048	0.01072	-				
CAT-1	0.17980	0.62875	0.13086	0.13834	-			
CUR-2	0.17649	0.56501	0.12384	0.13085	0.14179	-		
CUR-3	0.20763	0.57159	0.14231	0.14620	0.15743	0.05828	-	
CUR-4	0.18955	0.55685	0.12963	0.13648	0.14778	0.01069	0.06382	-
CUR-5	0.18596	0.57170	0.13895	0.14272	0.15743	0.02435	0.05219	0.02971
CUR-5E	0.18603	0.56045	0.13224	0.13599	0.15056	0.01890	0.04644	0.02422
CUR-6	0.18525	0.56992	0.12600	0.13303	0.14410	0.00805	0.05506	0.01334
DAR-1	0.19130	0.61190	0.12772	0.13521	0.02416	0.13206	0.14734	0.13792
FLA-1	0.21261	0.61036	0.11252	0.11960	0.10328	0.12618	0.14474	0.13192
GLA-1	0.20329	0.61520	0.13852	0.13630	0.14357	0.09123	0.08781	0.09687
IND-1	0.21758	0.59507	0.11838	0.11599	0.13996	0.09738	0.09708	0.10306
MUT-1	0.19397	0.58101	0.04111	0.04704	0.13090	0.11726	0.14914	0.12300
FLA-2	0.21950	0.63704	0.16418	0.17224	0.18333	0.16124	0.17403	0.16707
OLI-1	0.20096	0.57278	0.03253	0.03830	0.13733	0.11380	0.14900	0.11955
POB-1	*1.31239	*1.31239	*1.31239	*1.31239	*1.31239	*1.31239	*1.31239	*1.31239
TIM-1	0.20665	0.61349	0.11226	0.10983	0.13698	0.08200	0.07598	0.08760
TIM-2	0.20238	0.61123	0.11538	0.11297	0.14018	0.07873	0.07272	0.08435
UCH-2	0.19362	0.58463	0.04104	0.04695	0.12417	0.11716	0.14900	0.12284
VIE-1	0.19138	0.65365	0.13430	0.14170	0.04653	0.14250	0.16827	0.14844
VIE-2	0.19200	0.65620	0.13474	0.14217	0.04671	0.14297	0.16881	0.14892
VIE-3	0.16998	0.63357	0.12125	0.12852	0.02963	0.13245	0.15774	0.13836

Kimura 2-parameter distance matrix (continued)

	CUR-5	CUR-5E	CUR-6	DAR-1	FLA-1	GLA-1	IND-1	MUT-1
CUR-5	-							
CUR-5E	0.00529	-						
CUR-6	0.02145	0.01602	-					
DAR-1	0.14734	0.14062	0.13416	-				
FLA-1	0.14136	0.13466	0.12826	0.09711	-			
GLA-1	0.09680	0.09060	0.09372	0.14033	0.14104	-		
IND-1	0.10297	0.09668	0.09989	0.13387	0.14414	0.04110	-	
MUT-1	0.13215	0.12552	0.11937	0.12774	0.10618	0.14566	0.14497	-
FLA-2	0.17054	0.16704	0.16295	0.17985	0.16734	0.17125	0.16398	0.16456
OLI-1	0.12535	0.12535	0.11603	0.13406	0.11241	0.13206	0.13144	0.04405
POB-1	*1.31239	*1.31239	*1.31239	*1.31239	*1.31239	*1.31239	*1.31239	*1.31239
TIM-1	0.08496	0.07876	0.08444	0.12681	0.12821	0.02703	0.02995	0.11907
TIM-2	0.08157	0.07551	0.08116	0.13019	0.13123	0.02424	0.02707	0.12205
UCH-2	0.13200	0.12535	0.11923	0.11779	0.10288	0.14219	0.14491	0.01605
VIE-1	0.15146	0.15146	0.14494	0.06127	0.10303	0.15675	0.14642	0.13438
VIE-2	0.15193	0.15195	0.14540	0.06149	0.10338	0.15717	0.14678	0.13483
VIE-3	0.14802	0.14122	0.13483	0.04378	0.09055	0.14662	0.13645	0.12129

TABLE 12 (continued).

Kimura 2-parameter distance matrix (continued)

	FLA-2	OLI-1	POB-1	TIM-1	TIM-2	UCH-2	VIE-1	VIE-2
FLA-2	-							
OLI-1	0.14697	-						
POB-1	*1.31239	*1.31239	-					
TIM-1	0.16406	0.11259	*1.31239	-				
TIM-2	0.16378	0.11550	*1.31239	0.00263	-			
UCH-2	0.16407	0.04687	*1.31239	0.11901	0.12197	-		
VIE-1	0.18687	0.13425	*1.31239	0.13727	0.14021	0.12438	-	
VIE-2	0.18739	0.13467	*1.31239	0.13763	0.14060	0.12477	0.00000	-
VIE-3	0.18318	0.12765	*1.31239	0.12717	0.13022	0.11152	0.01604	0.01613

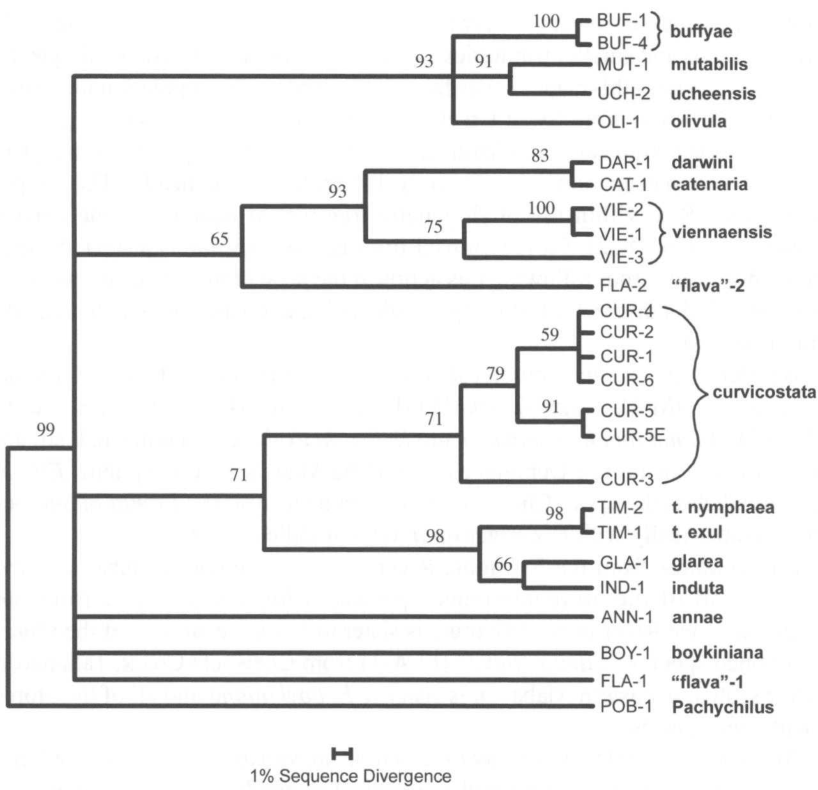

FIG. 211. Phylogram based on the maximum parsimony of a 385 base-pair sequence of mtDNA, CO1. Numbers at the nodes correspond to the bootstrap values.

pies a small creek system of the middle Chattahoochee River system, a tributary of the Apalachicola River. *Elimia olivula* is found in the Alabama River.

The second major cluster consists of the taxa identified as *Elimia darwini* (DAR-1), *E. catenaria catenaria* (CAT-1), and *Elimia viennaensis* (VIE-1). This cluster is separated from the others by a bootstrap value of 93. *Elimia viennaensis* occurs in the upper Flint River system and *E. darwinae* is found in a tributary of the Oconee River of the Altamaha River drainage system. *Elimia c. catenaria*, which is included for comparative purposes, is from the Santee River system in South Carolina. The sister species to this group, identified as *Elimia "flava"* (FLA-2), apparently is an undescribed species from the upper Tallapoosa River in west Georgia.

The third major clade, which contains the taxon identified as *Elimia curvicostata* (CUR-1 - CUR-6), is separated by a bootstrap value of 71. This "clade" occupies the lower Choctawhatchee, Econfina, Chipola, and Apalachicola river systems and smaller tributaries of the lower Flint River system. Sequence divergence within this clade ranges from < 1% to 6%. The population identified as CUR-3 (< 6%) from Swift Creek of the lower Flint River system remains unresolved taxonomically. It is hardly differentiated morphologically from typical *E. curvicostata* even though it is strongly differentiated genetically. The sample labeled CUR-3 within the phylogenetic tree would bear the name *Elimia doolyensis* (Lea 1862) if it is removed from *E. curvicostata* as a separate species. We refrain from following this action at the present time, because we have not identified a discreet set of morphological characteristics by which it can be differentiated.

A sister clade to *Elimia curvicostata* includes the taxa identified as *E. timida nymphaea* (TIM-1), *E. timida exul* (TIM-2), *E. glarea* (GLA-1), and *E. induta* (IND-1). *Elimia timida nymphaea* and *E. timida exul* are found in small stream tributaries of the middle Ocmulgee River of the Altamaha River system. *Elimia glarea* inhabits the upper Choctawhatchee drainage system. *Elimia induta* occurs sympatrically with *E. curvicostata* in the middle Flint River.

Elimia annae from the Escambia River system in southern Alabama is the sister to all of the aforementioned species. *Elimia boykiniana* from the Chattahoochee River in west Georgia is sister to *E. annae* and all of the aforementioned species. *Elimia "flava"* (FLA-1) from Chewacla Creek, Tallapoosa River system in eastern Alabama, is sister to *E. boykiniana* and all of the aforementioned species.

An over-view of the phylogeny of *Elimia* is unavailable, because of the large number of species that remain understudied. The number of valid species cannot be estimated at present, but certainly it is far greater than the number that is recognized now. Currently 135 species and subspecies are recognized in the literature, but this number is an under measure of species diversity within the genus (Thompson, 2000b; and this study). Burch (1989), following Goodrich (1920-1950) and Clench & Turner (1956), lists 111 species and subspecies from approximately 450 previously described species. Goodrich regarded about half of the remaining names as synonyms of the species he recognized. Goodrich omitted nearly 100 names from further mention, and their taxonomic status remains uncertain (*e.g., Goniobasis gabbiana* Lea 1862). Some of the names that were placed by previous authors in synonymy represent valid species (*e.g., E. induta*). Also, intense field surveys of individual streams reveal additional undescribed species (Thompson, 2000b; and this study). Thus, a comprehensive phylogeny of *Elimia* is not possible at present because of the many poorly known or unknown species that are involved.

The phylogeographic distribution pattern within the region indicate that the *Elimia* from the coastal plains of South Carolina, Georgia, Florida and Alabama are derived primarily from the fauna associated with the Alabama River system. A single species from the Chattahoochee River included in this study, *Elimia boykiniana*, has unresolved affinities within the genus.

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A project of this nature is dependant upon the assistance of other people. Without their help the project could never be completed, and more problems would be created than solved. The following persons have loaned us critical specimens from collections under their charge: Robert Hershler, National Museum of Natural History (USNM); Kenneth Boss, Museum of Comparative Zoology (MCZ); Fred Naggs, Richard Williams and Jonathan Todd, British Museum (Natural History); John B. Burch, Taehwan Lee, and Diarmaid O'Foighil, Museum of Zoology, University of Michigan. John Slapcinsky, Florida Museum of Natural History, assisted us in numerous ways in the laboratory and in the field.

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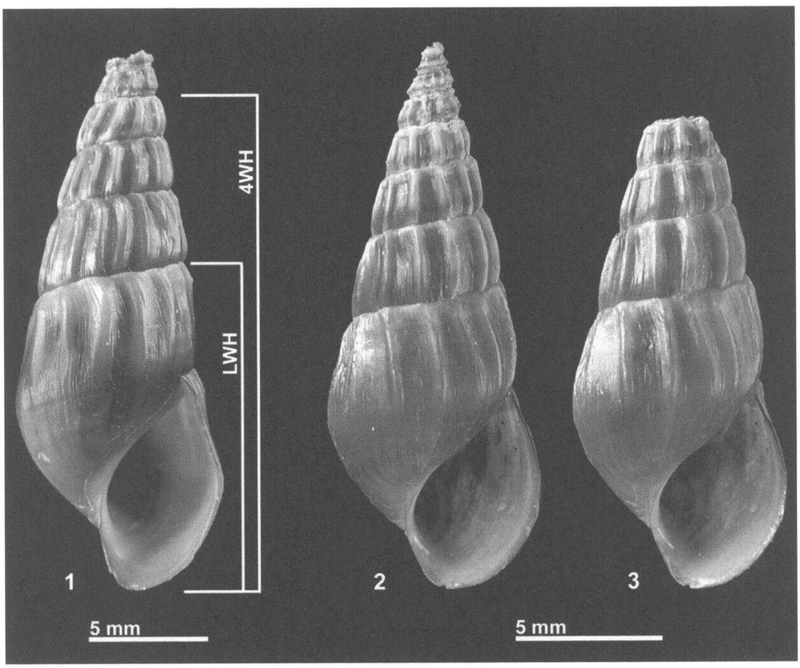
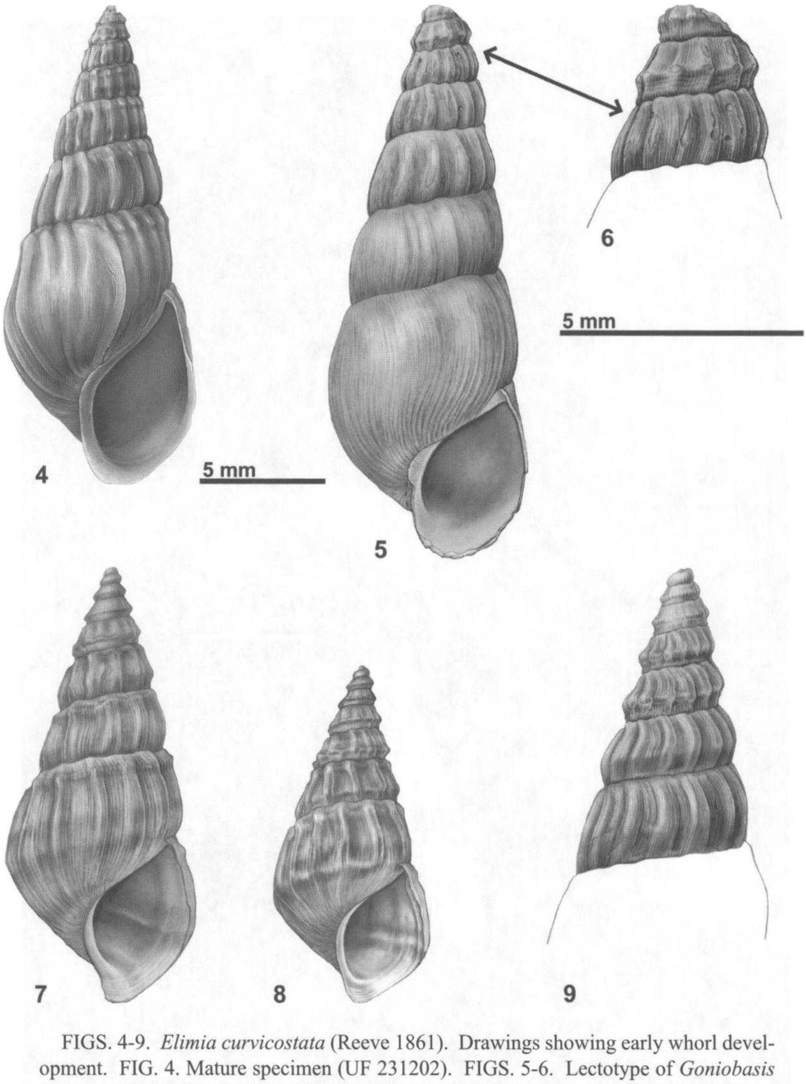
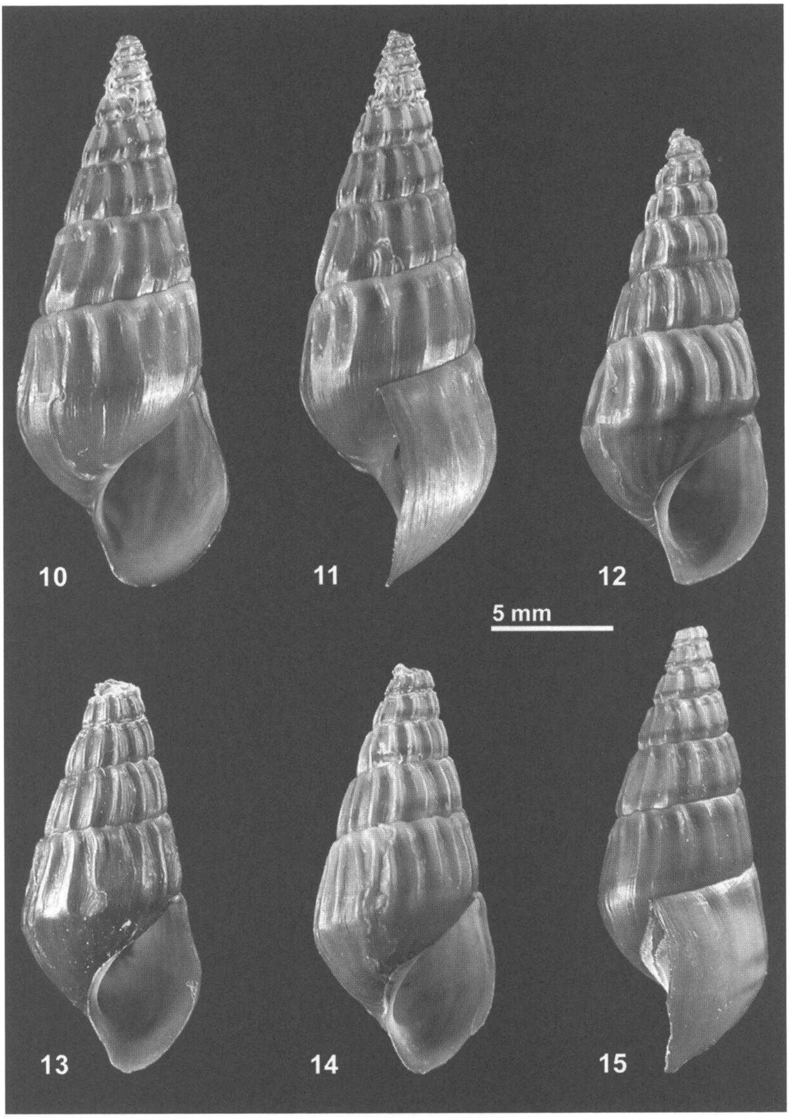


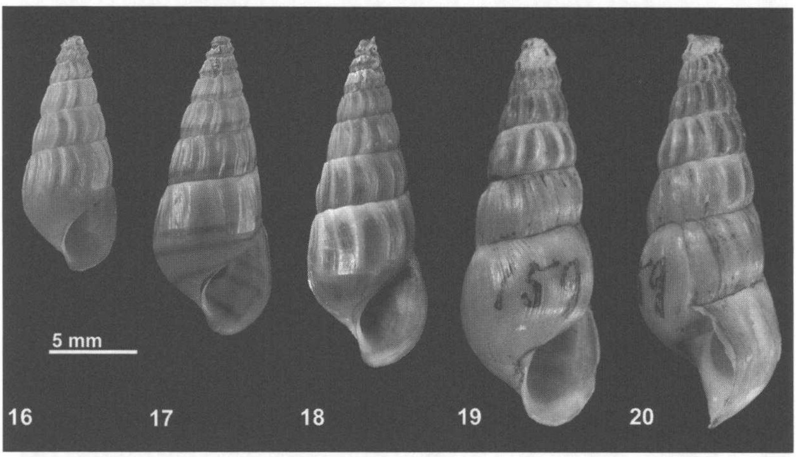
FIGS. 1-3. *Elimia curvicostata* (Reeve 1861), Florida, Jackson Co., Blue Hole Springs, 5.6 mi. north of Marianna (UF 291489). FIG. 1. Measurements for length of last four whorls (4Wh) and length of last whorl (LWh). FIGS. 2, 3. A specimen before and after the dead whorls were removed above the apical plug.



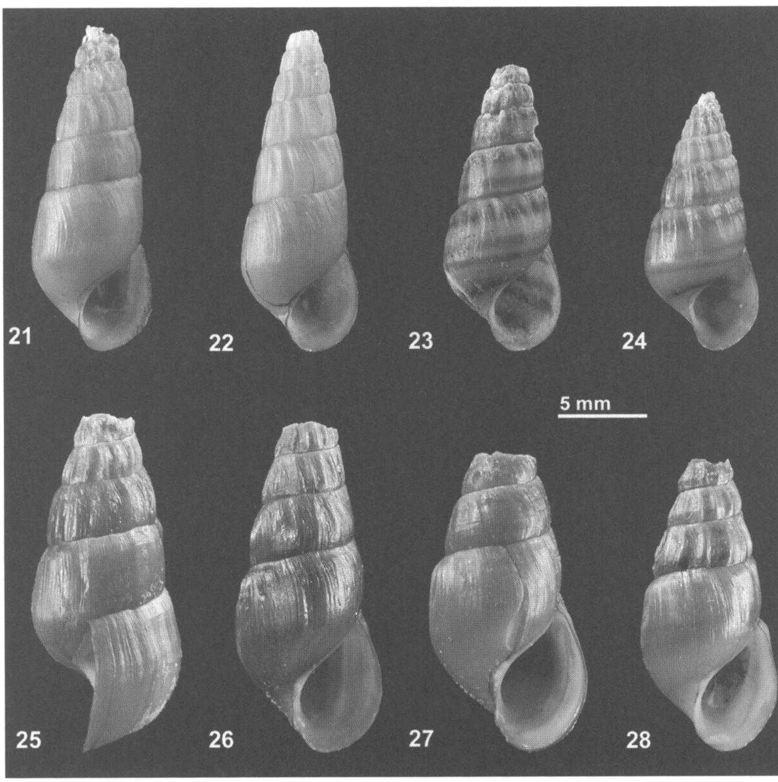
FIGS. 4-9. *Elimia curvicostata* (Reeve 1861). Drawings showing early whorl development. FIG. 4. Mature specimen (UF 231202). FIGS. 5-6. Lectotype of *Goniobasis doolyensis* Lea 1862 (USNM 119121). FIG. 7. Juvenile of *Elimia curvicostata* (Reeve 1861), Florida, Jackson Co., Chipola River, 1.4 mi. N Marianna (UF 231192). FIG. 8. Juvenile of *Elimia curvicosta* (Reeve 1861), Florida, Jackson Co., Baker Creek (UF 230664). FIG. 9. Immature Paralectotype of *Goniobasis doolyensis* Lea 1862 (USNM 873108). Left scale bar is for Figs. 4, 5; right scale bar is for Figs. 6-9.



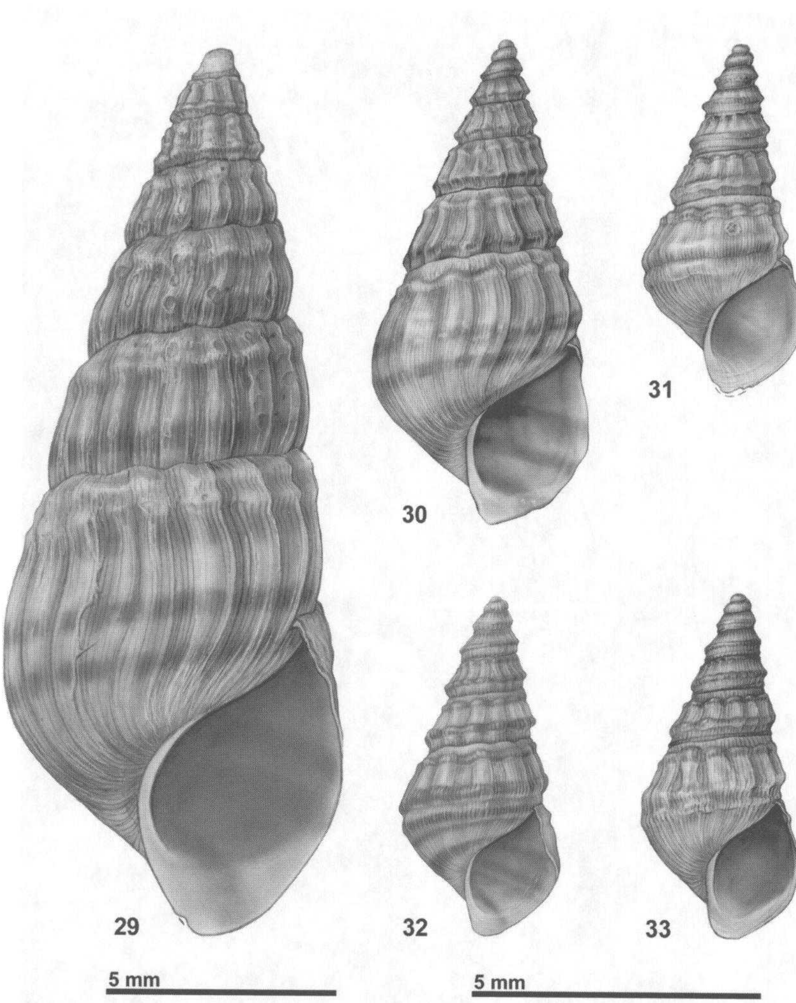
FIGS. 10-15. *Elimia curvicostata* (Reeve 1861), Florida, Jackson Co., Blue Hole Spring, 5.6 mi. N of Marianna. FIGS. 10, 11. UF 292208. FIGS. 12-15. UF 219489.



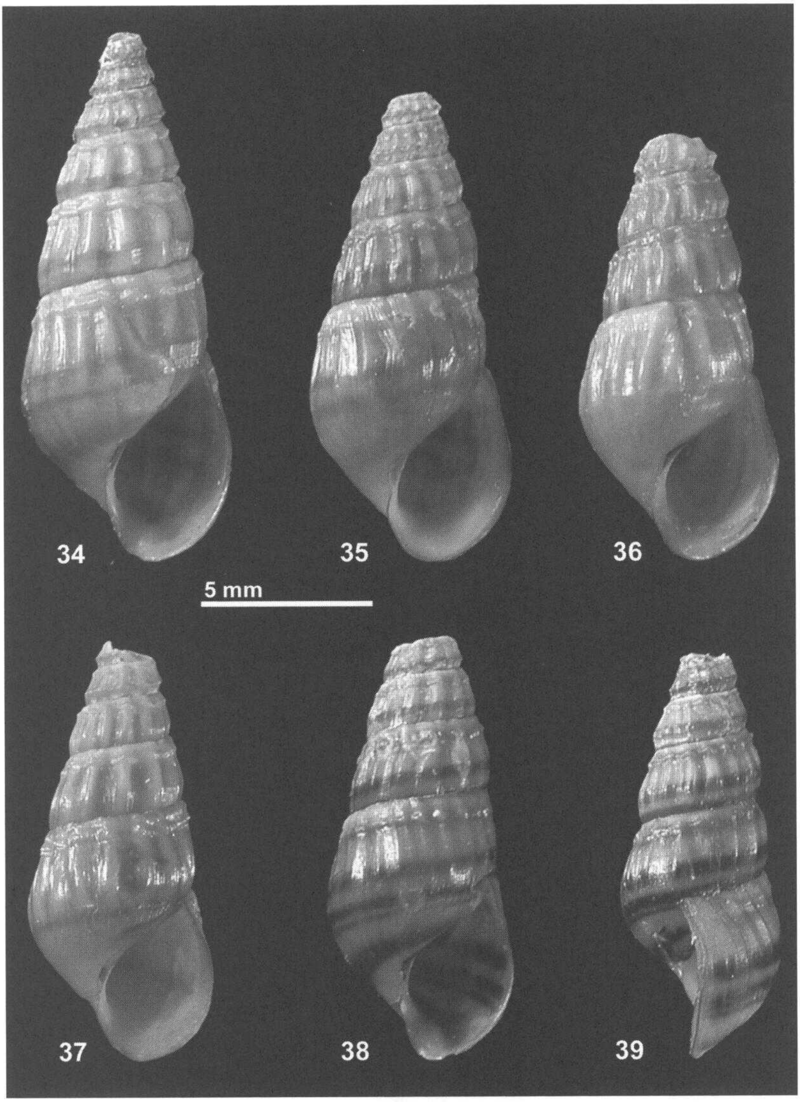
FIGS. 16-20. *Elimia curvicostata* (Reeve 1861). FIGS. 16-18. Georgia, Dooly Co., Limestone Creek at McCay Rd., 0.8 mi. NW of Drayton Rd. (UF 291482). FIGS. 19-20. Lectotype of *Goniobasis doolyensis* Lea 1862 (USNM 119121).



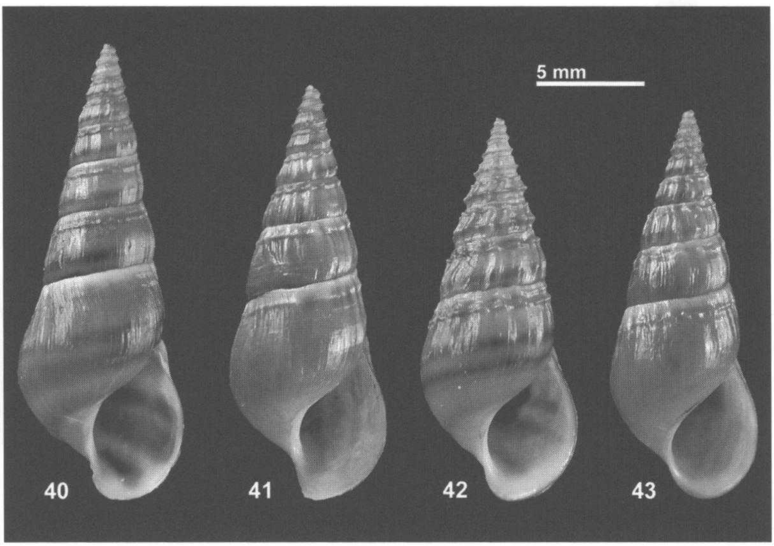
FIGS. 21-28. *Elimia curvicostata* (Reeve 1861). FIGS. 21-24. Georgia, Early Co., Sawhatchee Creek, at GA Hwy 273, 0.5 mi. W of Cedar Springs (UF 291486). FIGS. 25-28. Florida, Gadsden Co., Mosquito Creek, 1.0 mi. E of Chattahoochee (UF 291482).



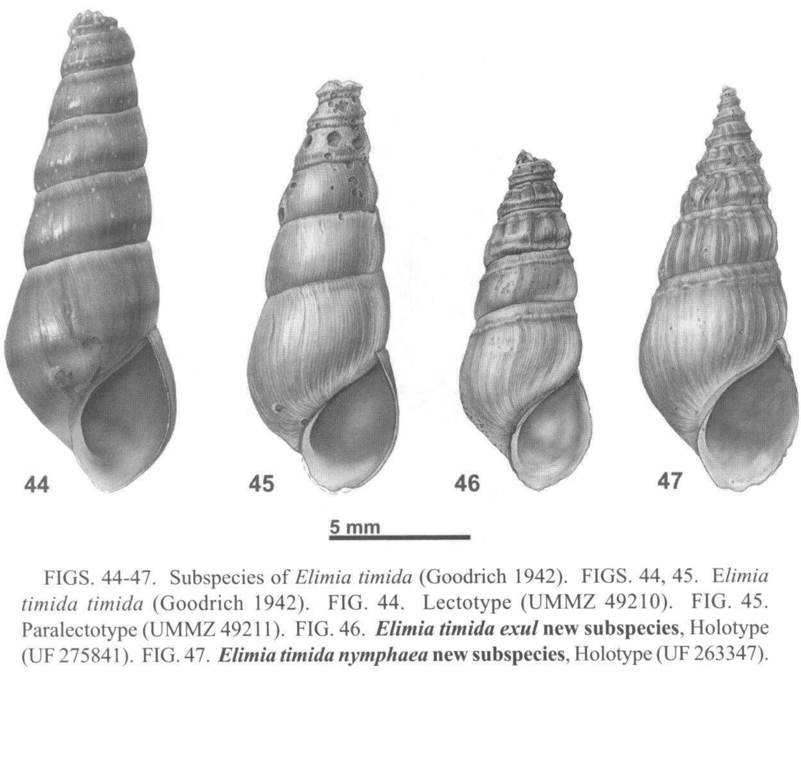
FIGS. 29-33. Species of *Elimia*. FIGS. 29, 30. *Goniobais induta* Lea 1862 (= *Elimia induta*), FIG. 29. Lectotype (USNM 119174). FIG. 30. Paralectotype (USNM 873111). FIG. 31. *Elimia induta*, Georgia, Dooly Co, Limestone Creek, at McCay Rd., ca. 4 mi. S, 2 mi. E of Drayton (UF 251651). FIG. 32. ***Elimia timida exul* new subspecies**, Paratype (UF 266283). FIG. 33. ***Elimia timida nymphaea* new subspecies,** Paratype (UF 263349).



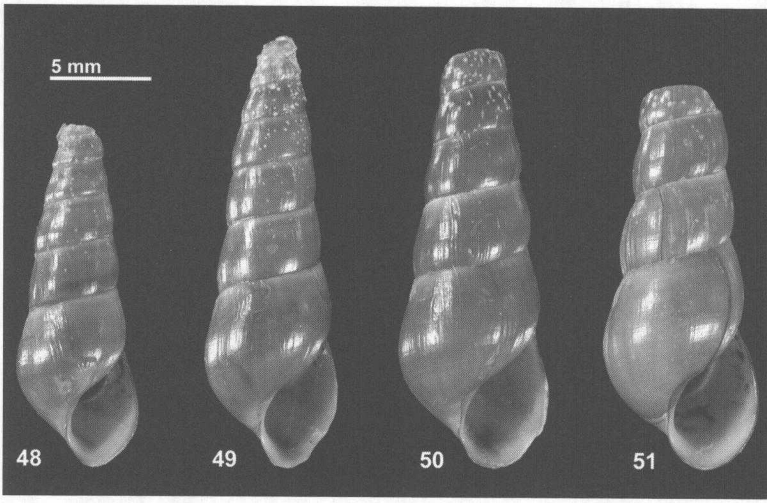
FIGS. 34-39. *Elimia induta* (Lea 1862), Georgia, Dooly Co., Limestone Creek at McCay Rd., ca. 4 mi. S, 2 mi. E of Drayton (UF 251651).



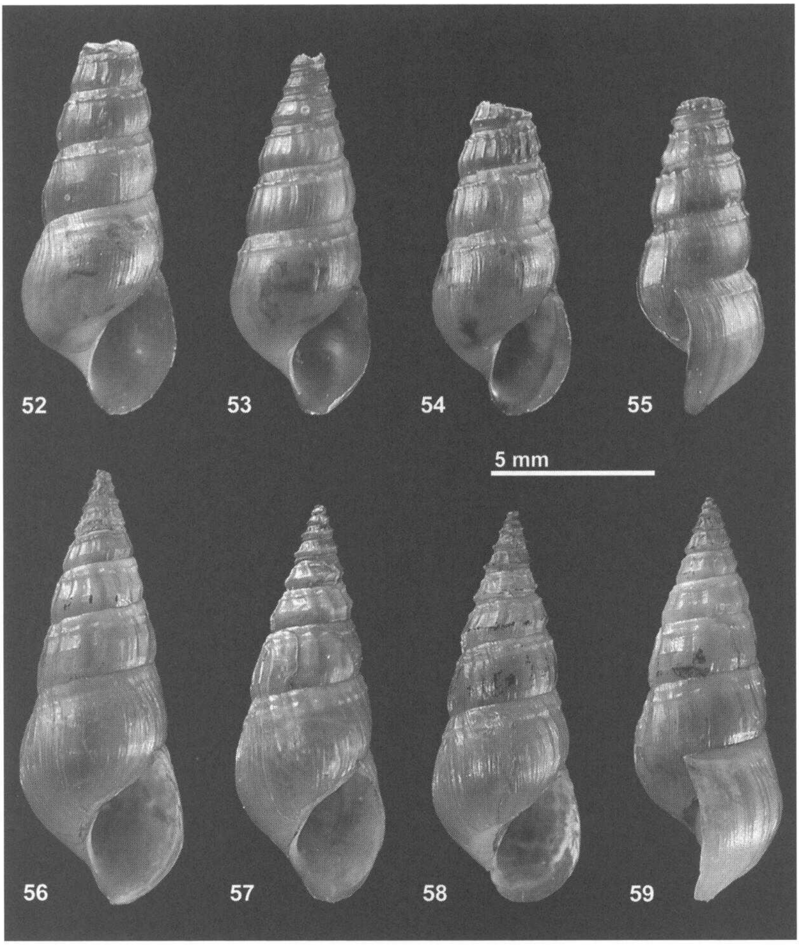
FIGS. 40-43. *Elimia induta* (Lea 1862), Georgia, Lee Co., small creek, 7 mi. NW of Albany (UF 79765).



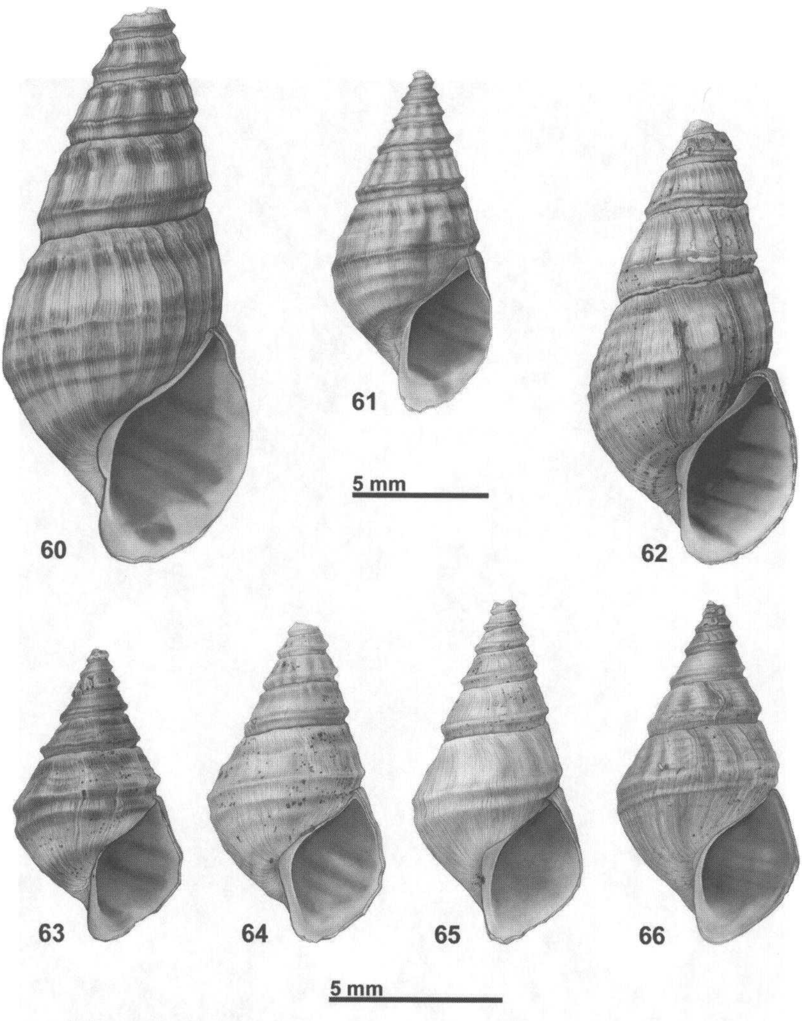
FIGS. 44-47. Subspecies of *Elimia timida* (Goodrich 1942). FIGS. 44, 45. *Elimia timida timida* (Goodrich 1942). FIG. 44. Lectotype (UMMZ 49210). FIG. 45. Paralectotype (UMMZ 49211). FIG. 46. ***Elimia timida exul* new subspecies**, Holotype (UF 275841). FIG. 47. ***Elimia timida nymphaea* new subspecies**, Holotype (UF 263347).



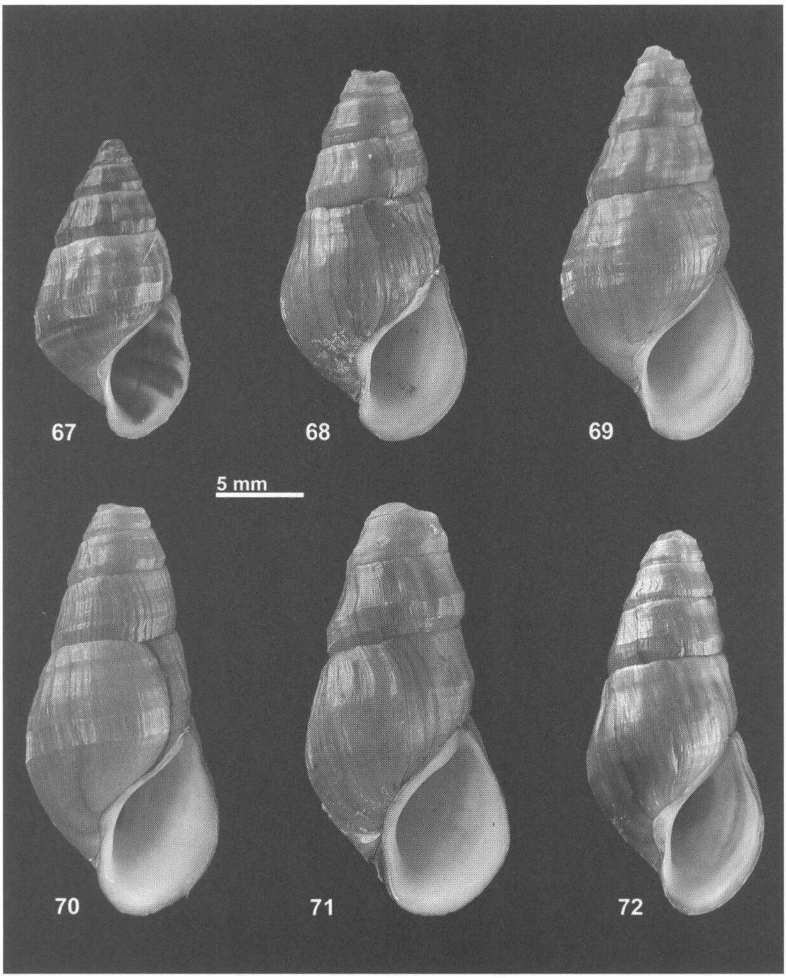
FIGS. 48-51. *Elimia timida timida* (Goodrich 1942). FIG. 48. Lectotype (UMMZ 49210). FIGS. 49-51. UMMZ (49211).



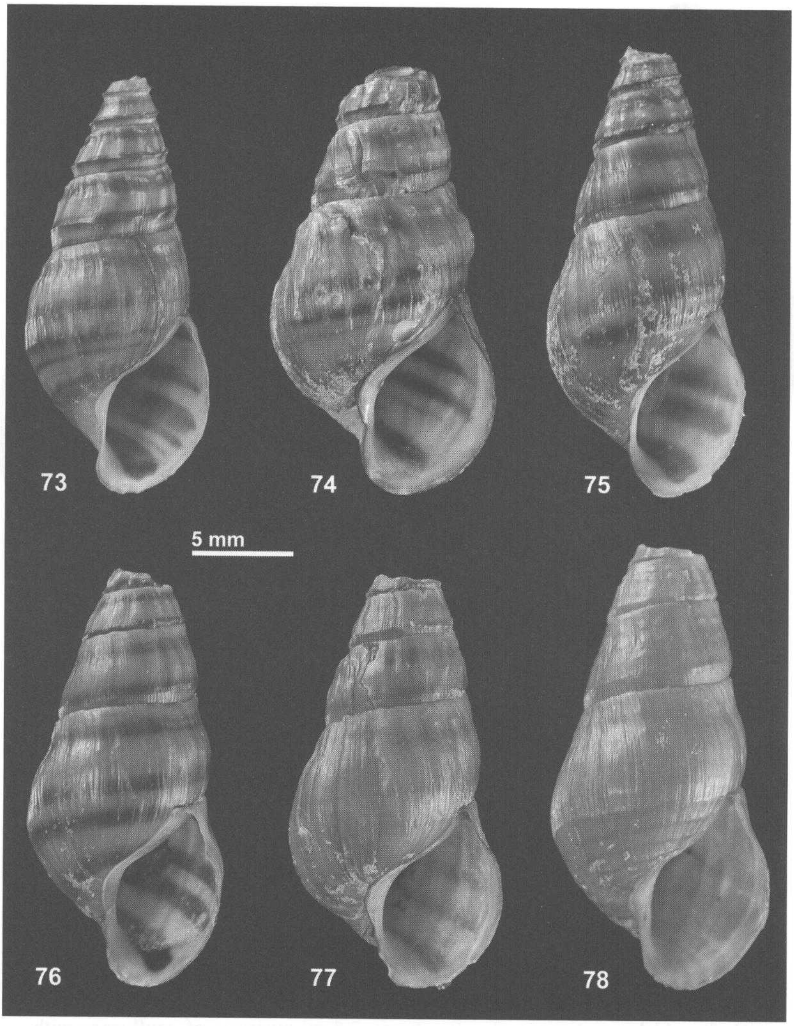
FIGS. 52-59. Subspecies of *Elimia timida* (Goodrich 1942). FIGS. 52-55. ***Elimia timida exul* new subspecies**, Paratypes (UF 275839). FIGS. 56-59. ***Elimia timida nymphaea* new subspecies**, Paratypes (UF 276084).



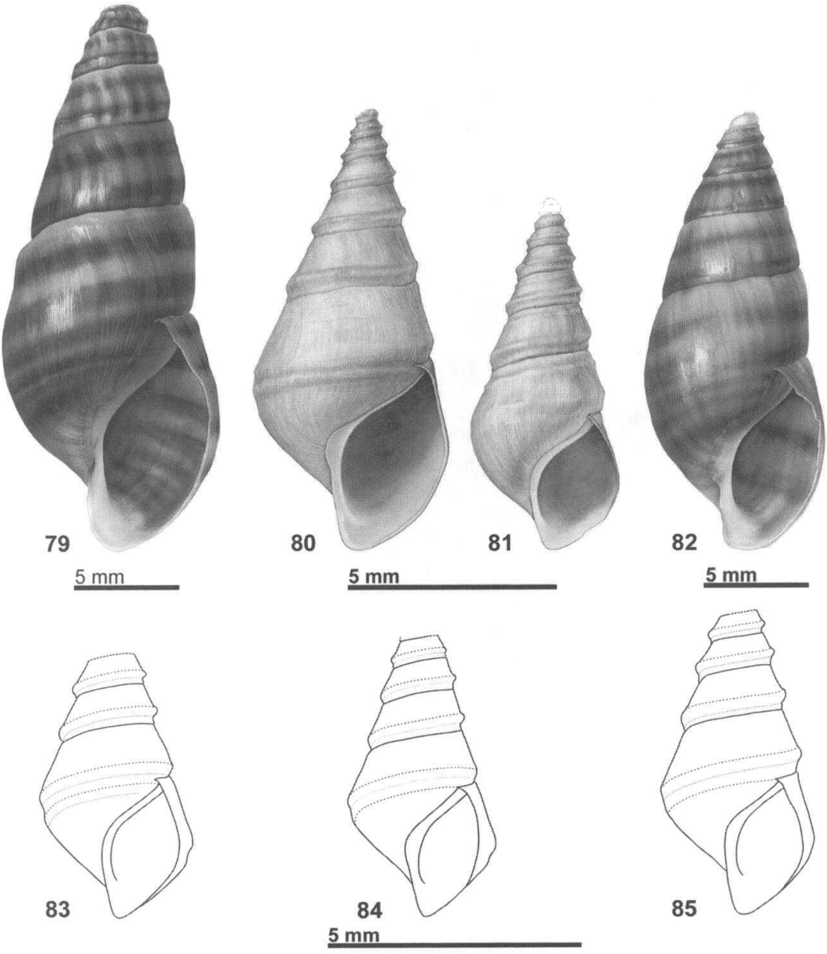
FIGS. 60-66. Species of *Elimia*. FIG. 60. ***Elimia darwini* new species**, Holotype (UF 41450). FIG. 61. ***Elimia darwini* new species**, Paratype (UF 274097). FIG. 62. *Goniobasis mutabilis* Lea 1862, Lectotype (USNM 118443) (= *Elimia mutabilis*). FIGS. 63-64. *Goniobasis mutabilis* (Lea 1862), Paralectotypes (**USNM 118443**) (= *Elimia mutabilis*). FIGS. 65-66. *Elimia mutabilis* (Lea 1862), Georgia, Newton Co, South River, Snapping Shoals (UF 251667). Upper scale bar is for Figs. 60-62; lower scale bar is for Figs. 63-66.



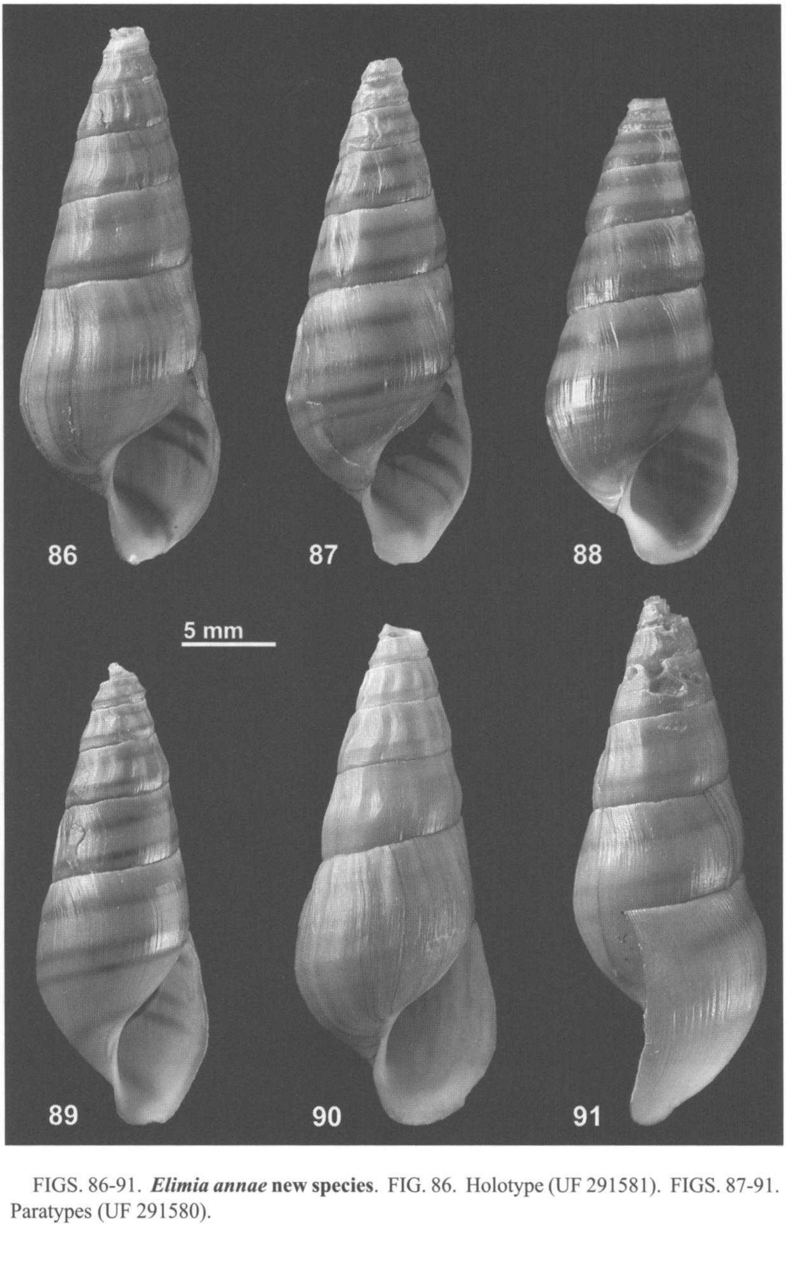
FIGS. 67-72. *Elimia mutabilis* (Lea 1862), Georgia, Butts Co., South River, Snapping Shoals (UF 251609).



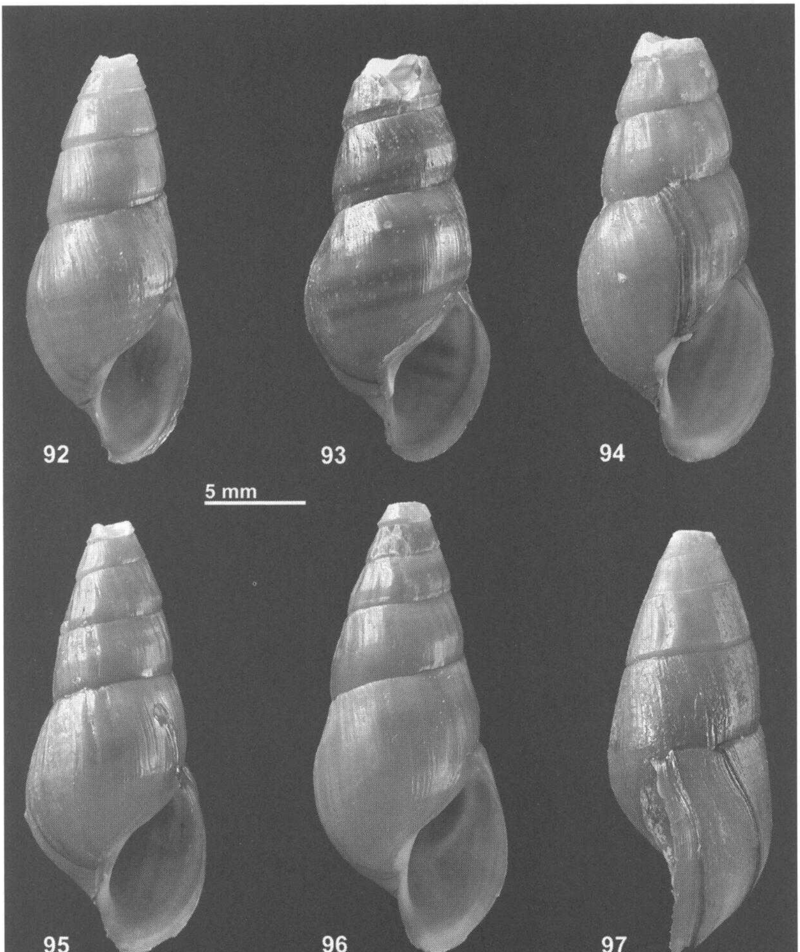
FIGS. 73-78. ***Elimia darwini* new species**. FIG. 73. Holotype (UF 41450). FIGS. 74-78. Paratypes (UF 274097).



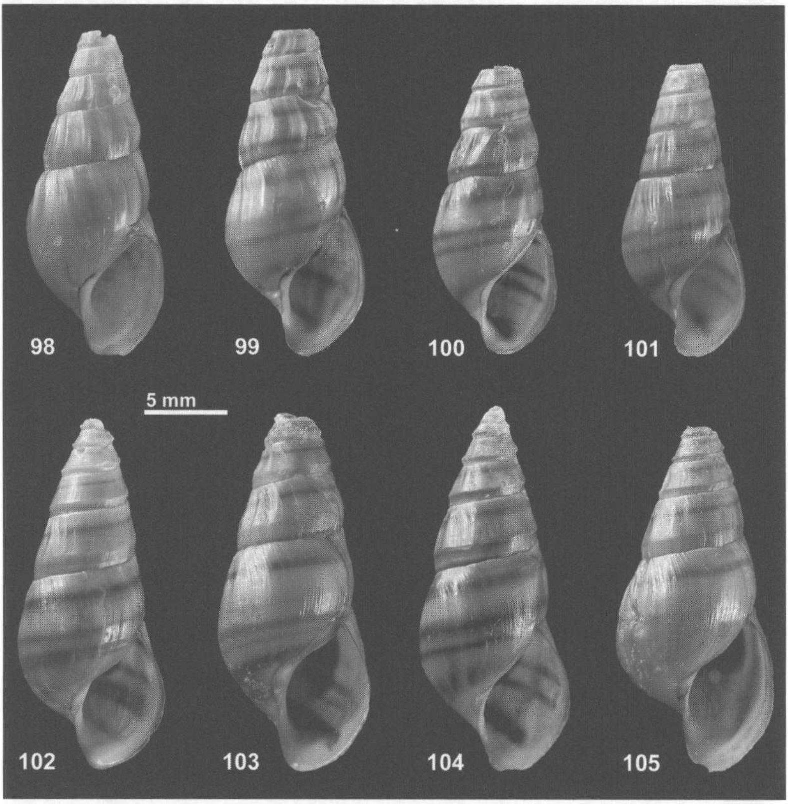
FIGS. 79-85. Species of *Elimia*. FIGS. 79-80. ***Elimia annae* new species**, Paratypes (UF 270490). FIGS. 81-85. ***Elimia buffyae* new species**. FIG. 81. Paratype (UF 270485). FIG. 82. Alabama, Geneva Co., Pea River, 2.8 mi upstream of confluence with Choctawhatchee River (UF 270826). FIGS. 83-85. Choctawhatchee River, ca. 2 mi. NE of Geneva (UF 258437).



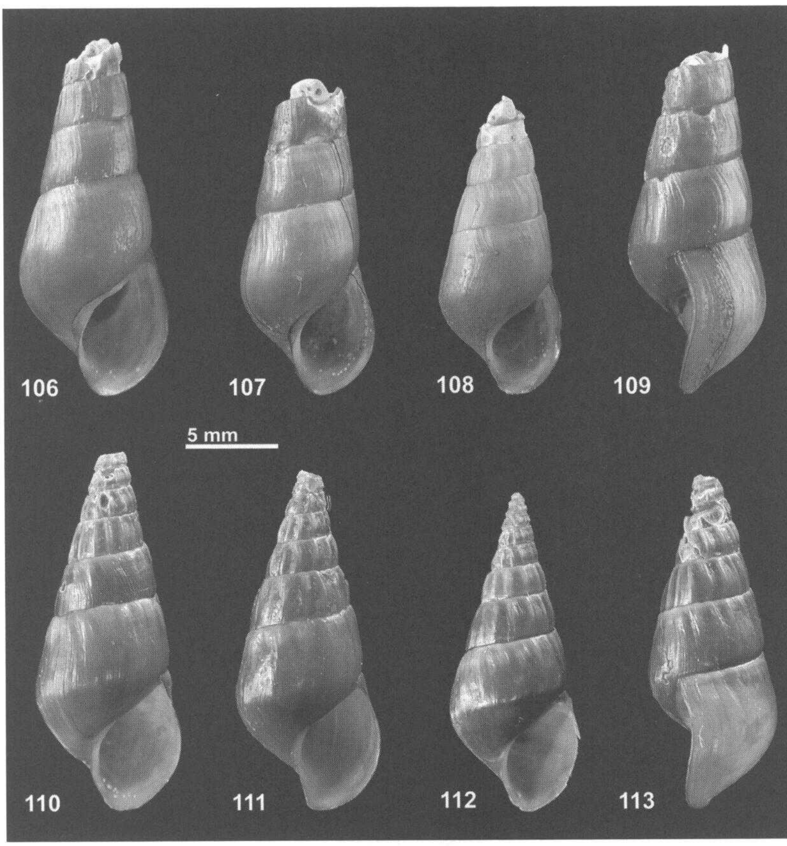
FIGS. 86-91. ***Elimia annae* new species**. FIG. 86. Holotype (UF 291581). FIGS. 87-91. Paratypes (UF 291580).



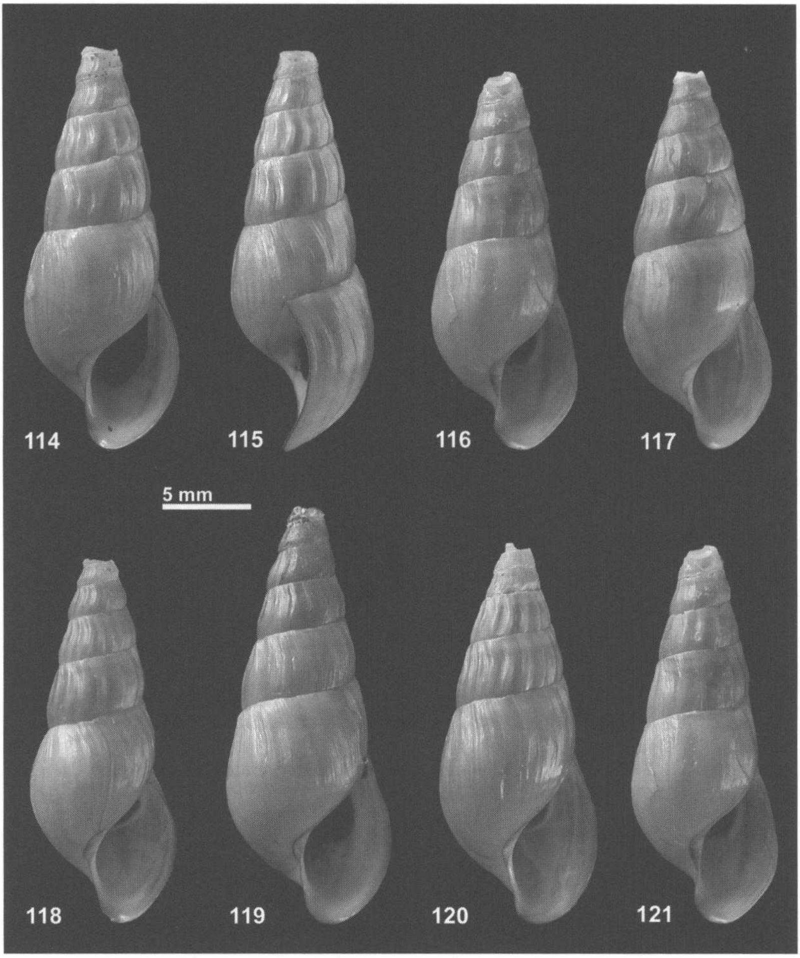
FIGS. 92-97. ***Elimia buffyae* new species**. FIG. 92. Holotype (UF 268735). FIGS. 93-97. Paratypes (UF 291575).



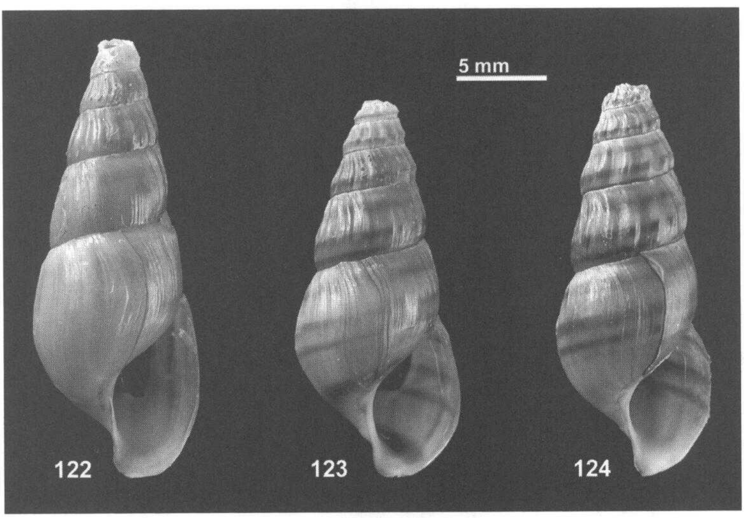
FIGS. 98-105. ***Elimia buffyae* new species**. FIGS. 98-101. Florida, Okaloosa Co., Yellow River, 4 mi. S of Ala. Hwy 4 (UF 291575). FIGS. 102-105. Florida, Walton Co., Limestone Creek, N of Darlington (UF 291577).



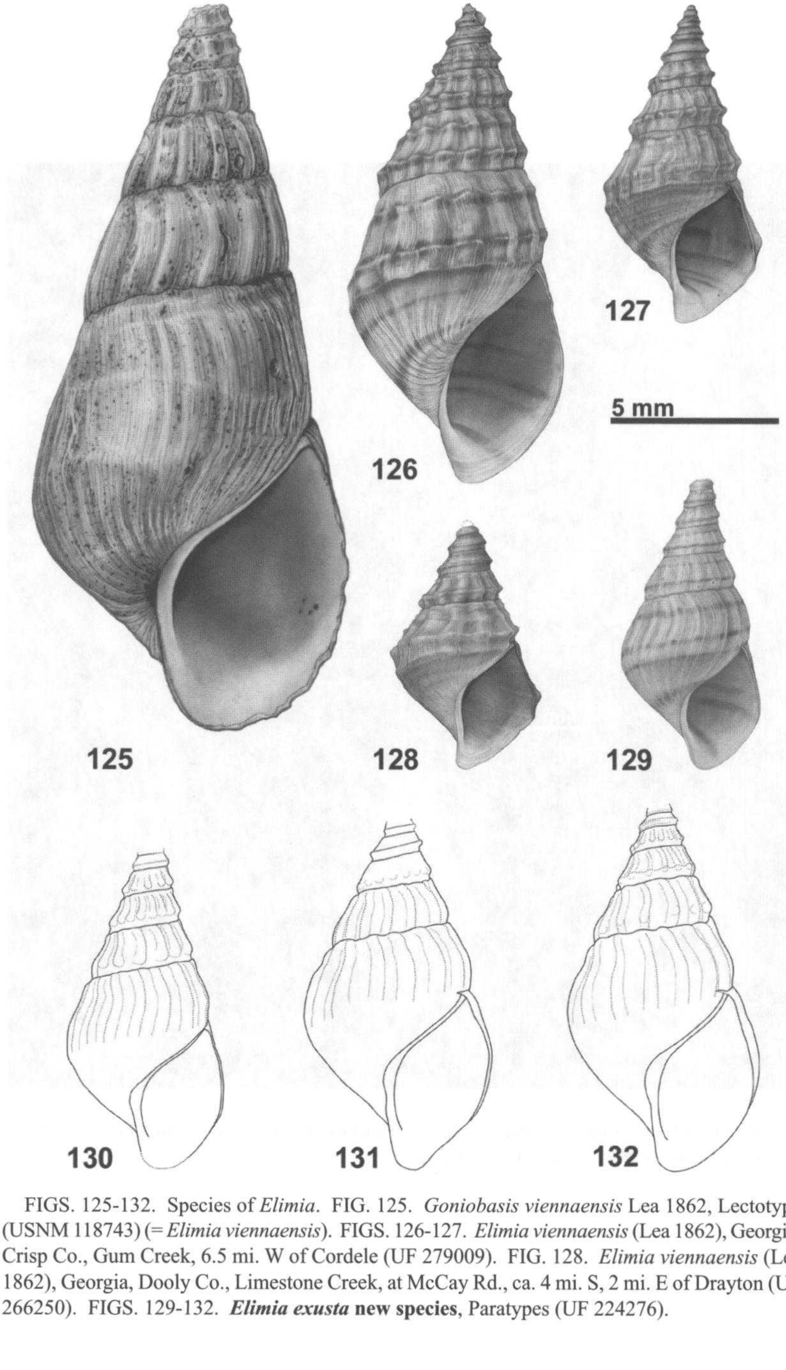
FIGS. 106-113. Species of *Elimia* from Beckton Springs, 2 mi. NE of Vernon, Washington Co., Florida. FIGS. 106-109. ***Elimia buffyae* new species** (UF 291590). FIGS. 110-113. *Elimia curvicostata* (Reeve 1861) (UF 291589).



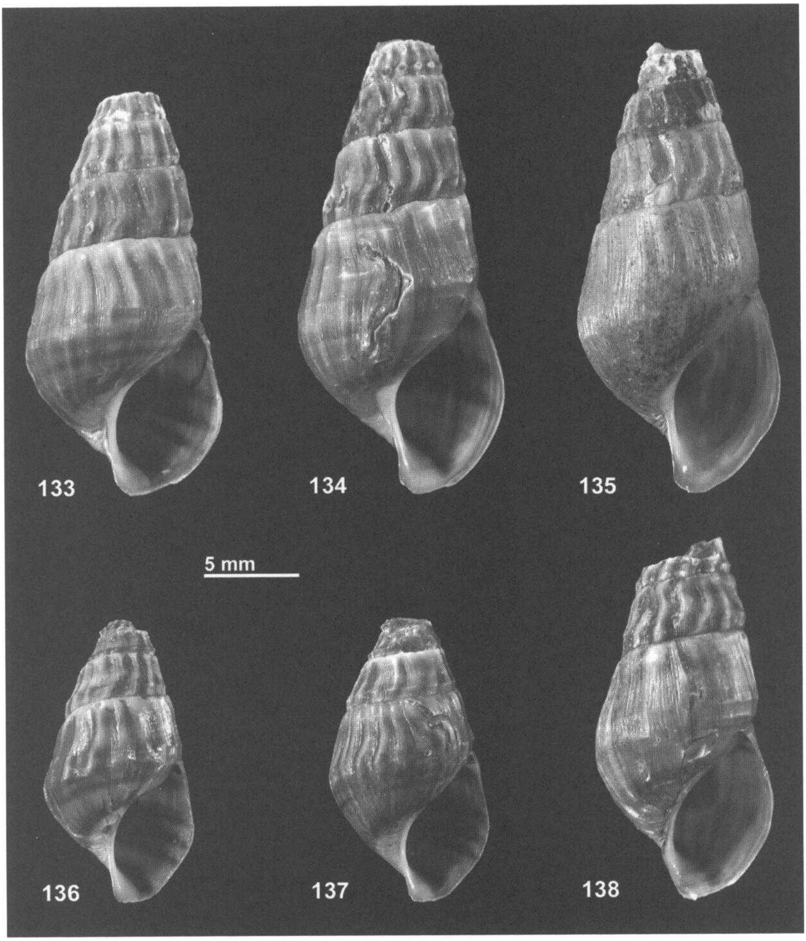
FIGS. 114-121. ***Elimia exusta* new species**. FIGS. 114-115. Holotype (UF 292165). FIGS. 116-121. Paratypes (UF 292276).



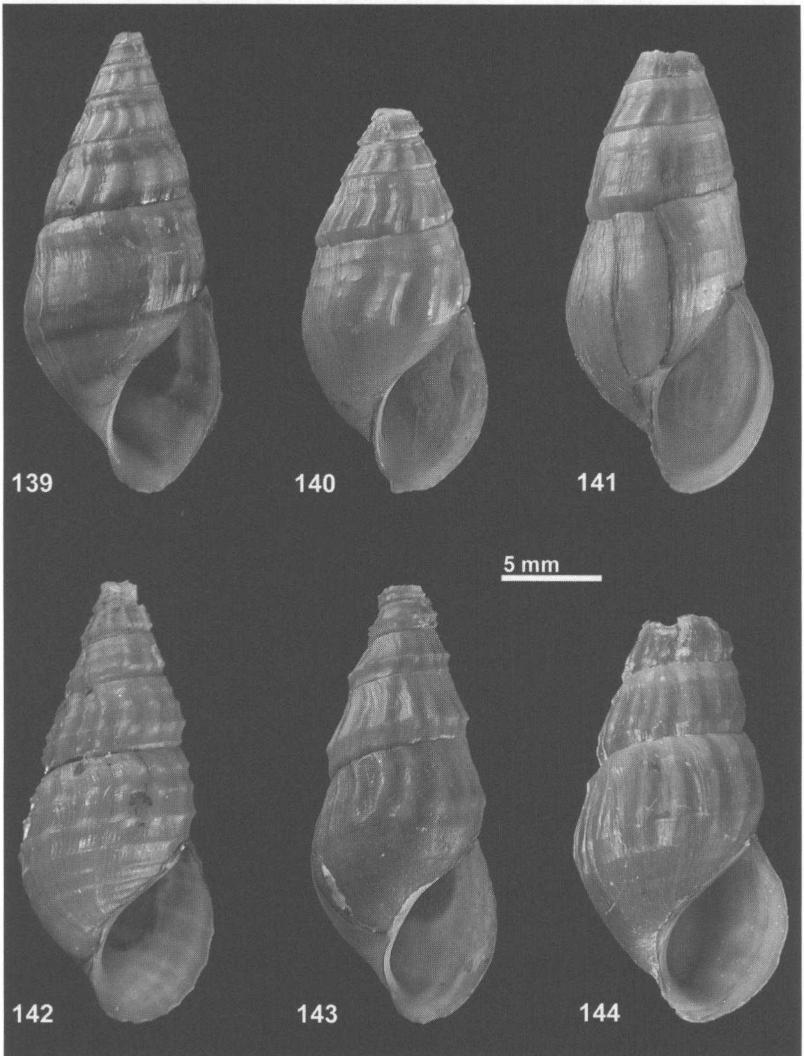
FIGS. 122-124. ***Elimia exusta* new species**, Alabama, Escambia Co., Burnt Corn Creek, at Co. Rd. 40, 1.3 mi. W of Appleton (UF 292277).



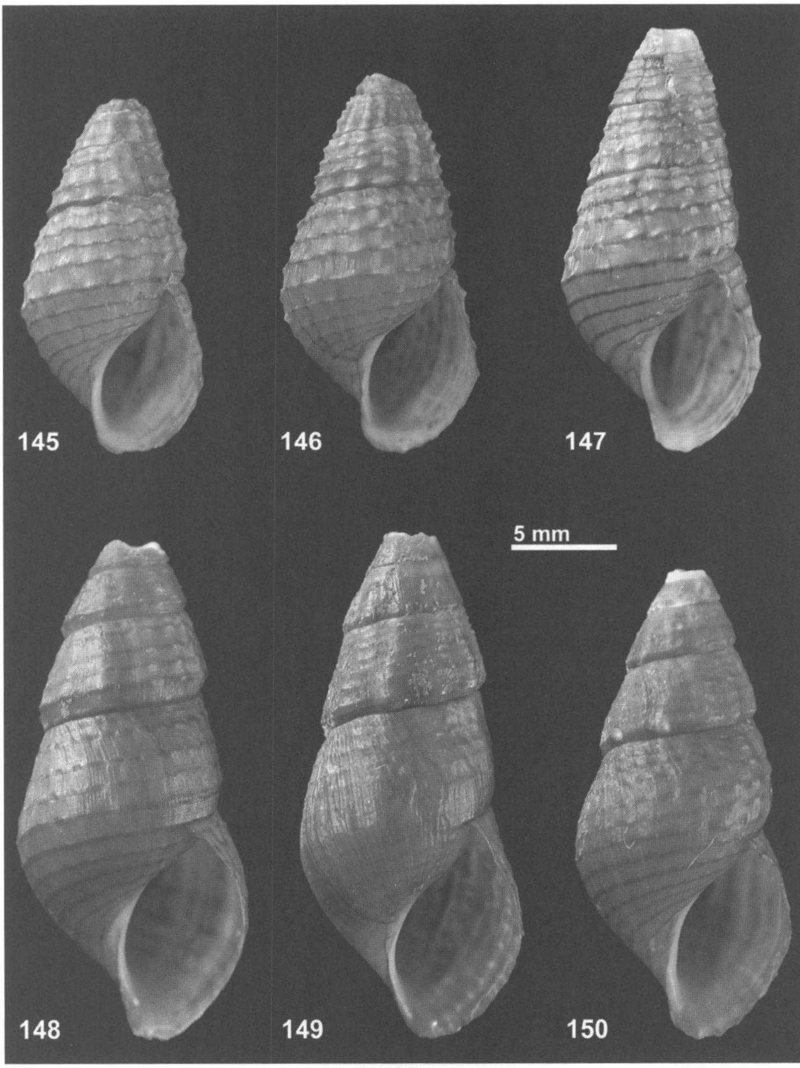
FIGS. 125-132. Species of *Elimia*. FIG. 125. *Goniobasis viennaensis* Lea 1862, Lectotype (USNM 118743) (= *Elimia viennaensis*). FIGS. 126-127. *Elimia viennaensis* (Lea 1862), Georgia, Crisp Co., Gum Creek, 6.5 mi. W of Cordele (UF 279009). FIG. 128. *Elimia viennaensis* (Lea 1862), Georgia, Dooly Co., Limestone Creek, at McCay Rd., ca. 4 mi. S, 2 mi. E of Drayton (UF 266250). FIGS. 129-132. ***Elimia exusta* new species**, Paratypes (UF 224276).



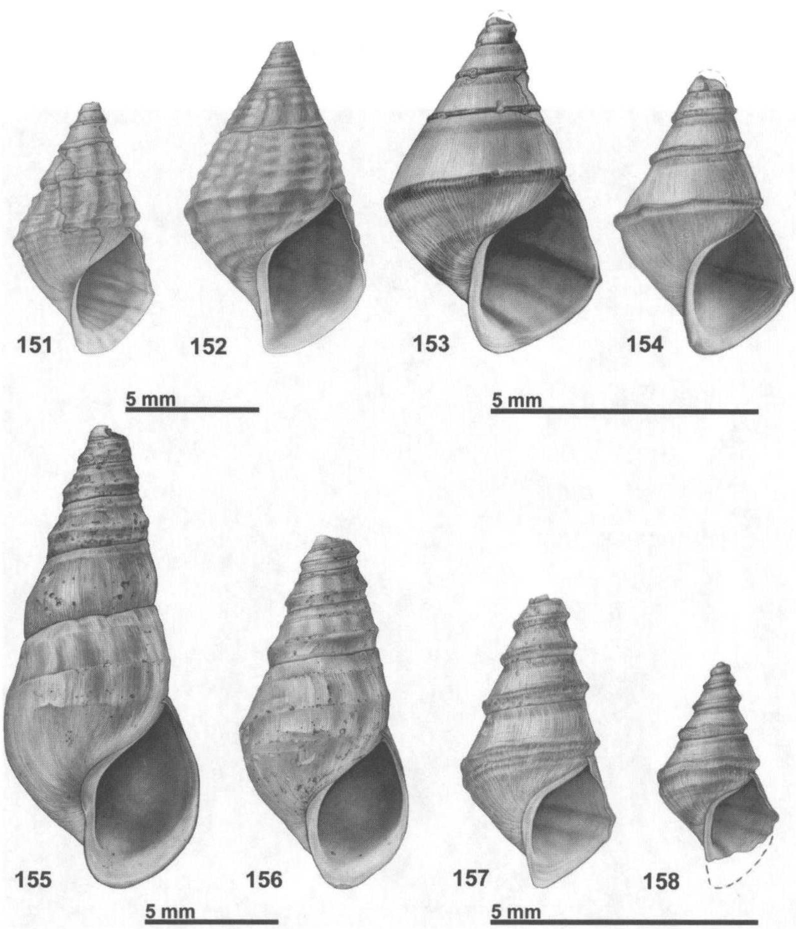
FIGS. 133-138. *Elimia viennaensis* (Lea 1862), Georgia, Dooly Co., Little Pennahatchee Creek, 3.5 mi. NW of Vienna (UF 230728).



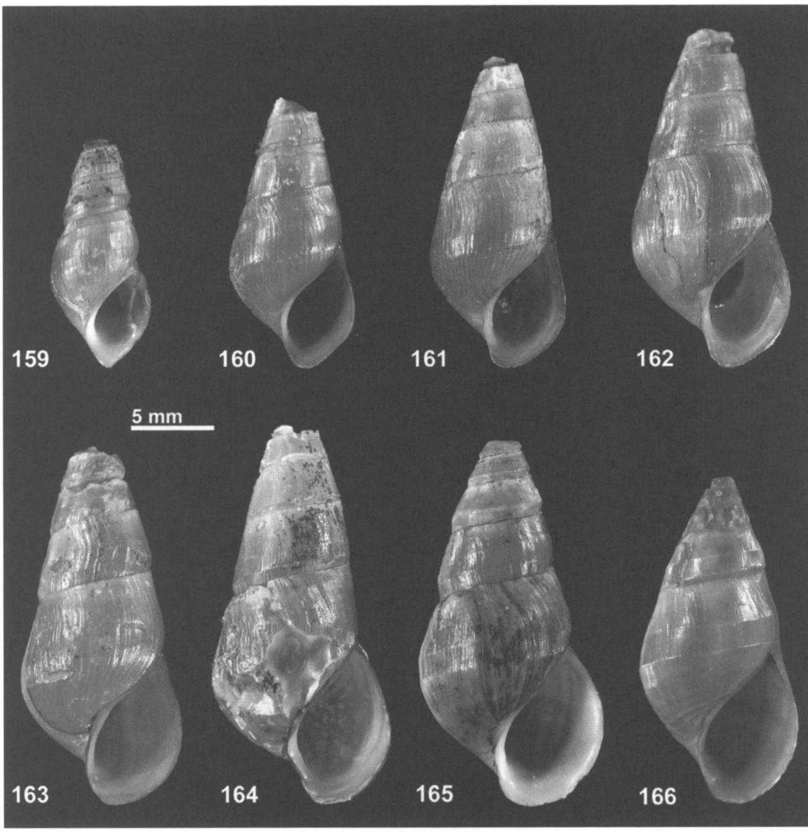
FIGS. 139-144. *Elimia viennaensis* (Lea 1862). FIGS. 139-141. Georgia, Upson Co., Potato Creek, 2.3 mi. WNW of Thomaston (UF 231869). FIGS. 142-144. Georgia, Meriweather Co., Flint River, Flat Shoals, 3.5 mi. SE of Gay (UF 289524).



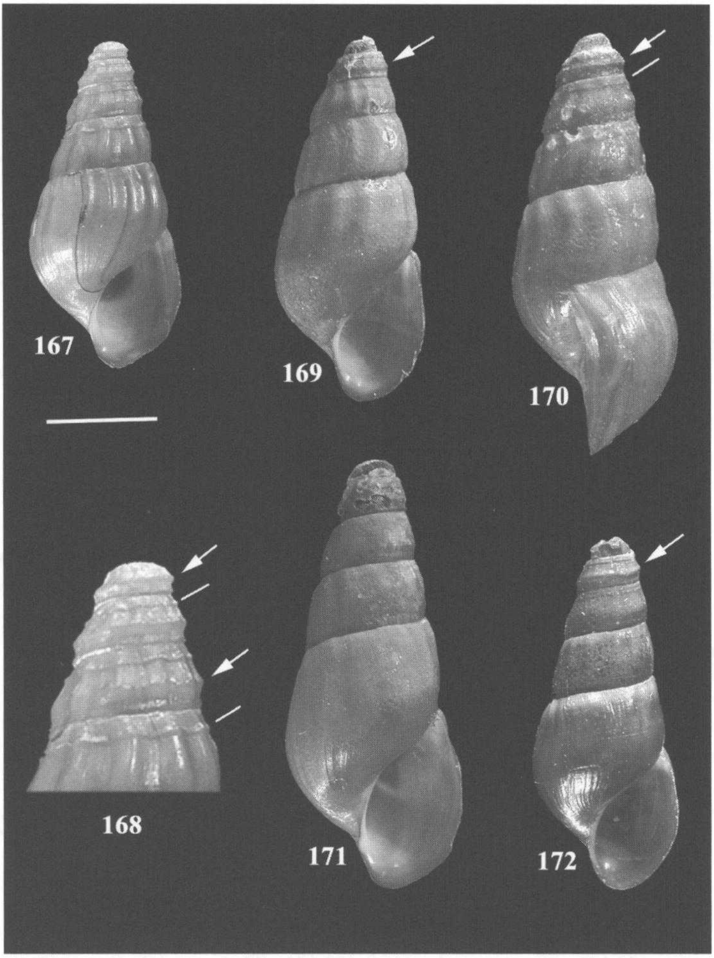
FIGS. 145-150. Species of *Elimia*. FIGS. 145-147. *Elimia albanyensis* (Lea 1862), Georgia, Dougherty Co., Flint River, Albany (UF 289696). FIGS. 148-150. *Elimia boykiniana* (Lea 1862), Alabama, Russell Co., Phenix City, Chattahoochee River, below dam (UF 289697).



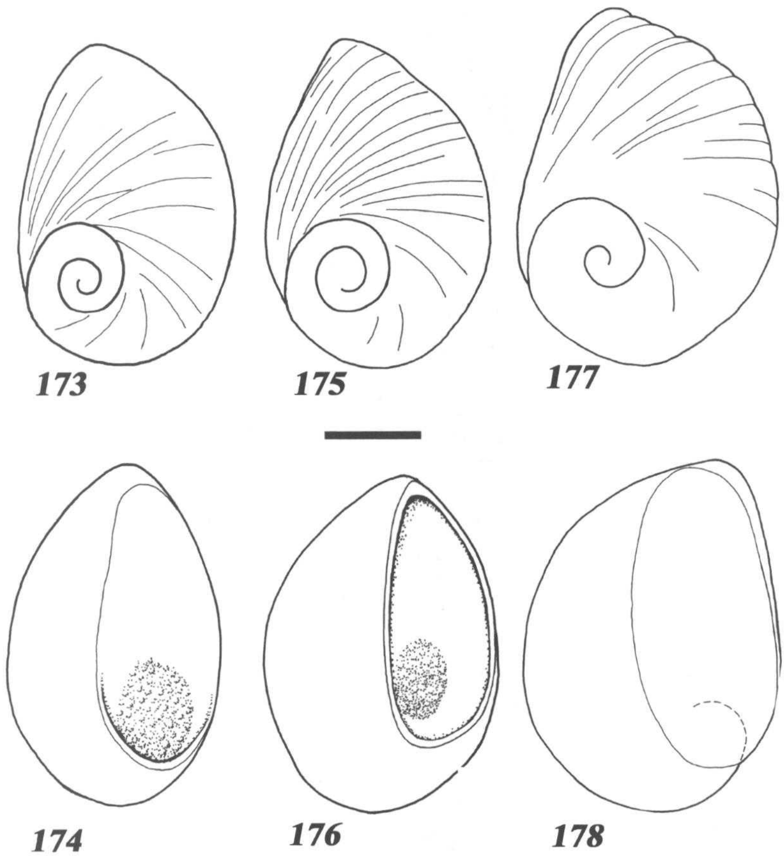
FIGS. 151-158. Species of *Elimia*. FIG. 151. *Elimia albanyensis* (Lea 1862), Georgia, Lee Co., Flint River ca. 10 mi. SSW of Warwick at Hwy 32 (UF 278975). FIG. 152. *Elimia boykiniana* (Lea 1862), Paralectotype (USNM 873106). FIGS. 153-154. *Elimia flava* (Lea 1862), Alabama, Tallapoosa Co., Tallapoosa River, 7.7 mi. SSW of Daviston (UF 230679). FIG. 155. *Goniobasis inosculata* Lea, 1862 Lectotype (USNM 119177) (= *Elimia ucheensis*). FIG. 156. *Goniobasis ucheensis* Lea 1862, Holotype (USNM 119259) (= *Elimia ucheensis*). FIGS. 157-158. *Elimia ucheensis* (Lea 1862), Alabama, Russell Co., Little Uchee Creek, 8.0 mi. NE of Seale (UF 279856).



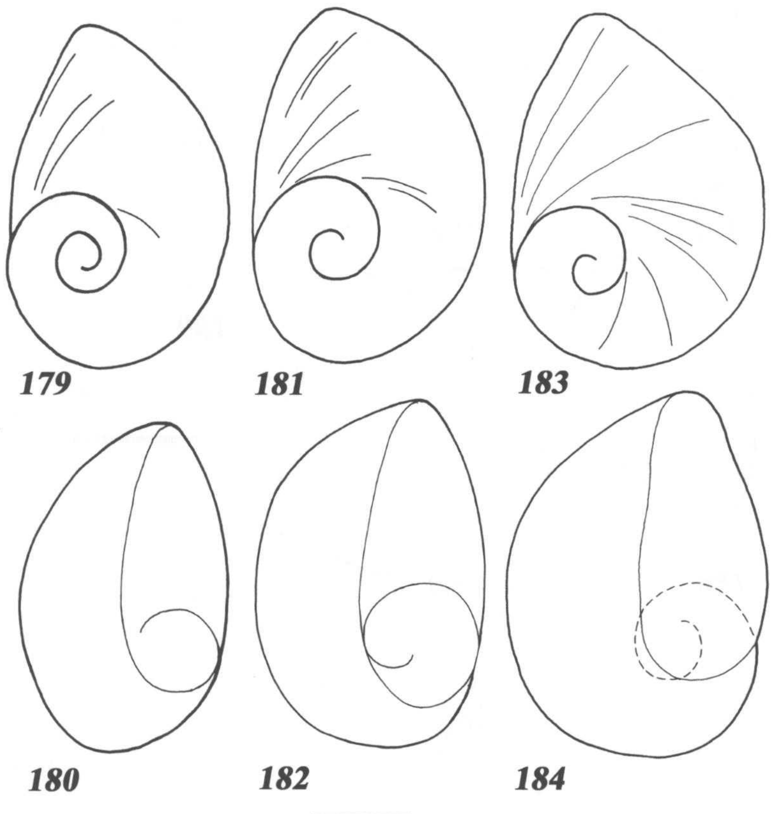
FIGS. 159-166. *Elimia ucheensis* (Lea 1862). FIGS. 159-164. Alabama, Russell Co., Little Uchee Creek, 8.0 mi. NE of Seale (UF 279856). FIG. 165. *Goniobasis elliotti* Lea 1862, Lectotype (USNM 119122) (= *Elimia ucheensis*). FIG. 166. *Goniobasis gesneri* Lea 1868, Holotype (USNM 119134) (= *Elimia ucheensis*).



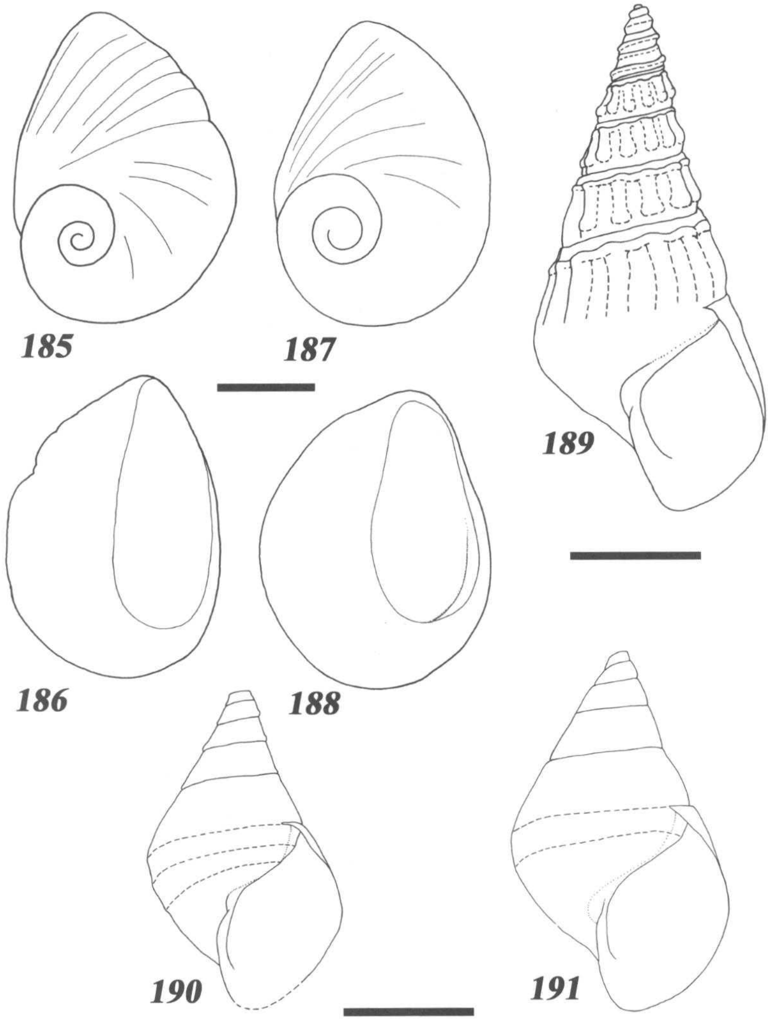
FIGS. 167-172. ***Elimia glarea* new species**, Alabama, Barbour County, Blue Springs State Park, Blue Springs. FIG. 167. Holotype (UF 296260). FIG. 168. Apex of holotype showing details of sculpture. FIGS. 169-172. Paratypes (UF 296259). Scale bar = 5 mm for Figs. 167, 169-172. Arrows indicate peripheral cord; lines indicate supra-peripheral cord.



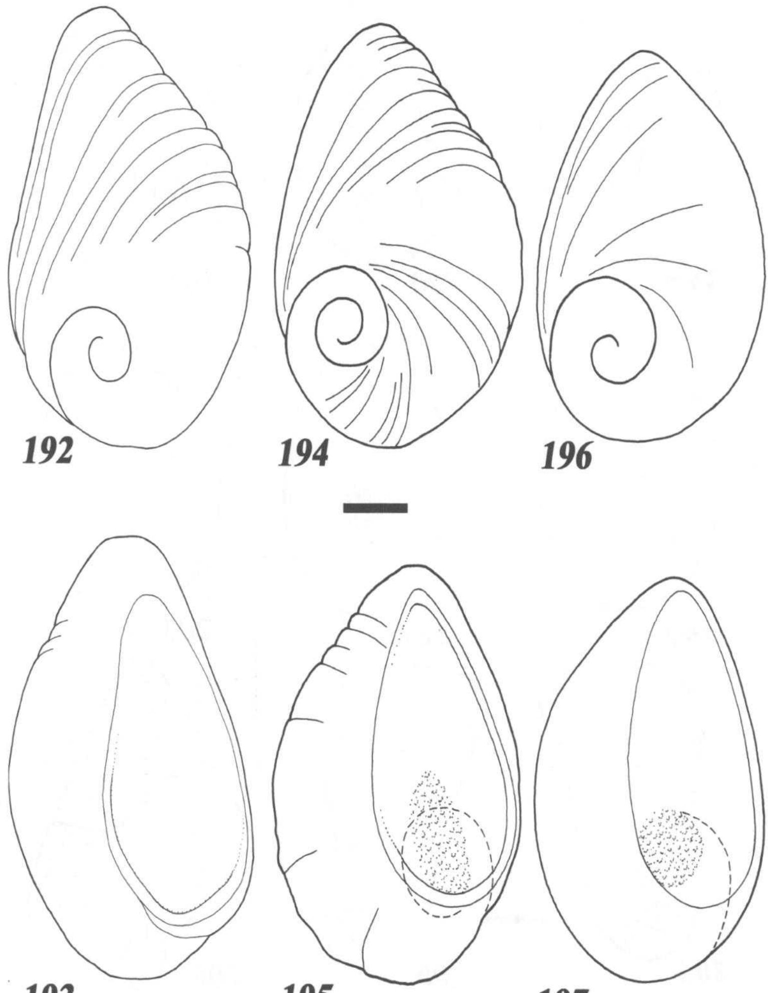
FIGS. 173-178. *Elimia* opercula. FIGS. 173-174. *Elimia mutabilis* (Lea 1862) (UF 251668). FIGS. 175-176. ***Elmia darwini* new species** (UF 2740988). FIGS. 177-178. *Elimia curvicostata* (Reeve 1861) (UF 293489). Scale bar = 1 mm.



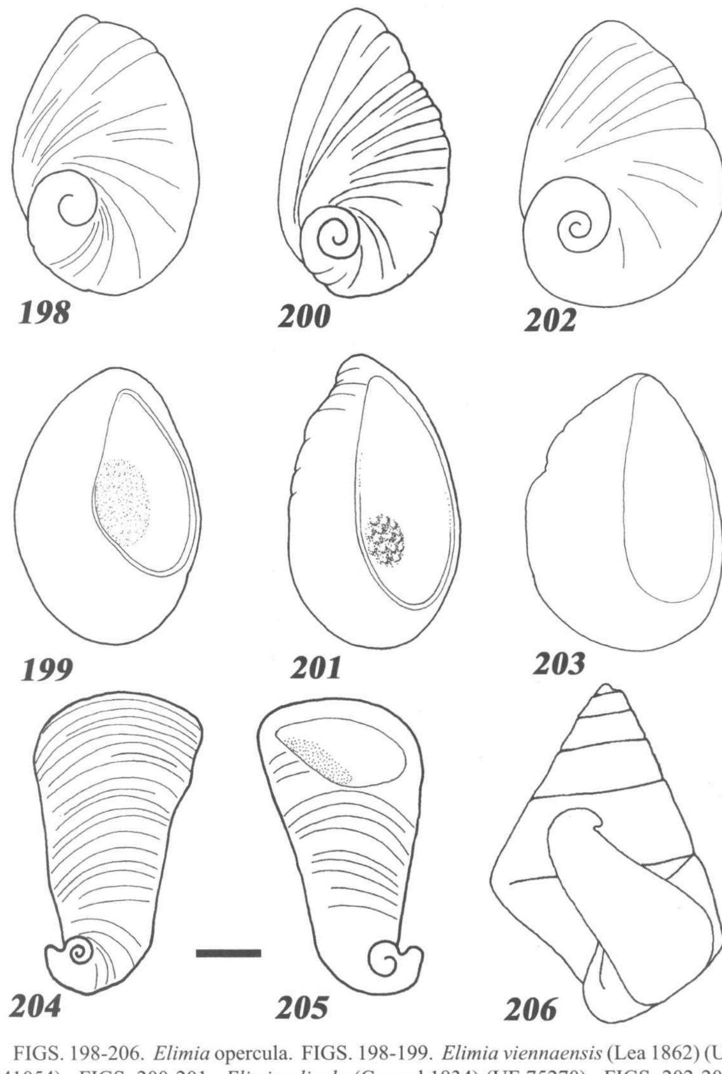
FIGS. 179-184. *Elimia* opercula. FIGS. 179-180. ***Elimia timida nymphaea*** **new subspecies** (UF 266247). FIGS. 181-182. ***Elimia timida exul*** **new subspecies** (UF 206283). FIGS. 183-184. *Elimia induta* (Lea 1862) (UF 284400). Scale bar = 1 mm.



FIGS. 185-191. *Elimia* opercula and juvenile shells. FIGS. 185-186. Opercula of ***Elimia glarea* new species** (UF 296261). FIGS. 187-188. Opercula of *Elimia ucheensis* (Lea 1862) (UF 279856). FIG. 189. Juvenile shell of ***Elimia glarea* new species**. (UF 296261). FIGS. 190-191. Juvenile shells of *Elimia olivula* (Conrad 1834) (UF 290203). Scale bar for opercula = 1 mm; scale bar for shells = 5 mm.



FIGS. 192-197. *Elimia* opercula. FIGS. 192-193. ***Elimia annae*** new species (UF 270490). FIGS. 194-195. ***Elimia buffyae* new species** (UF 270485). FIGS. 196-197. ***Elimia exusta* new species** (UF 73593). Scale bar = 1 mm.



FIGS. 198-206. *Elimia* opercula. FIGS. 198-199. *Elimia viennaensis* (Lea 1862) (UF 241054). FIGS. 200-201. *Elimia olivula* (Conrad 1834) (UF 75270). FIGS. 202-203. ***Elimia glarea* new species** (UF 296261). FIGS. 204-206. *Elimia pilsbryi* (Goodrich 1927). Scale bar for Figs. 198-201, 204-205 = 1 mm.

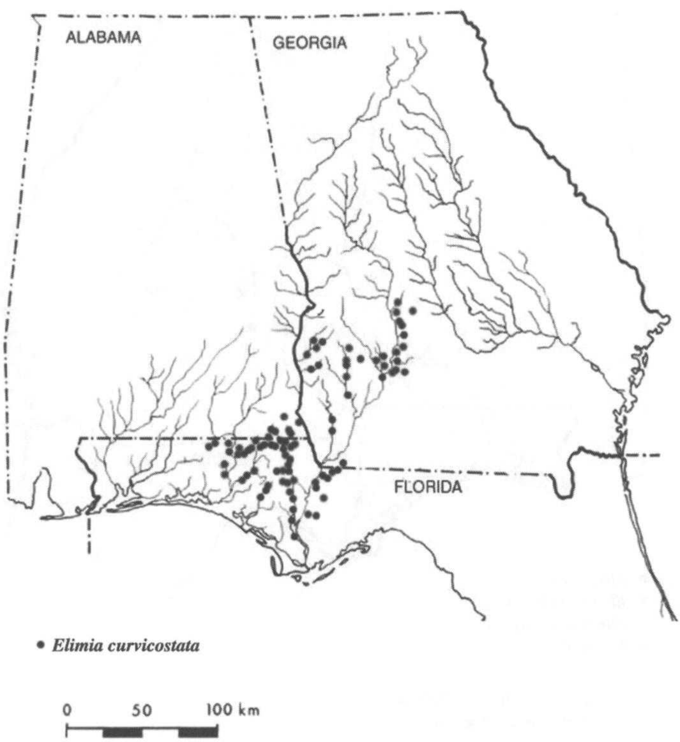


FIG. 207. Distribution of *Elimia curvicostata* (Reeve 1961).

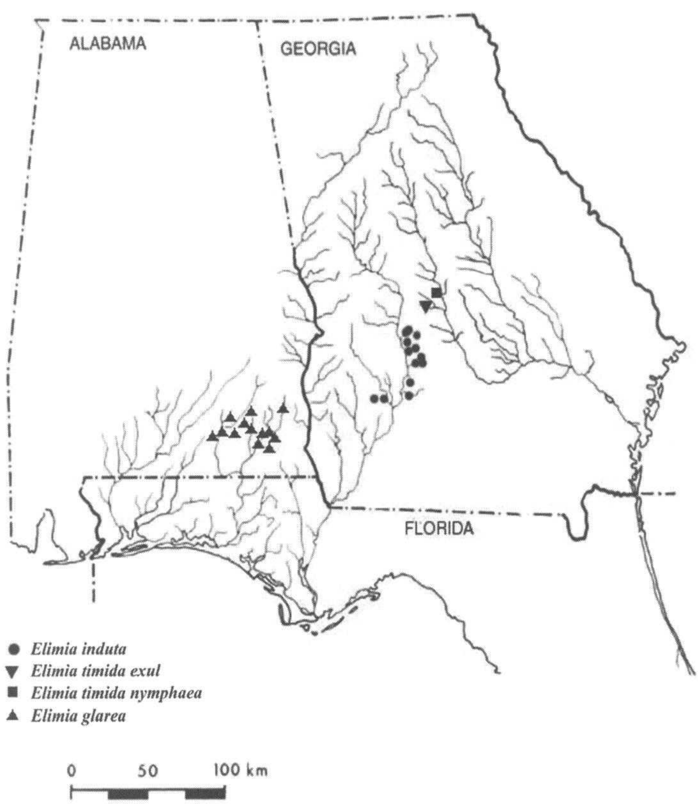


FIG. 208. Distributions of ***Elimia timida nymphaea* new subspecies**, ***Elimia timida exul* new subspecies**, *Elimia induta* (Lea 1862) and ***Elimia glarea* new species**.

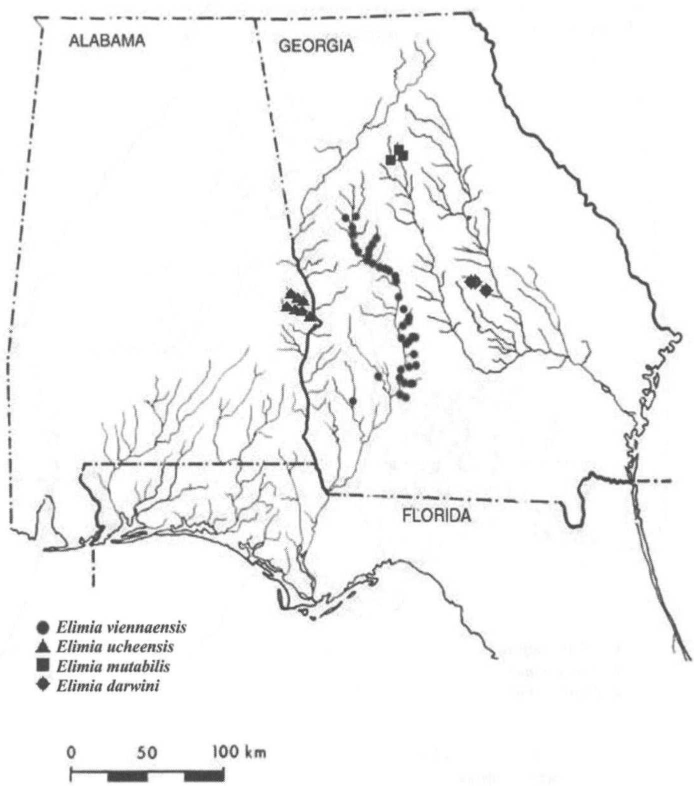


FIG. 209. Distributions of *Elimia mutabilis* (Lea 1862), ***Elimia darwini* new species**, *Elimia viennaensis* (Lea 1862) and *Elimia ucheensis* (Lea 1862).

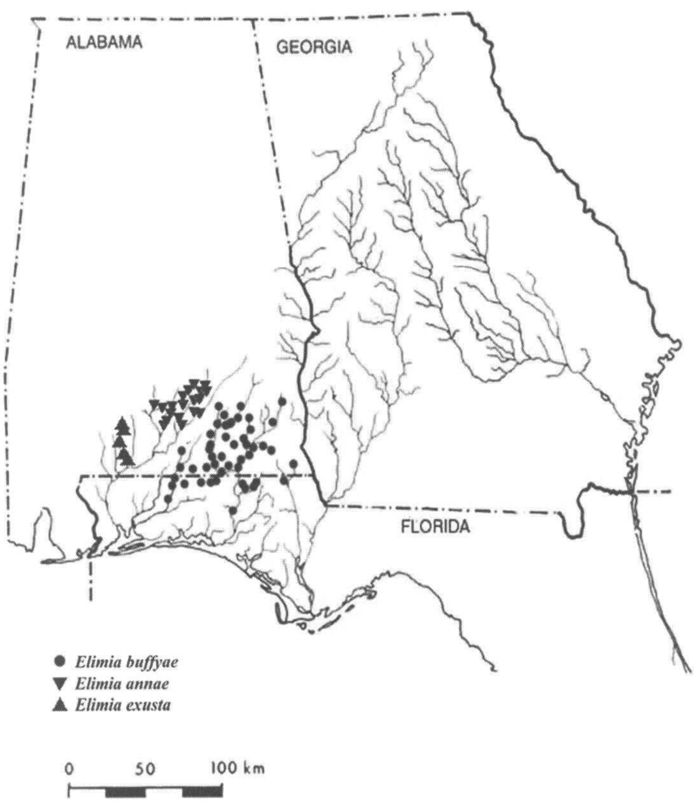


FIG. 210. Distributions of ***Elimia buffyae* new species**, ***Elimia annae* new species** and ***Elimia exusta* new species**.

Walkerana, 2002, 13(29/30): 109-112

VIRGINIA'S JAMES RIVER BASIN PROJECT. MOLLUSKS

John B. Burch[1]

In 1940, the Virginia Academy of Science initiated an ambitious program to gather together diverse information about one of the major areas of the state of Virginia, the James River Basin. This triangular area (Fig. 1), contained entirely within the state, encompasses roughly one-third of Virginia's land, and extends from the state's westernmost mountainous boundary with West Virginia eastward to the Chesapeake Bay. The James River travels about 335 miles from its headwaters in Highland County to the Bay, and along its way drains about 10,000 square miles of land. As it runs its course, the river drains wholly or in part 42 of the state's 100 counties, and transects all five of the state's physiographic provinces—Appalachian plateaus, Valley and Ridge, Blue Ridge, Piedmont, and Coastal Plain.

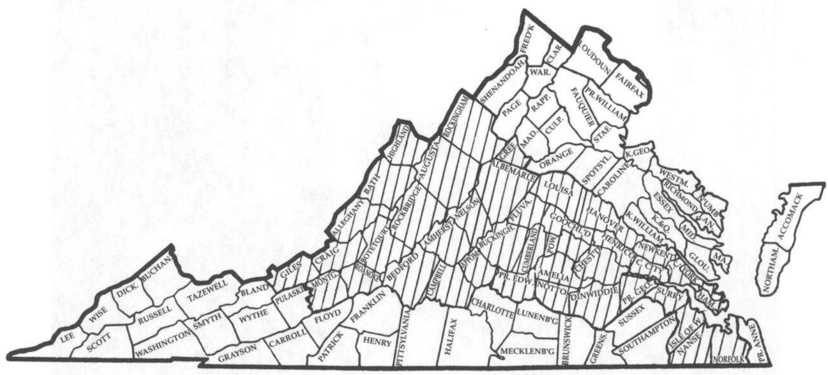


FIG. 1. County map of Virginia, with the counties of the James River Basin shaded. Forty-two of the state's 100 counties are drained wholly or in part by the James River and its tributaries (Anonymous, 1942).

The first phase of the James River Basin Project culminated in the publication of a 843-page book, *The James River Basin—Past, Present and Future.* This book, written by the individual or joint efforts of 44 different authors, contains five major sections: Conservation, Recreation, Education; Biological Sciences; Earth Sciences; Mathematical and Applied Sciences; and Industry and Transportation. In the Biological Sciences section, there are chapters on: Botany; Plant Pathology; Entomology; Mollusks; Marine Fishes and Invertebrates; Freshwater Fishes; Amphibians and Reptiles; Birds; Mammals; and Medical Sciences.

[1]Museum of Zoology, College of Literature, Science and the Arts, and School of Natural Resources and Environment, University of Michigan, Ann Arbor, Michigan 48109, U.S.A.

The chapter on the non-marine mollusks of the James River Basin was by Paul Randolph Burch (1898-1958) (Fig. 2), Professor of Biology, Radford College, Women's Division, Virginia Polytechnic Institute [now Radford University—co-educational, and independent of Virginia Polytechnic Institute (now Virginia Polytechnic Institute and State University)]. The short chapter (P.R. Burch, 1950) on the land and freshwater mollusks found within the James River Basin is a brief

FIG. 2. Paul Randolph Burch (1898-1958); Professor of Biology, Radford College, Women's Division, Virginia Polytechnic Institute. (Allen, 1959)

preliminary report from the first comprehensive, systematic study of the non-marine mollusks of Virginia.

P.R. Burch's research interests originally were not with mollusks, but with other organisms. At the University of Virginia, his Master of Science thesis demonstrated the occurrence of basal granules for the endodermal flagella of hydra (see Hegner, 1933 [Burch's name was misspelled as "Burck" in the figure legend]), and his Doctor of Philosophy dissertation was on the effect of injury caused by excision of cytoplasm, and the loss and gain of cytoplasm on the division rates of two sarcodine protistans (P.R. Burch, 1930). P.R Burch's "keen interest in the Mollusca resulted in his being commissioned in 1935 by the Virginia Academy of Science to study particularly the mollusks of Virginia. He spent as much time on the assignment as his teaching duties would allow. During the years which followed, he acquired an excellent collection, approximating 300 species of land and freshwater mollusks from all over the state. He contributed to the collections of the U.S. National Museum and the University of Michigan Museum of Zoology. Among his more notable publications in malacology is the study of the chromosomes of polygyrid snails (with Ladley Husted), which is considered to be the most comprehensive study of chromosomes of any group of mollusks. His discovery of a new species of snail which he designated as *Polygyra virginiana* reflects his affection for his native state. An avid systematist, his ultimate goal was a monograph of the mollusks of Virginia, and at the time of his demise, several manuscripts were well underway. Dr. Burch seemed to be driven by a consuming desire and great urgency to promote respect and concern for biology with particular emphasis on and recognition of Virginia's needs." (Allen, 1959).

In the chapter on mollusks, P.R. Burch reported mollusks from 25 of the counties within the James River Basin. From Albemarle County, he reported 21 species, from Alleghany, 43 species, Amherst (39 species), Augusta (36), Bath (28), Bedford (4), Botetourt (24), Campbell (18), Chesterfield (7), Craig (34), Cumberland (2), Dinwiddie (13), Elizabeth City (15), Fluvanna (23), Giles (39), Goochland (6), Henrico (9), Highland (14), James City (10), Louisa (18), Montgomery (1), Nelson (22), Norfolk (33), Prince George (3), Rockbridge (61). He included two counties bordering the James River Basin but not included within the designated area of the project—Rockingham County (with nine reported mollusk species), and Sussex County (with one reported species).

In P.R. Burch's list, there are 137 species and subspecies from four orders, 22 families, and 52 genera—a discrepancy from the numbers mentioned in his article (145 species, 55 genera, and 23 families). He lamented his not receiving galley or page proofs, and expressed his displeasure with the typesetting and lack of opportunity to correct the typographical errors. Obviously some lines from the original manuscript were dropped in the type-setting process, *e.g.,* the omission of the family name Hydrobiidae (which resulted in the inclusion of *Stimpson* *nickliniana* in the Pleuroceridae), which would account for the missing family, an additional genus, and one or more species.

The nomenclature P.R. Burch followed was basically that of F.C. Baker for the freshwater snails, and the pill (pea) and fingernail clams, C.T. Simpson for the unionid mussels, and H.A. Pilsbry for the land snails and slugs. P.R. Burch's initial malacological interest was especially with the land mollusks, and this is the group toward which most of his collecting efforts were directed. He had intended to devote equally as much time to procuring freshwater mollusks, but declining health terminated those efforts. [P.R. Burch was very ill during the time of preparing this James River Basin report, having a slowly progressing debilitating illness that caused his premature retirement from teaching in 1954, and his untimely death in 1958.]

P.R. Burch's article on non-marine mollusks of the James River Basin follows in this issue of *Walkerana* (pp. 113-122). It is his original list, with some of the obvious typographical errors corrected.

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Walkerana, 2002, 13(29/30): 113-122

MOLLUSKS

by

PAUL R. BURCH, *Professor of Biology,*
Radford College, Women's Division, Virginia Polytechnic Institute

MOLLUSKS are a group of animals that appeared early in the Paleozoic Era and at present number over 70,000 named species (and subspecies). Of approximately 6,000 species reported within the borders of the continental United States, 4,000 species are land or freshwater dwellers; the remaining are marine. Prior to this paper, 44 species had been reported from the James River Basin—mostly from Rockbridge, Bedford, and Amherst counties. This report, which is far from complete, lists 145 species from 27 of the 43 counties of the area. All of these have living representatives and belong to two of the five classes of Mollusca, namely: Gastropoda – snails and slugs; and Pelecypoda – mussels and pill clams.

Mollusks are soft-bodied animals which have a foot as their locomotor organ and, excepting slugs, carry a shell with them into which they can retreat. The slugs have never had an external shell and are not "snails which have crawled out of their shells." They do have a shell, but it is internal. Like other animals, mollusks have digestive, respiratory, nervous, excretory, reproductive, muscular, and blood systems. The external skin-like covering, called the "mantle," lines the shell and secretes it. The foot secretes mucus which is deposited as a roadway over which the snail or slug makes its way by means of wave-like peristaltic motions. The head of a snail or slug has two pairs of antennae-like tentacles, the longer of which bears eyes. On the right side of the body of the snail is a hole, which is the opening to the lung. The mouth is on the underside of the head and has a rasping tongue covered with thousands of hard teeth that are used to scrape food from the plants and animals that they eat.

Most of the snails and slugs are hermaphrodites, *i.e.,* bearing both male and female germ glands and reproductive organs. The fertilized eggs of land forms are deposited during the summer months and are generally hatched in early Fall. They spend the winter on the ground, under rocks or logs or other cover, and usually mature within two years. Very few live much longer than two years. The eggs of the water snails are deposited in masses of jelly on solid objects in water in spring, summer or fall. Those of one species are born alive.

The mussels lack head and tentacles but do have a sense organ around the mouth and a balancing organ in the foot. They are gill breathers. Sexes are separate and the gills of the female serve as a marsupium in which the eggs develop into larvae called glochidia. These glochidia attach themselves to the gills of fish, where they remain for weeks or months and during development may be carried great distances before they drop off, become adults and settle down to a sedentary existence. Their food and oxygen come from the current of water continually drawn into their shells by the beating of cilia on their gills.

Snails do not have direct economic importance but serve as food for other animals and as hosts for certain parasites of man and domestic animals. Land snails are not large enough or plentiful enough to serve as human food, but birds, salamanders, mice, moles, shrews, and squirrels eat them. Aquatic snails furnish food for fish and other animals. Approximately 20% of fish feed more or less on snails. F.C. Baker in 1916 (Bull. 4, N.Y. State Coll. Forestry) stated that "more than 40 species of mollusks are now known to be used as food by our common and game fish." Mussels serve as food for muskrat, mink, raccoon, and some birds. The Indians ate them but civilized man has not acquired a taste for them (although the author and some of his friends have found them very good in the form of chowder.) The pill clams form a large part of the food of many valuable game and food fish, either directly or indirectly, such as the Black Bass, Common Sucker, Yellow Perch, Pike, and Red Horse.

Land snails and slugs may be found almost anywhere provided they can get there, even in places which would seem too dry to support any life at all. Forested bluffs along rivers having outcrops of limestone seem to be most favorable habitats. Land snails are found at elevations of over 4,000 feet in Giles, Craig, and Augusta Counties, and almost at sea level near the sandy beaches of the eastern coast. Most snails are associated with distinctive kinds of environment and are found in greater numbers in forests of beech, buckeye, and tulip trees, but it seems that presence of shelter, moisture, and limestone are the three most important limiting factors. If these conditions are satisfactory and civilization has not encroached too much, land snails are usually found in great abundance and variety. Pond snails are found from sea level up to approximately 4,000 feet, and even in cold lakes. I have not seen the stream-dwelling operculate snails or mussels higher than 2,000 feet, but pill clams are found in the highest springs such as the one at over 4,000 feet furnishing water for Mountain Lake Biological Station in Giles County. Certain introduced species of snails and slugs and a few others live in gardens, in hedge rows and under almost any object that will afford protection from light, heat, drying, and enemies. From these hiding places, they raid gardens, orchards, and cellars where food can be found. Experiments have shown that the Striped Garden Slug can detect a rotten apple 50 yards away. John Taylor (1916) in *Land and freshwater Mollusca of the British Isles* tells of the food preferences of snails from among nearly 200 kinds of plants and animals. Snails eat a great variety of foods. In our area it seems that the mycelia of fungi are the preferred food of most land snails. They even feed on the poisonous mushroom *Russula emetica.* Mussels eat almost any organic detritus that enters the shell. Sewage in small quantities is eaten, but large quantities, such as dumped into rivers by some cities, kills all mussels.

In comparison with other areas, the James River Basin has about as many species as reported from other states, but less than the Ohio River drainage area in Southwest Virginia. The greater number of species in the latter area may be more apparent than real, and may be due to more extensive investigation nearer his home by the author. Or it may mean that those mollusks that evolved in the south have not yet been able to get into the James River Basin in their migrations north and northeast. In the four counties—Pulaski, Giles, Craig and Montgomery—more than 150 species have been identified by the author.

The mollusks of the area belong to two classes: Gastropoda – snails and slugs; and Pelecypoda – mussels and pill clams. These mollusks are represented by four orders: Pulmonata – lung breathers, Prosobranchiata – gill breathers, Teleodesmacea – pill clams, and Prionodesmacea – mussels. These four orders comprise 23 families, 55 genera, and 145 species and subspecies.

Classification and county records follow.

Class GASTROPODA

A. Order **Prosobranchiata**

Family HELICINIDAE

Hendersonia occulta (Say), Rockbridge and Augusta counties.

Family VIVIPARIDAE

Campeloma decisum (Say), Amherst, Craig and Rockbridge counties.
Campeloma integrum (Say), Cumberland, Fluvanna.

Family PLEUROCERIDAE

Goniobasis symmetrica (Haldeman), Botetourt and Rockbridge.
Goniobasis sordida (Lea), Augusta.
Goniobasis virginica (Gmelin), Amherst and Chesterfield.
Nitocris carinata (Bruguière), Albemarle, Alleghany, Bath, Botetourt, Craig, Fluvanna, Highland, Rockbridge.
Nitocris carinata monodontoides (Conrad), Alleghany, Amherst, Craig, Botetourt, Chesterfield, Fluvanna, Rockbridge.

Family HYDROBIIDAE

Stimpsonia nickliniana (Lea), Bath.

B. Order **Pulmonata**

Family ELLOBIIDAE

Carychium exile Lea, Alleghany, Amherst, Augusta, Botetourt, Rockbridge.

Melampus bidentatus Say, Norfolk.
Melampus floridanus Adams, Norfolk.

Family LYMNAEIDAE
Fossaria obrussa (Say), Campbell, Giles.
Fossaria galbana (Say), Rockbridge.
Fossaria humilis (Say), Botetourt, Campbell, Highland, Rockbridge.
Pseudosuccinea columella (Say), Alleghany, Fluvanna.
Stagnicola palustris elodes (Say), Campbell.

Family PLANORBIDAE
Gyraulus hirsutus (Gould), Chesterfield, Craig, James City.
Gyraulus parvus (Say), Botetourt, Rockbridge.
Helisoma anceps (Menke), Alleghany, Amherst, Augusta, Craig, Louisa, Rockbridge. (= *antrosa* Conrad).
Helisoma anceps unicarinata (Haldeman), Alleghany, Botetourt, Rockbridge.
Helisoma trivolvis (Say), Norfolk.

Family PHYSIDAE
Physella elliptica aurea (Lea), Bath, Louisa, Rockbridge.
Physella heterostropha (Say), Alleghany, Augusta, Bath, Botetourt, Craig, Henrico, James City, Norfolk, Rockbridge.

Family PUPILLIDAE
Columella edentula (Draparnaud), Augusta, Giles, Fluvanna.
Gastrocopta armifera Say, Albemarle, Alleghany, Amherst, Augusta, Dinwiddie, Giles, Norfolk, Rockbridge.
Gastrocopta contracta (Say), Albemarle, Alleghany, Augusta, Highland, Nelson, Norfolk.
Gastrocopta corticaria (Say), Alleghany, Augusta.
Gastrocopta holzingeri (Sterki), Rockbridge.
Gastrocopta pellucida hordeacella (Pilsbry), Norfolk.
Gastrocopta pentodon (Say), Alleghany, Amherst, Augusta, Campbell, Elizabeth City.
Gastrocopta procera (Gould), Alleghany, Nelson, Norfolk.
Pupoides marginata (Say), Alleghany, Amherst, Augusta, Dinwiddie, Highland, Norfolk.
Vertigo gouldi (Binney), Giles.
Vertigo milium (Gould), Norfolk.
Vertigo ovata Say, Norfolk.
Vertigo parvula Sterki, Rockbridge.

Vertigo bollesiana (Morse), Norfolk.

Family SUCCINEIDAE

Succinea aurea Lea, Norfolk.
Succinea avara Say, Elizabeth City.
Succinea ovalis Say, Albemarle, Augusta, Rockbridge.
Succinea retusa Lea, Dinwiddie.

Family ENDODONTIDAE

Anguispira alternata (Say), Alleghany, Giles, Norfolk, Elizabeth City.
Anguispira alternata angulata Pilsbry, Amherst, Augusta, Bath, Nelson, Rockbridge.
Anguispira alternata costata (Lewis), Giles.
Anguispira alternata mordax (Shuttleworth), Alleghany, Bath, Botetourt, Rockbridge, Sussex.
Discus patulus (Deshayes), Alleghany, Amherst, Craig, Fluvanna, Giles, Goochland, Henrico, James City, Louisa, Rockbridge.
Punctum minutissimum (Lea), Albemarle, Amherst, Augusta, Campbell, Dinwiddie, Fluvanna.
Punctum vitreum H.B. Baker, Bath.

Family COCHLICOPIDAE (Cionellidae)

Cochlicopa [*Cionella*] *lubrica* (Müller). Alleghany, Augusta, Bath, Fluvanna, Giles, Nelson, Rockbridge.

Family VALLONIIDAE

Vallonia costata (Müller), Augusta, Norfolk.
Vallonia excentrica Sterki, Alleghany, Craig, Norfolk.
Vallonia parvula Sterki, Augusta.

Family PHILOMYCIDAE

Pallifera dorsalis (Binney), Nelson, Norfolk, Rockbridge.
Philomycus carolinianus (Bosc), Albemarle, Amherst, Craig, Fluvanna, Giles, Louisa, Montgomery, Norfolk, Rockbridge.

Family LIMACIDAE

Deroceras laeve (Müller), Campbell, Norfolk.
Limax flavus Linnaeus, Albemarle, Bath, Campbell, Henrico, Norfolk.
Limax maximus Linnaeus, Campbell, Rockbridge (perhaps all cities of the James River Basin).

Family ZONITIDAE

Euconulus chersinus (Say), Albemarle, Alleghany, Augusta, Craig, Eliza-

beth City, Goochland, Louisa, Highland, Nelson.
Euconulus chersinus dentatus (Sterki), Amherst, Rockingham.
Euconulus fulvus (Müller), Amherst, Bath, Botetourt, Goochland, Nelson.
Guppya sterki (Dall), Rockingham.
Hawaiia minuscula (Binney), Amherst, Alleghany, Bath, Dinwiddie, Elizabeth City, Highland, Nelson, Norfolk.
Mesomphix capnodes (Binney), Rockbridge.
Mesomphix cupreus (Rafinesque), Alleghany, Augusta, Bath, Craig, Giles, Rockbridge.
Mesomphix inornatus (Say), Bath, Botetourt, Craig, Fluvanna, Giles, Highland, Nelson, Rockingham.
Mesomphix perlaevis vulgatus H.B. Baker, Albemarle, Alleghany, Bath, Elizabeth City, Giles, Nelson.
Paravitrea capsella (Gould), Albemarle, Alleghany, Bath, Botetourt, Fluvanna, Giles, Nelson.
Paravitrea multidentata (Binney), Rockbridge.
Paravitrea pontis H.B. Baker, Alleghany, Rockbridge.
Retinella carolinensis (Cockerell), Nelson, Rockbridge.
Retinella carolinensis wetherbyi (Cockerell), Giles.
Retinella burringtoni (Pilsbry), Giles, Louisa, Rockbridge.
Retinella electrina (Gould), Albemarle, Augusta, Bath, Botetourt, Elizabeth City.
Retinella indentata (Say), Albemarle, Alleghany, Amherst, Augusta, Botetourt, Craig, Fluvanna, Giles, Elizabeth City, James City, Nelson, Norfolk.
Retinella indentata paucilirata (Morelet), Craig, Dinwiddie, Louisa.
Retinella rhoadsi (Pilsbry), Alleghany, Amherst, Bath, Botetourt, Giles, Rockbridge.
Retinella rhoadsi austrina H.B. Baker, Amherst, Rockbridge.
Striatura ferrea Morse, Craig.
Striatura meridionalis (Pilsbry & Ferriss), Albemarle, Alleghany, Amherst, Fluvanna, Giles, Louisa, Rockbridge, Rockingham.
Oxychilus draparnaldi (Beck), Norfolk.
Ventridens acerra (Lewis), Botetourt, Craig, Giles, Rockbridge.
Ventridens arboreus Say, Albemarle, Alleghany, Augusta, Campbell, Craig, Dinwiddie, Fluvanna, Giles, Henrico, Louisa, Nelson, Norfolk, Prince George, Rockbridge, Rockingham.
Ventridens collisella (Pilsbry), Amherst, Dinwiddie, Rockingham.
Ventridens demissus (Binney), Alleghany, Amherst, Augusta, Craig, Elizabeth City, Giles, James City, Norfolk, Rockbridge.
Ventridens intertextus (Binney), Amherst, Bedford.

Ventridens cerinoideus (Anthony), Norfolk.
Ventridens ligera (Say), Amherst, Augusta, Botetourt, Giles, Elizabeth City.
Ventridens limatulus (Ward & Binney), James City.
Ventridens suppressus (Say), Albemarle, Alleghany, Bath, Botetourt, Craig, Elizabeth City, Giles, Louisa, Nelson, Rockbridge.
Ventridens suppressus magnidens Pilsbry, Amherst, Augusta, Rockbridge.
Ventridens suppressus virginicus (Vanatta), Albemarle, Alleghany, Amherst, Augusta, Rockbridge, Nelson.

Family STROBILOPSIDAE
Strobiops aenea Pilsbry, Fluvanna, Goochland, Louisa, Norfolk.
Strobiops labyrinthica (Say), Amherst, Louisa, Nelson, Norfolk.

Family HAPLOTREMATIDAE
Haptotrema concavum (Say), Albemarle, Alleghany, Amherst, Augusta, Bath, Botetourt, Chesterfield, Craig, Dinwiddie, Fluvanna, Giles, Henrico, Highland, James City, Louisa, Nelson, Rockbridge.

Family POLYGYRIDAE
Allogona profunda (Say), Craig, Rockbridge.
Mesodon appressus (Say), Rockbridge.
Mesodon appressus laevior Pilsbry, Dinwiddie.
Mesodon appressus sculptior (Chadwick), Amherst, Bedford, Giles.
Mesodon andrewsae normalis (Pilsbry), Craig, Giles.
Mesodon inflectus (Say), Botetourt.
Mesodon mitchellianus (Lea), Amherst.
Mesodon rugeli (Shuttleworth), Campbell, Giles, Rockbridge.
Mesodon thyroidus (Say), Alleghany, Amherst, Augusta, Campbell, Dinwiddie, Giles, Elizabeth City, Fluvanna, Henrico, James City, Louisa, Norfolk, Rockbridge.
Mesodon thyroidus sanctisimonis (Pilsbry), Bath, Craig.
Stenotrema fraternum (Say), Amherst, Bath, Rockbridge.
Stenotrema hirsutum (Say), Albemarle, Alleghany, Amherst, Augusta, Bath, Elizabeth City, Giles, Goochland, Henrico, Highland, Louisa, Nelson, Rockbridge, Rockingham.
Stenotrema monodon aliciae (Pilsbry), Alleghany, Craig.
Stenotrema stenotrema (Pfeiffer), Alleghany, Amherst, Craig, Giles, Rockbridge.
Triodopsis albolabris (Say), Albemarle, Alleghany, Augusta, Amherst, Bath, Botetourt, Campbell, Craig, Elizabeth City, Fluvanna, Giles, Goochland, James City, Louisa, Norfolk, Rockbridge.

Triodopsis albolabris traversensis (Walker), Elizabeth City.
Triodopsis dentifera (Binney), Craig, Giles.
Triodopsis fallax (Say), Albemarle, Campbell, Dinwiddie, Fluvanna, Henrico, James City, Rockbridge.
Triodopsis fraudulenta (Pilsbry), Alleghany, Augusta, Campbell, Craig, Giles, Highland, Rockbridge, Rockingham.
Triodopsis fraudulenta vulgata Pilsbry, Alleghany, Amherst, Augusta, Campbell, Giles, Highland, Rockbridge, Rockingham.
Triodopsis hopetonensis chincoteagensis Pilsbry, Norfolk.
Triodopsis tridentata (Say), Alleghany, Amherst, Augusta, Bedford, Bath, Craig, Giles, Highland, Nelson, Rockbridge.
Triodopsis tridentata bidentata F.C. Baker, Amherst, Botetourt.
Triodopsis tridentata edentilabris Pilsbry, Alleghany, Bath, Botetourt, Campbell, Giles, Highland, Rockbridge.
Triodopsis tridentata juxtidens Pilsbry, Albemarle, Alleghany, Amherst, Augusta, Bath, Bedford, Botetourt, Campbell, Craig, Dinwiddie, Fluvanna, Giles, Louisa, Nelson, Norfolk, Rockbridge.
Triodopsis tridentata unidentata (F.C. Baker), Alleghany, Amherst, Augusta, Bath, Campbell, Giles, Highland, Nelson.

Family HELICIDAE
Cepea nemoralis Linnaeus, Augusta, Bath, Campbell, Rockbridge.

Class PELECYPODA

C. Order **Prionodesmacea**

Family UNIONIDAE
Alasmidonta collina (Conrad), Rockbridge.
Anodonta cataracta Say, Cumberland.
Anodonta undulata Say, Prince George.
Elliptio complanatus (Dillwyn), Chesterfield, Craig, Fluvanna, Louisa, Prince George, Rockbridge.
Elliptio productus (Conrad), Chesterfield.
Elliptio lanceolatus (Lea), Rockbridge.
Lampsilis constricta (Conrad), Rockbridge.
Pleurobema subplanum (Conrad), Chesterfield, Rockbridge.
Strophitus fisherianus (Lea), Rockbridge.

D. Order **Teleodesmacea**

Family SPHAERIIDAE
Musculium partumeium (Say), Henrico, Norfolk.

Pisidium abditum Haldeman, Giles.
Pisidium compressum Prime, Craig.
Pisidium virginicum '(Gmelin)' Sterki, Craig, Fluvanna.
Sphaerium fabale (Prime), Fluvanna.
Sphaerium striatinum (Lamarck), Craig.

The conchologists H.A. Pilsbry, W.G. Binney, H.B. Baker, T.A. Conrad, W.J. Clench, and A.F. Archer collected in Rockbridge County. Other collectors in Rockbridge County: J.B. Clark, J.P.E. Morrison, M. McDonald, H.N. Wardle, Carl McConnell, T.D. Cockerell; in Norfolk (area): S.N. Rhoades, H.B. Meredith, Leslie Hubricht; in Craig: Wm. B. Hughes; in Bath and Giles: P.P. Calvert. Thirty-two of the 44 species mentioned prior to this report came from Rockbridge County, in the vicinity of Lexington or of Natural Bridge. The other 12 species came from five counties: Norfolk, Bedford, Amherst, Craig and Giles.

No descriptions, figures or ecological data for species have been included here because these data are to be found in the excellent monographs listed below. Anyone interested in any of the species listed above is advised to consult the indexes of these comprehensive works.

For the present report I am indebted to present and former Curators of Mollusks, Drs. Harald Rehder and Paul Bartsch of the U.S. National Museum for many courtesies, and to Associate Curator, Dr. J.P.E. Morrison for identification of many species and for much helpful information. The extensive collections would not have been possible without the help of many friends and students, or without the fellowships provided by the Mountain Lake Biological Station of the University of Virginia under the Direction of Dr. Ivey F. Lewis and Dr. Bruce D. Reynolds. I am especially indebted to Dr. J.C. Strickland, Col. Robt. P. Carroll, Mr. Wm. Ferrell, my wife, Doris, our children, David, Jack, Teddy, Donald and Mary for specimens and active help on many expeditions. Miss Josephine Stewart collected the Elizabeth City County specimens. Mr. Richard Hoffman furnished some of the specimens from Alleghany and Augusta Counties.

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A NEW SPECIES OF *PARABOYSIDIA* (PUPILLIDAE: GASTROCOPTINAE) FROM LAOS

Somsak Panha[1], Piyoros Tongkerd[1], Chirasak Sukarit[1], Sakbovon Tumpeesuwan[1] and Chanda Vongsombath[2]

ABSTRACT

The genus *Paraboysidia* Pilsbry is reported for the first time from Laos, and a new species, *P. wangviangensis,* is described from the Wangviang limestone area. The shell of the new species is characterized especially by its elongated, turreted shell, and its peculiarly skewed aperture and arrangement of apertural barriers (teeth). The angular lamella is the most prominent, and both it and the outer, upper palatal plica reach the edge of the peristome, and nearly touch, almost isolating the angular-palatal embayment.

Key words: *Paraboysidia wangviangensis,* Pulmonata, Pupillidae, Laos.

INTRODUCTION

The pupillid gastrocoptine genus *Paraboysidia* Pilsbry 1917 extends from India and Myanmar eastward to southern China, and southward through Thailand and the Malay Peninsula, to Indonesia (Java). Previously named species in the genus include one species from India (Pilsbry, 1915), two species from Myanmar (Burma) (Theobald, 1870; Stoliczka, 1871), six species from Thailand (Panha & Burch, 2000, 2001), three species from Indochina (Bavay & Dautzenberg,1912), 11 species from the Malay Peninsula (Möllendorff, 1897; Collinge, 1902; Sykes, 1902; and Benthem Jutting 1950, 1961), and one species from China (Gredler, 1901). ***Paraboysidia wangviangensis* n.sp.,** from Laos, is an additional species recognized from the region.

Paraboysidia wangviangensis Panda and Tongkerd, new species

(Figs. 1-3)

Description of holotype. Shell tiny, 1.2 mm in length, 1.0 mm in width, and with about four and a half whorls. The spire is conical, turreted, and evenly tapered, except for the last part of the last whorl. The last half to one third of the ultimate whorl changes slightly in the direction of spiral growth. The spire whorls are evenly rounded; the last whorl is roundly shouldered. On the surface of about the terminal third of the last whorl there is a shallow spiral sulcus, which leads to the peristome area where the outer upper palatal plica is located. The

[1]Department of Biology, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand.
[2]Department of Biology, Faculty of Science, National University of Laos, Dong Dok, Viantiane, Peoples Democratic Republic of Laos.

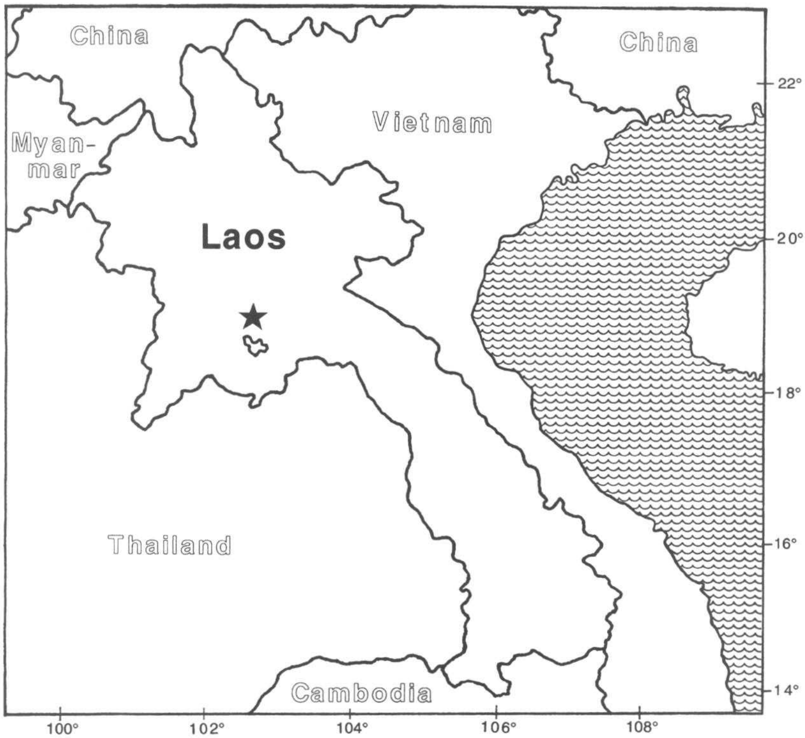

FIG. 1. Map showing the locality of Tam Chang Cave (star), Wangviang, Laos.

peristome is entire and thickened, except in the area between the angular and upper palatal teeth, and is more or less adnate to the last whorl. The apertural barriers are six: parietal, infraparietal and angular lamellae, two upper palatal plicae, and a lower palatal plica. The two upper palatal plicae are located in line, one behind the other. The more deeply set of the upper palatal plicae is ornamented with sharp, outwardly directed spines. The outermost of the two upper palatal teeth extends to the edge of the aperture, and nearly touches the angular tooth (which also extends to the shell lip), nearly closing off the angular embayment. The largest, strongest apertural tooth is the angular lamella. The deep-set lower palatal plica, like the inner-most upper palatal plica, is armed with sharp, outwardly directed spines (Fig. 3b). The shell surface sculpture consists of raised transverse and spiral striae. Among the fine transverse striae, or growth lines, are dispersed—at somewhat irregular intervals—coarser transverse striae.

The dimensions of the holotype and seven paratypes are shown in Table 1.

Type locality. Tam Chang Cave, Wangviang, Laos, 18°54'47" N, 102°26'33"E, TALBE 1. Holotype and paratype dimensions of *Paraboysidia wangviangensis* n. sp.

Types	Dimension (mm)		
	Height	Width	Height of aperture
Holotype	1.2	1.0	0.4
Paratypes			
1	1.2	1.0	0.4
2	1.1	0.9	0.4
3	1.1	0.9	0.4
4	1.1	0.9	0.4
5	1.1	0.9	0.4
6	1.0	0.9	0.4
7	1.0	0.9	0.4

140 meters elevation, Thailand 1998 (CUIZM, collected by S. Panha and party).

Etymology. The specific epithet *wangviangensis* is from the name of Wangviang city, near where the new species was found.

Type material. The holotype (CUIZM, Ver 988) is deposited in the Chulalongkorn University Zoological Museum together with 12 shells (CUIZM, Ver 089). Another six shell paratypes (CUIZM, Ver 090) will be deposited in the University of Michigan Museum of Zoology (UMMZ), Ann Arbor.

Habitat and geographical distribution. *Paraboysidia wangviangensis* n.sp. is known only from its type locality. The specimens were found in the rock crevices of limestone walls near the entrance of Tam Chang Cave. *Cyclophorus siamensis* (Sowerby 1850) was also found in this habitat.

Diagnosis. A *Paraboysidia* species with a relatively large, strong angular lamella that reaches the peristome. The angular lamella and the outer, upper palatal plica nearly touch, almost closing off the angular-palatal apertural embayment. The shell aperture has a thickened peritreme, and a peculiarly skewed shape.

Comparisons. The shell of *Paraboysidia wangviangensis* differs from all other presently known species of the genus by the characteristics of its aperture—shape, teeth and peristome.

Three species of *Paraboysidia* have been named previously from "Indochina," all by Bavay & Dautzenberg (1912): *P. lamothei* [Ban-Lao; Muong-Hum; Muong-Kong], *P. paviei* [Pac-Kha; Long-Ping] and *P. robusta* [Phong-Tho]. These three species all have more teeth in the aperture than does *P. wangviangensis*, and all have columellar lamellae, which P. *wangviangensi* lacks. *Paraboysidia wangviangensi* has the minute granulose surface and the growth striae common to other *Paraboysidia,* but it also has fine, spiral striae, which are not mentioned for the three Indochinese species. In *P. lamothei* and *P. paviei* the peristome is

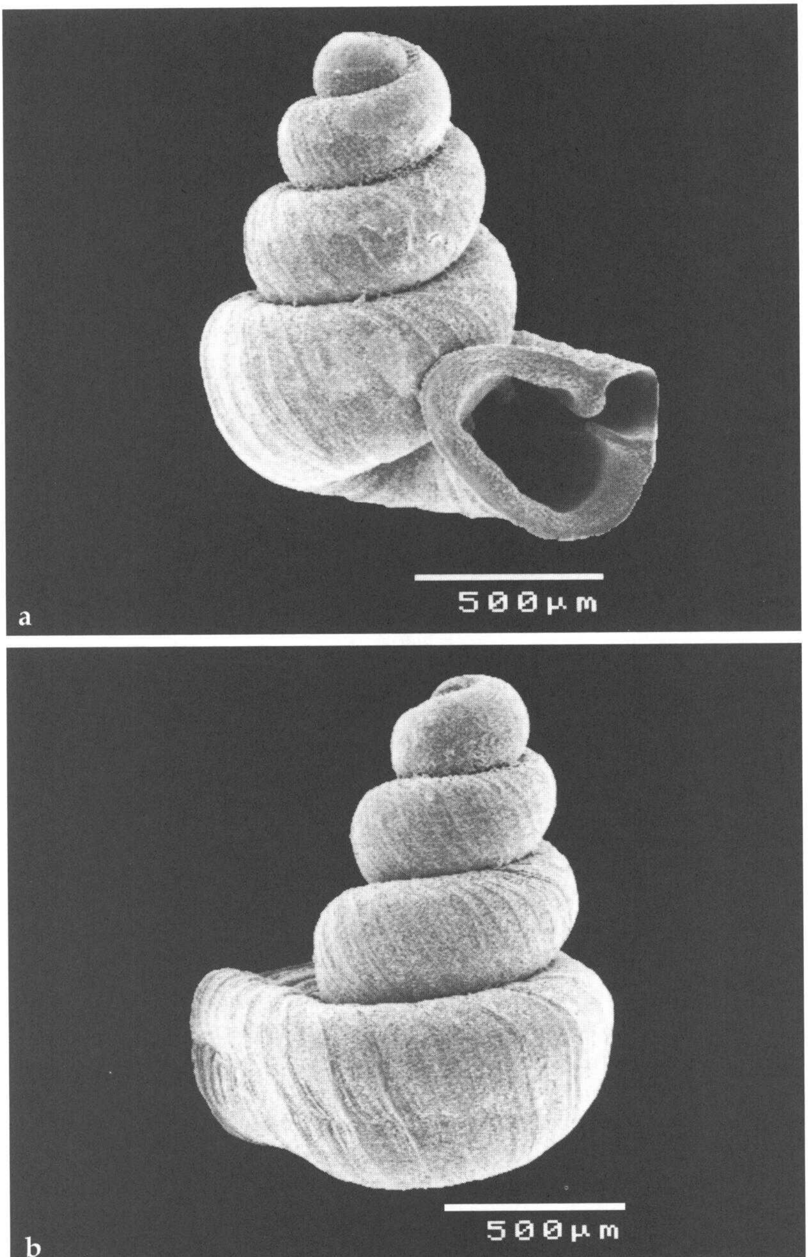

FIG. 2. Shell of *Paraboysidia wangviangensis* n. sp. **a**, Apertural view; **b**, abapertural view.

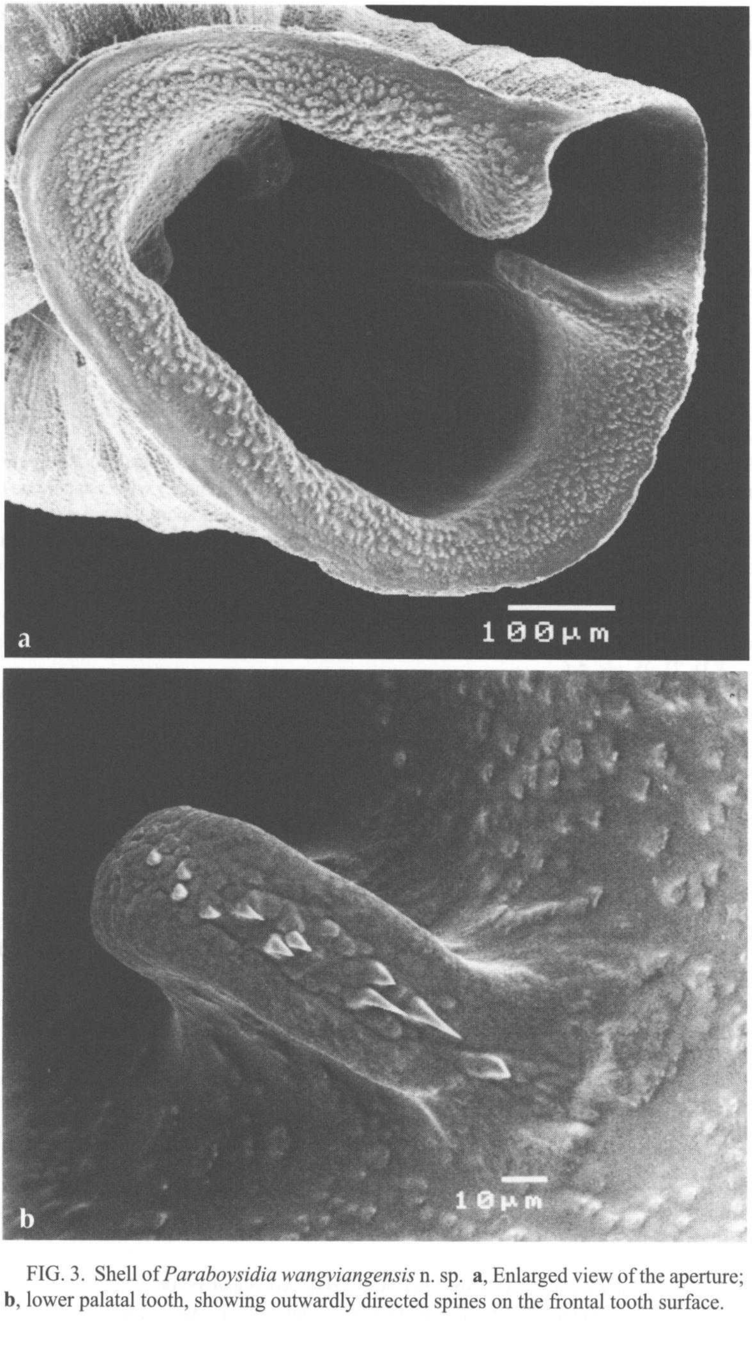

FIG. 3. Shell of *Paraboysidia wangviangensis* n. sp. **a**, Enlarged view of the aperture; **b**, lower palatal tooth, showing outwardly directed spines on the frontal tooth surface.

not entire, as it is in *P. wangviangensis.* The sides of the spire in *P. robusta* are slightly convex, and in *P. paviei* they are rather concave. *Paraboysidia robusta* has concrescently joined parietal and angular lamellae (which Pilsbry, 1917, believed to have evolved independently for the concresent lamellae in other Asian pupillids).

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NEW TAXA OF PUPILLIDAE (PULMONATA: STYLOMMATOPHORA) FROM THAILAND

John B. Burch[1,2,*], Somsak Panha[3,*] and Piyoros Tongkerd[1,3]

ABSTRACT

The new species are minute gastrocoptine pupillid pulmonate gastropods. Each of them have the characteristic major apertural barriers for their genus (angular and parietal [or concrescent angulo-parietal], columellar, and upper and lower palatal), except *Hypselostoma panhai,* which has only one to three barriers, all depauperate. ***Anauchen chatnareeae*** **n.sp.** has an elongate shell with high, evenly sloped, pyramidal spire; its last several whorls are angular and have a distinct supra-angular groove; its peristome is solute and on the end of a very short tuba. ***Gyliotrachela khaochakan*** **n.sp.** has an elongate shell with a high, pyramidal spire and a short, horizontal tuba. The whorls are rounded, except for the body whorl, which is obtusely angular and roundly shouldered. The shell aperture contains five thin, blade-like major barriers, plus a smaller blade-like basal plica and a low, mound-like infraparietal lamella. ***Gyliotrachela saraburiensis*** **n.sp.** has a moderate spire, and a short, horizontal tuba. The shell is moderately umbilicate. The last whorl is weakly angulate, without sulci or carinae. Accessory apertural barriers are three infraparietals, two supracolumellar, three subcolumellar, five infrapalatals, three interpalatals, five suprapalatals, two parallels, and an additional barrier between the parietal and angular lamellae deep within the aperture. ***Gyliotrachela kohrin*** **n.sp.** has a depressed spire, a moderately long, upwardly directed tuba that reaches to or near the apex. The shell is moderately umbilicate, its last whorl weakly carinate. Accessory apertural barriers are two infraparietals, two supracolumellar lamellae, one subcolumellar lamella, two infrapalatals, two interpalatals, and two suprapalatal plicae. All of the apertural barriers have spinose surfaces, except the angular lamella. ***Gyliotrachela diarmaidi*** **n.sp.** has a very depressed spire with a mammillate apex, and a long, upwardly directed tuba that goes beyond the apex. The last whorl has a high, dorsally sulcate carina. Accessory apertural barriers are an infraparietal, a supracolumellar, a subcolumellar, an infrapalatal, two interpalatals, two suprapalatals, and two parallel lamellae. ***Gyliotrachela surakiti*** **n.sp.** has a depressed spire and rather wide umbilicus. The last whorl has a well defined carina. Accessory apertural barriers are three infraparietals, two supracolumellars, three infrapalatals, four interpalatals, three suprapalatals, three parallels and a twin. ***Hypselostoma erawan*** **n.sp.** has a very depressed spire and mammillate apex, a moderately long, upwardly directed tuba that reaches to or near the apex, and a very wide umbilicus. The last whorl has a flat periphery and strong shoulder, and lacks a carina and a sulcus. Accessory apertural barriers are two infraparietals, two infrapalatals, two interpalatals, and a suprapalatal. ***Hypselostoma taehwani*** **n.sp.** has a high spire and a long, downwardly directed tuba. The shell is somewhat moderately umbilicate; the last whorl is rather sharply angular, with an obtuse carina. In addition to the four major apertural barriers, there is a basal plica and an infraparietal lamella. ***Hypselostoma panhai*** **n.sp.** has a high spire, adnate aperture, narrow umbilicus, and evenly rounded last whorl that lacks a carina and sulcus. Apertural barriers are only three, depauperate in both size and number. The shells of *Anauchen chatnareeae* and *Hypselostoma surakiti* have

[1]Museum of Zoology, College of Literature, Science and the Arts, and [2]School of Natural Resources and Environment, University of Michigan, Ann Arbor, Michigan 48109, U.S.A.
[3]Department of Biology, Chulalongkorn University, Bangkok 10330, Thailand.
[*]Corresponding authors.

granulate surface sculpture; the rest of the species are spirally striate. *Gyliotrachela diarmaidi, G. khaochakan, G. kohrin, G. saraburiensis* and *Hypselostoma erawan* are, additionally, decussate. In *H. taehwani* the spiral sculpture is very delicate and easily rubbed off. All of the *Gyliotrachela* species have spinose apertural barriers. The protoconch sculpture of *A. chatanaree* and *H. taehwani* is spirally striate (threads or cordlets), in *G. diarmaidi* it is wrinkled, in *G. suraburiensis* and *G. surakiti* it is pitted, and the protoconch sculpture in *H. panhai* is rugose.

Key words: Pulmonata, Stylommatophora, Pupillidae, *Anauchen chatnareeae, Gyliotrachela diarmaidi, G. khaochakan, G. kohrin, G. saraburiensis, G. surakiti, Hypselostoma erawan, H. panhai, H. taehwani,* Thailand.

INTRODUCTION

Previous taxonomic publications on, or including, the Pupillidae of Thailand are those of Möllendorff (1894), Pilsbry (1917, 1920), Thiele (1931), Zilch (1959, 1982, 1984), Thompson & Lee (1988), Thompson & Upatham (1997); Panha (1997a,b,c), Panha & Burch (1999a,b,c; 2000; 2001a,b; 2002); and Burch & Panha (2000). In these publications, 37 species are recorded for Thailand, belonging to nine genera (*Acinolaemus, Anauchen, Antroapiculus, Gyliotrachela, Hypselostoma, Krobylos, Montapiculus, Nesopupa* and *Systenostoma*). The present paper describes an additional nine species, belonging to three of these genera—*Anauchen, Gyliotrachela* and *Hypselostoma.* Each of these species, except *H. erawan,* is known only from its type locality (approximate locations of type localities are shown in Fig. 1), but as more intensive collecting is undertaken in Thailand and other Asian countries, the known distributions of these species may be extended. The habitats of all of the new species except one, the leaf-litter-inhabiting *Hypselostoma panhai*, were limestone walls. The impetus for naming these species at this time is that they are included in a molecular study, about to be published, of the relationships of various Pupillidae in Thailand (Tongkerd *et al.,* 2003).

The three genera, *Anauchen, Gyliotrachela* and *Hypselostoma,* belong to Pilsbry's (1917) Hypselostoma-Boysidia group, and our placement of the nine new species into these genera basically follows Pilsbry. This taxonomic placement relies on the presence and condition of the barriers on the parietal wall of the shell aperture (the parietal and angular lamellae), and the condition of the last whorl of the shell, *i.e.,* whether or not a portion of the last whorl is "free" from (unattached to) the preceding whorls. In the genus *Anauchen,* only the parietal lamella is present (the angular lamella is absent), and the entire last whorl is attached to the preceding whorls. In *Gyliotrachela,* in addition to the parietal lamella, the angular lamella is present, and a portion of the last whorl is free, forming an extension (tuba). In *Hypselostoma*, the last whorl is also free, but the parietal and angular lamellae are fused (concrescent). Exceptions to our use of these characters are discussed with the two exceptional species, *Hypselostoma panhai* and *H. taehwani.* [Pilsbry was aware that his might not be a perfect generic-level classification system for the Hypselostoma-Boysidia group: "...no doubt a great many species remain to be discovered in southern China and Indo-China, and they will test the distinctions now drawn" (Pilsbry, *op. cit.,* p. 174).]

The nine species in this paper can be grouped for easier recognition by the characteristics of their last whorls, *i.e.,* as to whether or not part of the last whorl forms a tuba, and the characteristics of this tuba. In one of the species (*Hypselostoma panhai*) there is no tuba, *i.e.,* the last whorl and the shell aperture, including the peristome, are adnate. *Hypselostoma panhai* can be easily distinguished from other high-spired, tubaless pupillids by a combination of additional characteristics, *e.g.,* spire contour, shape of whorls, surface sculpture, and number and configuration of apertural barriers. In the other eight species, in which part of the last whorl forms a tuba, the nature of the tuba itself is important in species recognition, *i.e.,* whether the tuba extends horizontally out from the shell, or bends upward, or downward, and in the comparative relative length of the tuba (whether it is long, short, or something in between). *Anauchen chatnareeae, Gyliotrachela khaochakan* and *G. saraburiensis* have short, more or less horizontal tubas; *Gyliotrachela kohrin* and *Hypselostoma erawan* have moderately extended, upwardly directed tubas; *G. diarmaidi* and *G. surakiti* have long, upwardly directed tubas, and *Hypselostoma taehwani* has a downwardly directed tuba.

Since none of the nine species described in this paper seem to fit the descriptions of species described in the past, the purpose of this paper is to formally describe these species as new to science. Their descriptions follow.

MATERIALS AND METHODS

The descriptions of the shells were made using of a Wild M5 stereoscopic light microscope with camera lucida attachment, augmented by scanning electron microscope (SEM) pictures. Drawings were made of the shell apertures and the included barriers, because the details of these sometimes do not show in SEM pictures. In preparation for having pictures taken by the SEM, the shells were gently and carefully cleaned with a delicate brush while they were immersed in water. In the description of the snails' shells, the terms "upward" and "downward" are in reference to the shell when it is observed with the apex up, the base down, and the shell aperture toward to the observer. The width of the umbilicus was measured from where the coil of the body whorl diverges from the regular coiling direction of the shell to the opposite side of the umbilicus. For those species with a sulcus (groove) in the umbilicus wall, two measurements were taken, one from suture to opposing suture, and the other from the edge of the sulcus on one side of the umbilicus to the edge of the opposing sulcus on the opposite side of the umbilicus. The latter measurement was taken as the width of the umbilicus. Shell color was determined by making comparisons (a somewhat subjective procedure) with Ridgeway's (1912) *Color Standards and Color Nomenclature*—to be found in most libraries connected with substantial natural history museums—and, for those without access to Ridgeway's book, with a *Pantone® Process Color Imaging Guide,* although the latter is not as easy to use as is

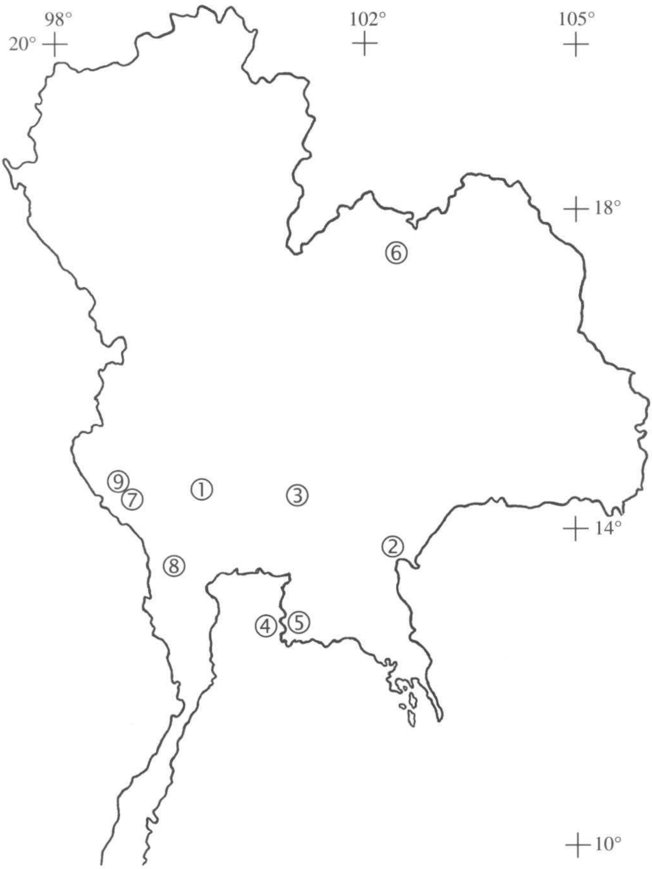

FIG. 1. Map showing the locations of the type localities of the nine microsnails described in this paper. **1**, *Anauchen chatnareeae*; **2**, *Gyliotrachela khaochakan*; **3**, *G. saraburiensis*; **4**, *G. kohrin*; **5**, *G. diarmaidi*; **6**, *G. surakiti*; **7**, *Hypselostoma erawan*; **8**, *H. taehwani*; **9**, *H. panhai.*

Ridgeway's book. Holotype and paratype specimens of the new species have been deposited in the Chulalongkorn University Zoological Museum (CUMZ), Bangkok, Thailand. Additional paratypes are housed in the Museum of Zoology, University of Michigan (UMMZ), Ann Arbor, Michigan.

Anauchen chatnareeae Panha & Burch, new species
(Figs. 2, 3)

Description of holotype. Shell elongate, pyramidal, turreted, with a very brief tuba. In cross-section, the tuba is nearly square, with rounded corners. Buffy Brown (Ridgeway) or ca. a light OGZR-C (Pantone) in color, with 5 1/2 whorls. Shell measurements are given in Table 1. Nearing maturity, growth of the last half of the body whorl changes direction a little, continuing at about a 14° angle upward from the direction of the previous shell growth. Then, near the end of shell growth and near attainment of adulthood, the direction of shell growth changes again—to about the original angle of coiling. Spire elongated, high, turreted, evenly sloped. Sutures deeply impressed. Periphery of the first and second whorls rounded, third and fourth whorls angular, almost carinate; body whorl angular, with a furrow running just dorsal to the angulation; this furrow begins on the penultimate whorl. Umbilicus rather narrow and some-

TABLE 1. Shell measurements of holotype specimens.

Character	Species (measurements in mm)								
	A. chatnareeae	*G. khaochakan*	*G. saraburiensis*	*G. kohrin*	*G. diarmaidi*	*G. surakiti*	*H. erawan*	*H. taehwani*	*H. panhai*
shell height, including aperture lip, or tuba if present	2.90	3.11	2.16	1.72	2.10	2.40	1.55	2.52	2.40
height of body whorl and spire	2.85	3.01	2.09	1.63	1.65	1.89	1.55	2.32	2.40
shell width, including aperture lip, or tuba if present	2.77	3.00	2.94	2.90	3.78	4.40	2.78	3.44	1.98
width of body whorl (to where tuba begins)	2.42	2.15	1.92	1.90	2.15	2.27	1.79	2.04	–
major diameter, including aperture lip, but not including tuba if present	2.77	2.42	2.06	2.10	2.60	2.65	2.06	2.26	2.06
minor diameter	2.26	2.19	1.92	1.90	2.17	2.25	1.78	2.00	1.75
length of tuba	0.25	0.44	0.58	0.56	1.30	1.8	0.36	1.04	–
number of whorls, excluding tuba if present	5 3/8	6 1/2^{+}	4 5/8	3 3/4	4^{+}	4 1/4	4 1/4	4 3/8	5 1/4^{-}
width of umbilicus	0.71	0.84	0.73	0.69	1.07	1.03	1.08	0.60	0.36
number of striae per 0.5 mm at and near center of body whorl	–	13.3	13.3	9	12	–	5	11	20

what deep. Nuclear whorls ca. 2 1/5; with delicate, close-set spiral cordlets; whorls become striatulate near the end of the protoconch. Teleoconch finely tuberculate; striatulate. Shell surface generally lacks spiral striae, although at a few places on the shell surface the granules seem to coalesce to form, rough, raised spiral striae. Beginning at the third whorl is a slight supra-angular (*i.e.,* just above [dorsal to] the peripheral angle) spirally-running depression on the outer surface of the shell, which becomes more obvious and deeper as the whorls elongate with continued growth, until on the last (body) whorl it is a well-delineated groove, ending at the expanded apertural lip. This is the *upper palatal groove*. On the base of the shell a second slight depression starts soon after the beginning of the body whorl and continues on the neck of the short tuba, becoming more expressed along its way to the expanded apertural lip. This is the *lower palatal groove*. A third groove begins at the commencement of the body whorl along the basal part of the outer umbilicus, becoming deeper as it proceeds to the expanded apertural lip. This is the *columellar groove.*

Aperture roundly trapezoidal; peristome solute, at the end of the very short tuba, rather broadly expanded, weakly sinuated at the columellar-parietal lip and at the angulo-palatal lip. Apertural embayments are as follows: a weakly developed, round angulo-palatal, a rounded columellar-parietal, and an elongately rounded baso-palatal embayment. There are four apertural "teeth" or barriers—parietal, upper and lower palatal, and columellar—all rather deep-set, and each pointing toward the center of the lumen of the aperture, as though they represent the ends of a cross. The parietal and lower palatal barriers oppose each other, as—at right angles to these two—the columellar and upper palatal oppose each other. The largest and best developed of the four barriers is the parietal lamella, followed by the lower palatal plica. On the parietal lamella there is a thin, low, distal flange-like extension going to the flexure of the peristome, and ending as a small bulbous thickening. The smallest barrier is the columellar lamella. The upper and lower palatal and columellar barriers sit on low mounds projecting centrad from the apertural wall—where, on the outer side of the shell, occur furrows or grooves. None of the barriers are spinose.

Variation. The holotype measures 2.90 mm in length (height); the eight paratypes at the UMMZ range in size from 2.88 to 3.12 mm in length. The spire angles of the shells range from 43° to 51° (holotype). On several of the paratypes, the smallest apertural barrier is the upper palatal plica rather than the columellar lamella. The distal flange on the parietal tooth is accentuated in two of the paratypes, present as a low terminal mound in another, and absent from the other five shells.

Type locality. Tam Sua, on the limestone hill on the west side of Tam Sua Temple, Utong District, Suphanburi Province, 14° 17' 31" N, 100° 7' 31" E, 20 meters elevation, Thailand.

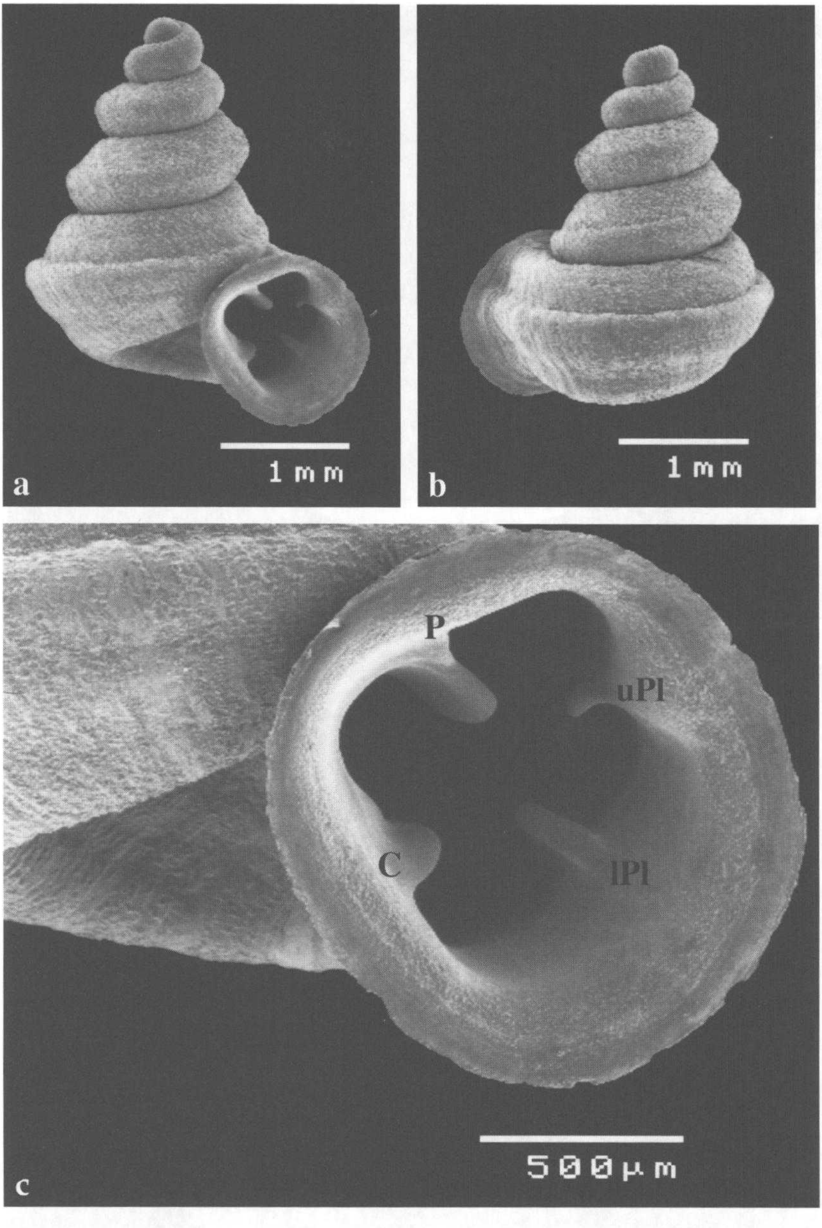

FIG. 2. *Anauchen chatnareeae* n. sp., paratype. **a**, Apertural view; **b**, abapertural view; **c**, aperture enlarged. C = columellar lamella, P = parietal lamella, lPl = lower palatal plica, uPl = upper palatal plica.

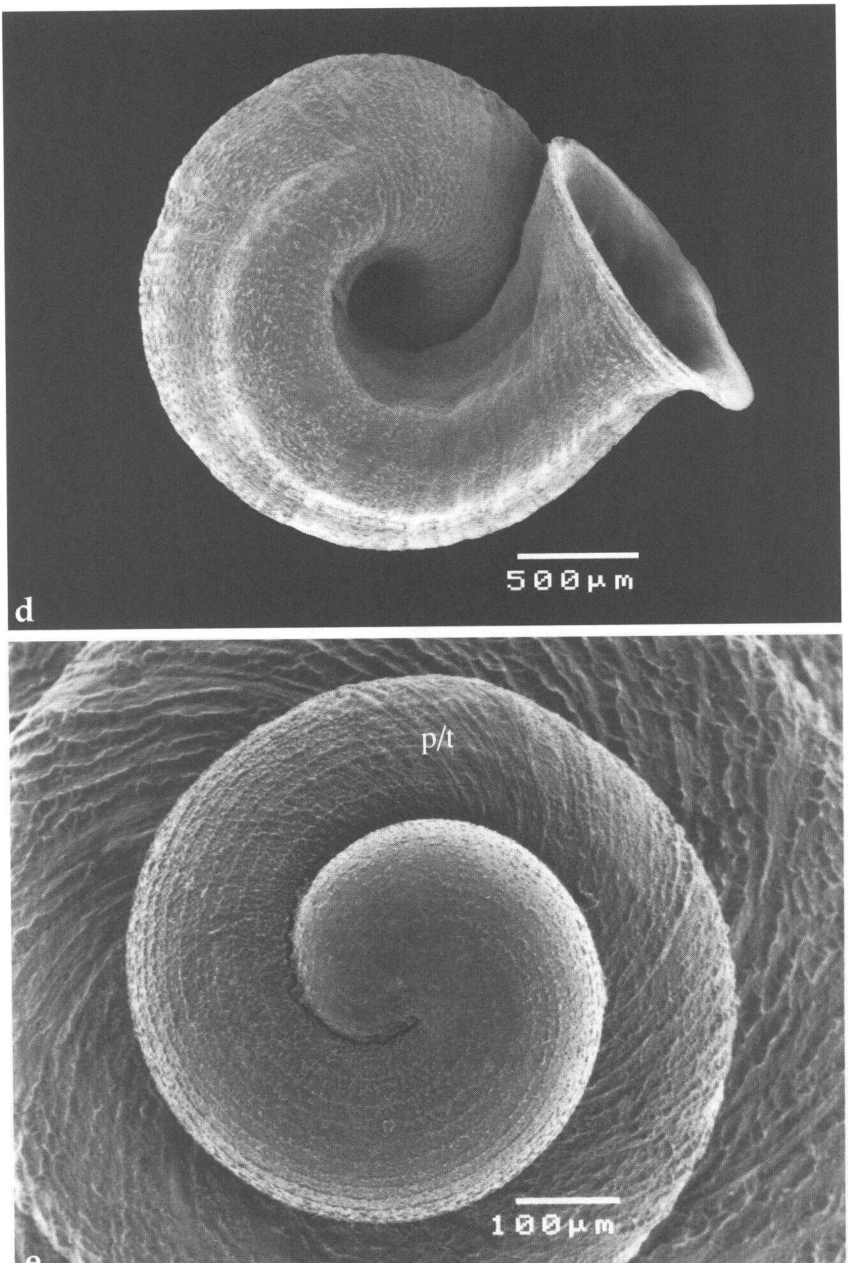

FIG. 2. *Anauchen chatnareeae* (continued). **d**, Umbilical view; **e**, apical whorls. p/t = transition region between the protoconch and the teleoconch.

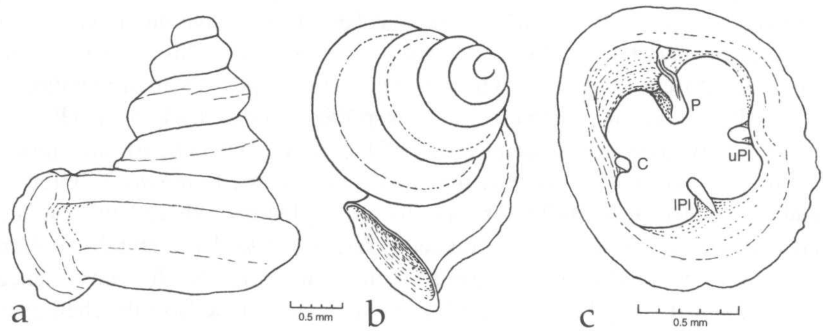

FIG. 3. *Anauchen chatnareeae* n. sp., holotype. **a**, Abapertural view of the shell showing the change in direction of growth of the terminal half of the last whorl; **b**, shell in apical view, but tilted to show the very short tuba; **c**, apertural barriers. Lamellae and plicae: C = columellar; P = parietal; lPl = lower palatal; uPl = upper palatal.

Etymology. This species was named after the collector, Ms. Chatnaree Meesukkho.

Type material. The holotype (CUMZ 44034) and 21 paratypes (CUMZ 44035) are deposited in the Chulalongkorn University Zoological Museum. Another eight paratypes (UMMZ 300097) have been deposited in the Museum of Zoology, University of Michigan.

Habitat. Found on limestone walls and in rock crevices with very small areas of moss, under the shade of some large trees. Sua cave [Tam Sua] is in the opposite part of the hill, about 100 meters from the type locality. Many *Cryptozona siamensis* (Tomlin) ariophantid snails were on the ground near the wall where the collection was made.

Diagnosis. *Anauchen chatnareeae* is a minute gastrocoptine pupillid pulmonate gastropod with an elongate shell with high, evenly sloped, pyramidal spire, its last several whorls angular and with a distinct supra-angular groove, its peristome solute and on the end of a very short tuba, and four (only) well developed apertural barriers (parietal, columellar, and upper and lower palatal), granulate teleoconch, and nuclear whorls pitted on top and spirally striate on the lower part.

Remarks. *Anauchen chatnareeae* has a very short tuba, which is hardly evident in most views of the shell, but it can best be seen looking down on the shell with the apex toward the viewer, in a tilted apical view (Fig. 3b). In the latter view, the tuba although distinct is but little more than the solute flare of the peristome. During growth, the last ca. half whorl changes its normal direction of coil—as it does in the other species described in this paper—and then near the aperture, shell growth assumes the regular coiling direction. The genus *Anauchen*, in comparison with other Asian members of the Hypselostoma-Boysidia group of genera (Pilsbry, 1917), lack an angular lamella and have but a single non-concrescent parietal lamella, and the last whorl is adnate. "This last is not a very important difference, and one which may perhaps disappear with further discoveries" (Pilsbry, *op cit.,* p. 188). Of the four species of *Anauchen* known to Pilsbry, two (*A. messageri* and *A. gereti* [both of Bavay & Dautzenberg]) are spirally striate. It is not known whether the other two species (*A. angulinus* [Gredler] and *A. rochebruni* [Mabille]) are spirally striate, but nevertheless Pilsbry (*loc. cit.*) mentioned that *Anauchen* is related to *Hypselostoma* by its spiral sculpture.

Our species "*chatnareeae*" is placed in the genus *Anauchen* for convenience, our placement being based on the lack of an angular lamella in the shell aperture, and a non-concrescent parietal lamella. However, our specimens lack spiral teleoconch sculpture, and have a solute peristome and a very short tuba (if the projected and reflected peristome can be called that). Further studies may indicate that the latter characters are of greater importance and dictate some other generic placement.

The shell of *Anauchen chatnareeae* differs from *A. messageri* and *A. gereti* (both from northern Vietnam) by lacking spiral teleoconch striae, having instead a granulose sculpture. It differs from *A. angulinus* (from east central China) by having four apertural barriers rather than one, by its solute peristome, and by its angular, almost carinate body whorl. *Anauchen chatnareeae* differs from *A. rochebruni* (from Vietnam) by its four rather than two apertural barriers, and its complete, solute peristome. It differs from *A. angthongense* Panha, *A. chedi* (Panha), *A. huaykhakang* Panha and *A. utaithanesis* Panha (all four residents of Thailand) by its pronouncedly angular last whorl, and by the supra-angular (upper palatal) groove on the last several whorls. The shell of *Anauchen chatnareeae* differs from *A. angthongense, A. chedi* and *A. huaykhakan* by its granulate rather than spirally striate surface sculpture, and by having four apertural barriers rather than five (for *A. chedi,* see Burch & Panha, 2000, fig. 5). *Anauchen chatnareeae* differs from *A. utaithanensis* by having only four apertural teeth, the parietal lamella is not bifid, interpalatal and infrapalatal plicae are lacking, and the periphery is angular.

Gyliotrachela khaochakan Panha & Burch, new species
(Figs. 4, 5)

Description of holotype. Shell elongate, pyramidal, turreted, with a very short tuba, neither ascending nor descending. In cross-section, the tuba is roundly triangular. The shell is a rather light Dark Olive-Buff (Ridgeway) or ca. 4505 C (Pantone) in color, and has 6 1/2 whorls. Shell measurements are given in Table 1. Nearing maturity, growth of the last half of the body whorl changes direction slightly, continuing upward at about an 8° angle from the direction of the previ-

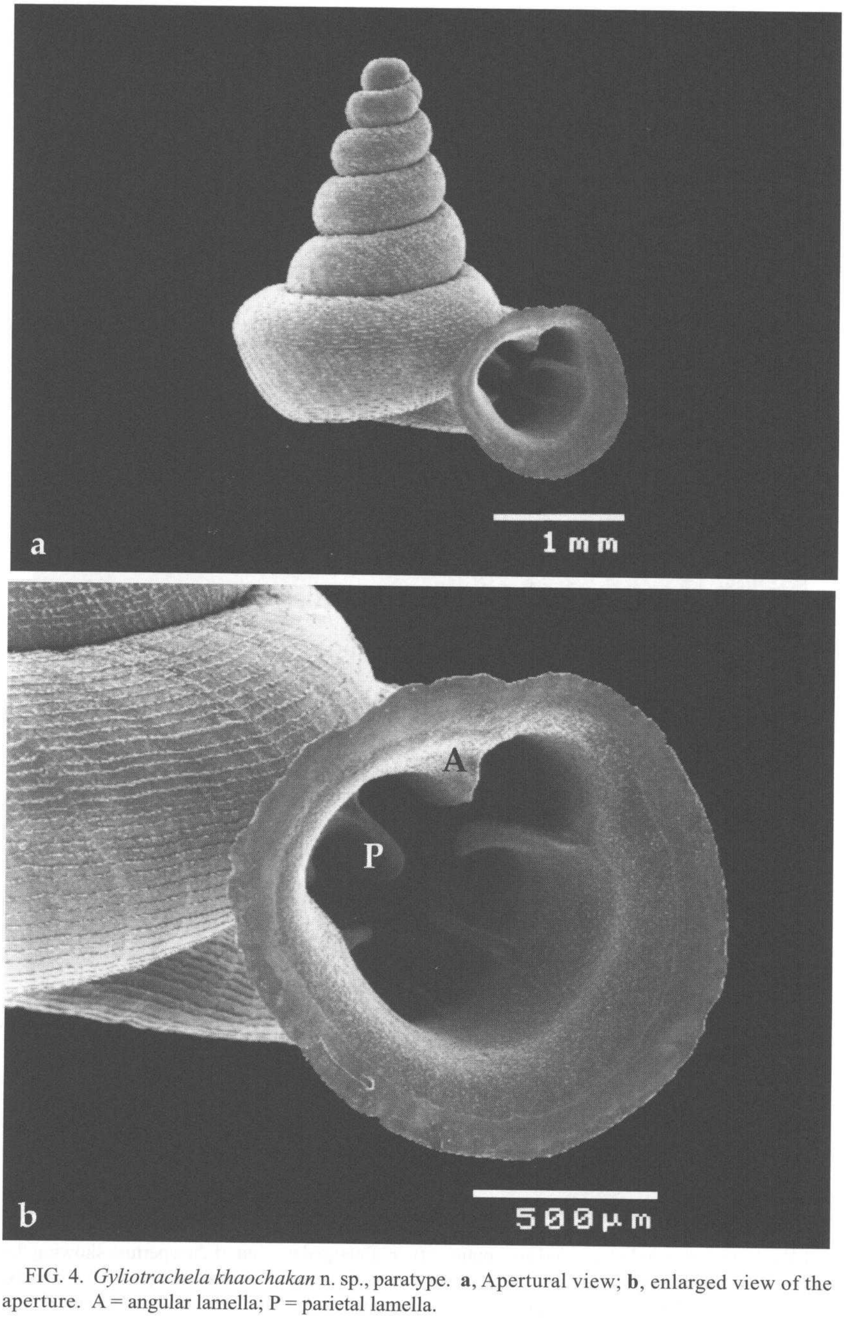

FIG. 4. *Gyliotrachela khaochakan* n. sp., paratype. **a**, Apertural view; **b**, enlarged view of the aperture. A = angular lamella; P = parietal lamella.

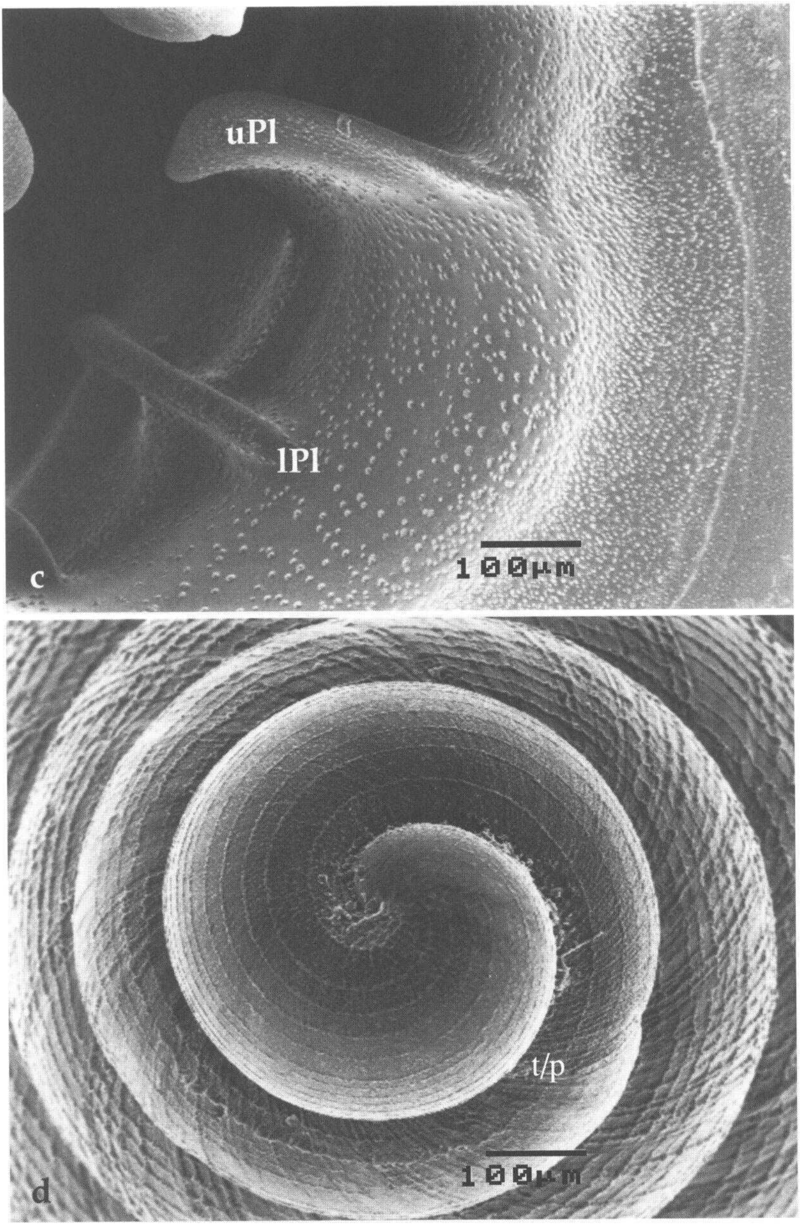

FIG. 4. *Gyliotrachela khaochakan* (continued). **c**, Enlarged portion of the aperture showing the lower (lPl) and upper (uPl) palatal plicae; **d**, shell apex showing the protoconch (first 1 3/4 whorls) and the spiral and transverse sculpture of the protoconch and teleoconch. t/p = transition region between the protoconch and the teleoconch.

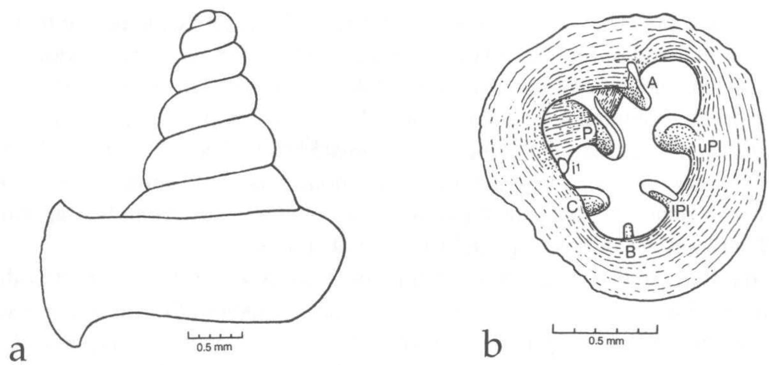

FIG. 5. *Gyliotrachela khaochakan* n. sp., holotype. **a**, Abapertural view of the shell showing the change in direction of growth of the terminal half of the last whorl; **b**, apertural barriers. Lamellae and plicae: A = angular; B = basal; C = columellar; P = parietal; lPl = lower palatal; uPl = upper palatal; i^1 = infraparietal.

ous shell growth. There is a short tuba, which extends more or less perpendicularly out from the spire axis. The spire is elongated, high, nearly evenly sloped, but slightly concave-sided. Sutures deeply impressed. Body whorl obtusely angular; other whorls rounded. Umbilicus of moderate depth and size, measuring ca. 1/3 to 1/4 the shell diameter. Nuclear whorls 1 1/3. The protoconch sculpture as seen on a SEM photograph of a paratype (Fig. 4d) consists of well developed spiral cordlets; some rounded shallow pits occur on the dorsum of the protoconch, especially near the suture. The teleoconch sculpture is spirally striate, finely striatulate, decussate, with close, irregularly spaced radial cordlets. A hardly noticeable upper palatal groove is evident on part of the last whorl, then disappears, reappearing as a more defined groove at the distal-end area of the upper palatal plica and continuing nearly to the peristome. The lower palatal groove is evident only on the side of the whorl opposite the lower palatal barrier, and even there it is hardly noticeable. The same applies to the upper palatal groove, until it reaches the end of the upper palatal plica area; then—and nearly to the peristome—it is a more defined groove. A well-defined columellar groove extends from the umbilicus to shortly beyond the distal end of the columellar lamella.

Aperture irregularly rounded; peristome free, continuous, rather broadly expanded. The apertural embayments are a semi-circular angulo-palatal and a broadly curved columellar-angular, the latter with the parietal lamella deep-set within it. The five major barriers (angular, parietal, columellar, and upper and lower palatal) are all prominent, elongate, noticeably thin, and entering. They all project well into the lumen of the aperture. The basal plica is also blade-like and entering, but it is much shorter and lower than the other teeth. The angular and parietal barriers are rather widely separated. The angular lamella extends to the reflection of the peristome; the upper palatal plica extends nearly that far. The parietal and infraparietal lamellae remain wholly on the parietal wall of the body whorl, not extending outward (distally) onto the tuba. The distal ends of the parietal, columellar, and lower palatal barriers terminate deeper within the aperture. The columellar lamella is laminate, and directed downward. The infraparietal barrier is deep-set, very low, mound-like, not lamellar, and is not readily evident without close inspection. The apertural barriers and the apertural wall surfaces are minutely granulose, but not spinose.

Variation. In the 11 specimens examined, there is very little variation in shell shape, sculpture, color, and in number and characteristics of the apertural barriers. Several specimens have a slightly more acute peripheral angle, several are a bit more tannish in color, and one of the 11 specimens had two infraparietal lamellae rather than one.

Type locality. Chakan Mountain, east of Khaochakan Temple, Khaochakan District, Srakeaw Province, 13° 39' 17" N, 102° 5' 12" E, 70 meters elevation, Thailand.

Etymology. This species was named after Chakan Mountain, where the snail was discovered.

Type material. The holotype (CUMZ 44040) and 31 paratypes (CUMZ 44041) are deposited in the Chulalongkorn University Zoological Museum. Another nine paratypes (UMMZ 300098) have been deposited in the Museum of Zoology, University of Michigan.

Habitat. *Gyliotrachela khaochakan* was found on a limestone wall, which also supported mosses. There were many ariophantid land snails, *Cyclophorus volvulus* (Müller), in the area.

Diagnosis. *Gyliotrachela khaochakan* is a minute gastrocoptine pupillid pulmonate gastropod with an elongate shell with a high, pyramidal spire and a short, horizontal tuba. The whorls are rounded, except for the body whorl, which is obtusely angular and roundly shouldered. The teleoconch is sculptured with closely-spaced spiral cordlets, crossed at somewhat regular intervals by transverse cordlets, producing an irregular latticed appearance. The shell aperture contains seven thin, blade-like barriers.

Remarks. The great majority of the species of the Hypselostoma-Boysidia group have short, more or less horizontal tubas. Some species with these characteristics are placed in the genus *Hypselostoma* by their having the dominant barrier on their parietal walls being a concrescent, fused, parietal-angular lamella. Other species of the group, by virture of their separate parietal and angular lamellae, are assigned to the genus *Gyliotrachela.* It is to the latter group that *G. khaochakan* belongs.

Gyliotrachela species may be divided into two major subgroups on the basis of the microsculpture of their teleoconchs—those species with spiral cordlets (*i.e.*, minute, closely-set, raised parallel ridgelets running in the same direction as the shell's spiral coil), and those species that lack spiral sculpture (some species of which are decorated instead with minute granulations). *Gyliotrachela khaochaken* belongs to the spirally striate group. Some of these spirally striate species (*G. adela* Thompson & Upatham, *G. saxicola* Benthem Jutting) have depressed spires, others (*G. dohertyi* Fulton, *G. everetti* Smith, *G. napierana* Solem, *G. ningbingia* Solem, *G. salpinx* Benthem Jutting) have moderately depressed spires, and yet other species (*G. catherina* Solem, *G. concreta* Benthem Jutting, *G. fruhstorferi* Möllendorff, *G. saraburiensis* Burch & Panha) have moderately raised spires. *Gyliotrachela khaochakan* differs from all of the currently known spirally striate gyliotrachelas by its exceptionally high spire. Other high-spired, striate species occur in the Hypselostoma-Boysidia group (*H. annamiticum altus* Pilsbry, *H. cambodjense* Benthem Jutting, *H. dilatatum* Benthem Jutting, *H. edentulum* Möllendorff, *H. rupestre* Benthem Jutting), but these species have concrescent parietal teeth and so by current taxonomy they are placed in the genus *Hypselostoma*.

Gyliotrachela saraburiensis **Panha & Burch, new species**
(Figs. 6, 7)

Gyliotrachela saraburiensis Panha, Panha & Burch, 2002, *Walkerana,* 12(28), p. 81, *nomen nudum*.

Description of holotype. Shell conoid with enlarged body whorl, and a short, slightly ascending tuba. In cross-section, the tuba is obtusely triangular. The shell is Light Buckthorn Brown (Ridgeway) or ca. OJZI-C (Pantone) in color, and has about 4 3/4 whorls. shell measurements are given in Table 1. Nearing maturity, growth of the last half of the body whorl changes direction a little, continuing upward at about a 17° angle from the direction of the previous shell growth. The spire is somewhat depressed, with a disproportionately enlarged body whorl. The first three spire whorls are evenly sloped. The sutures are well impressed. The body whorl is very weakly angulated and slightly shouldered; other whorls rounded. The umbilicus is deep and rather wide, measuring more than 1/2 the shell diameter. The nuclear whorls are ca. 1 3/4. The protoconch appears pitted under a stereomicroscope; spiral striae (cordlets) are not evident (these begin with the teleoconch). The teleoconch is spirally striate, finely striatulate, decussate, with radial cordlets. The angulo-parietal groove is short, relatively wide at its beginning, and narrow at its distal end, which is at about the commencement of the flare of the peristome. The upper palatal groove begins as a very shallow depression, and ends as a wide, deeper depression near the peristome. There is no lower palatal groove. The columellar groove is shallow, ending at the beginning of the expansion of the peristome. It is paralleled by a very shallow groove corresponding to the larger subcolumellar lamella. This latter groove is a continuation of the groove of the columella carina. The columellar groove is an extension of a shallow mid-whorl concavity on the inner body whorl of the umbilicus.

The aperture is nearly round. The peristome is free, continuous, broadly expanded, strongly sinuated at the angulo-palatal lip, and moderately sinuated at the columellar-palatal lip. The apertural embayments are as follows: a semicircular angulo-palatal, a semicircular columellar-angular, and a rectangular basal embayment. There are the usual five major barriers in the aperture: parietal, angular, upper and lower palatal, and columellar. The four that form the ends of a cross (the parietal, columellar and the upper and lower palatal) in so many species of this group do so here also. But in addition to these relatively large teeth, there are numerous smaller barriers: three infraparietals, two supracolumellar, three subcolumellar, five infrapalatals, three interpalatals, five suprapalatals, two parallels, and an additional barrier between the parietal and angular lamellae deep within the aperture. All of the barriers are rather deep within the aperture, but the angular and the upper palatal extend distally to near the peristome. The high and narrow five major teeth are elongate barriers, especially the parietal and angular lamellae. The apertural barriers are granulose (or spinose).

Variation. The spire angle (not including the body whorl) of the holotype is 58°; in the five paratypes at UMMZ, the spire angle varies from 50° to 59°. There is some rather minor variation in spire height, tuba length, and in shell color. There is little variation in peripheral angulation and umbilical width.

Type locality. East of Tepitak Tamaram Temple, Tepitak Mountain, Muang Saraburi District, Saraburi Province, 14° 36' 57" N, 101° 15' 50" E, 510 meters elevation. Thailand.

Etymology. This species is named after Saraburi province, where the snail was found.

Type material. The holotype (CUMZ 44046) and 11 paratypes (CUMZ 44047) are deposited in the Chulalongkorn University Zoological Museum. Another five paratypes (UMMZ 300099) have been deposited in the Museum of Zoology, University of Michigan.

Habitat. *Gyliotrachela saraburiensis* was living on a limestone wall east of the temple with some small plants—*Chromolaema odoratum* (Linnaeus) R.M. King & H. Robinson. The snails were on the face of the wall or hiding in its small holes or crevices.

Diagnosis. *Gyliotrachela saraburiensis* is a minute gastrocoptine pupillid pulmonate gastropod with moderate spire, and a short, horizontal tuba. The teleoconch surface is spirally striate and decussate, especially in the upper whorls. The shell is moderately umbilicate. The last whorl is weakly angulate, without

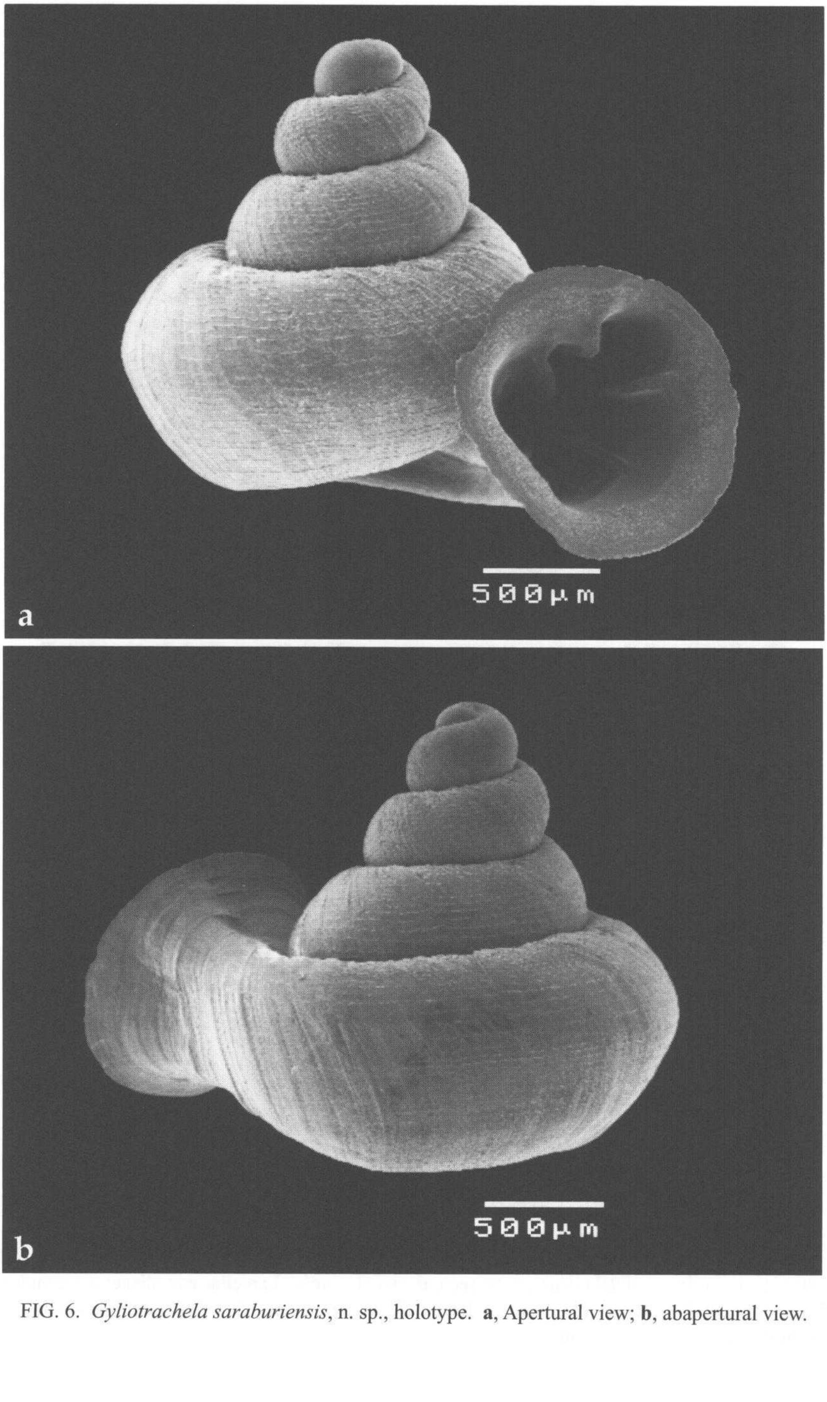

FIG. 6. *Gyliotrachela saraburiensis*, n. sp., holotype. **a**, Apertural view; **b**, abapertural view.

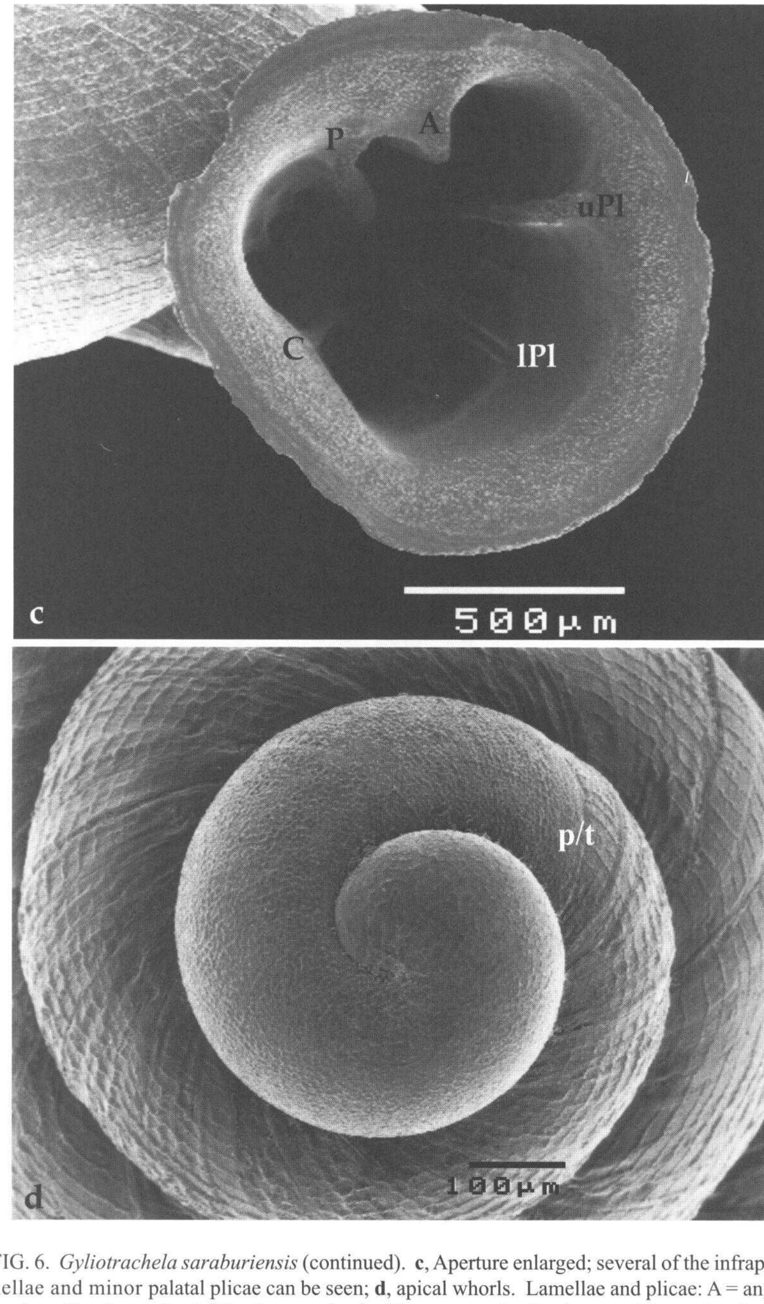

FIG. 6. *Gyliotrachela saraburiensis* (continued). **c**, Aperture enlarged; several of the infrapalatal lamellae and minor palatal plicae can be seen; **d**, apical whorls. Lamellae and plicae: A = angular, C = columellar, P = parietal, lPl = lower palatal, uPl = upper palatal. p/t = transition region between the protoconch and the teleoconch.

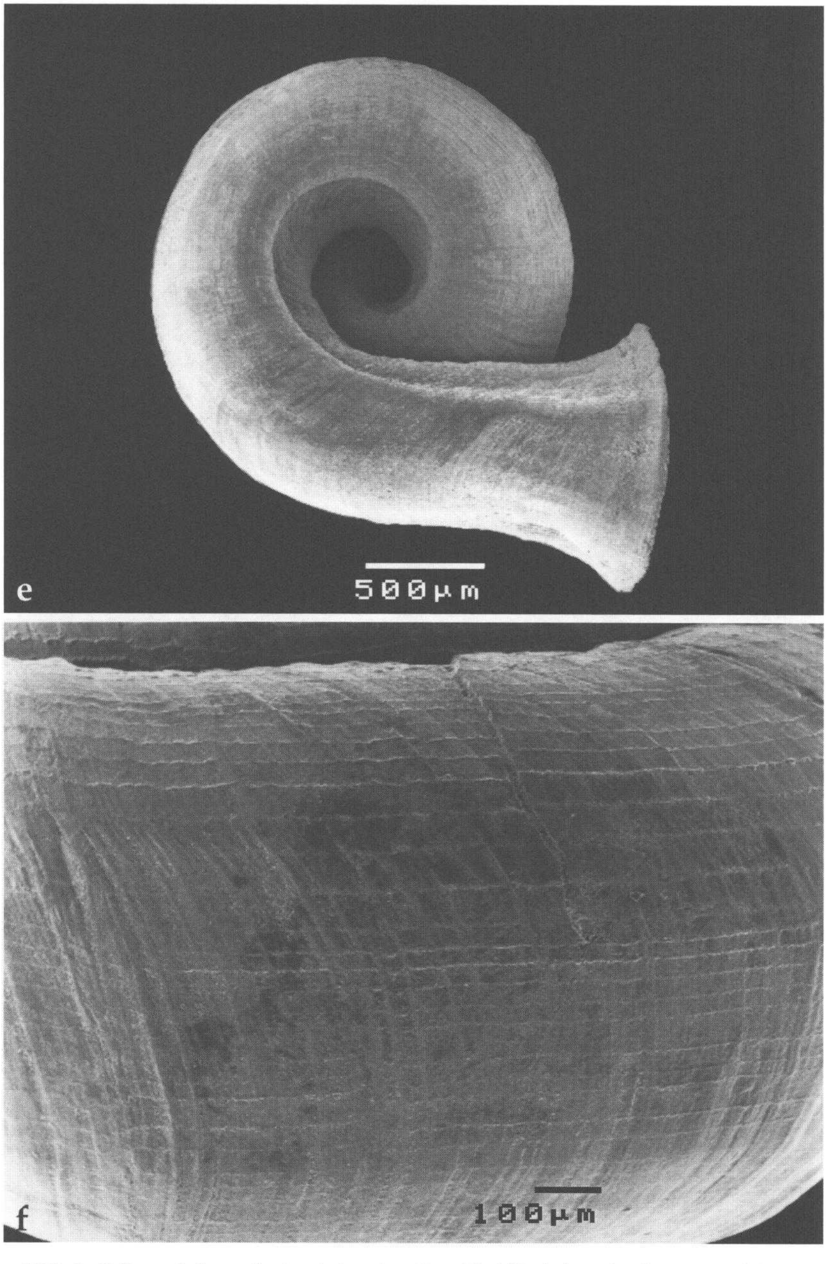

FIG. 6. *Gyliotrachela saraburiensis* (continued). **e**, Umbilical view; **f**, enlargement of the sculpture on the last whorl.

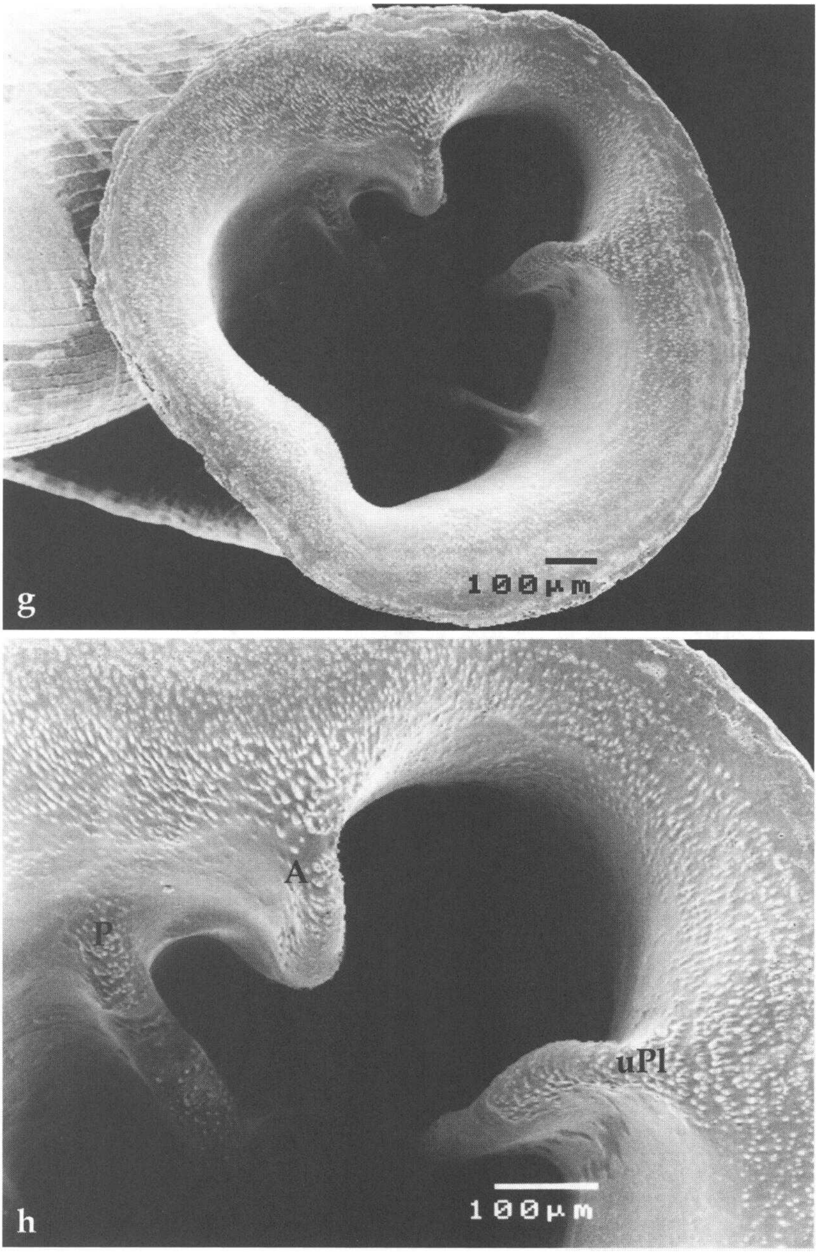

FIG. 6. *Gyliotrachela saraburiensis* (continued). **g**, Aperture enlarged; **h**, several teeth enlarged. A = angular lamella, P = parietal lamella, uPl = upper palatal plica.

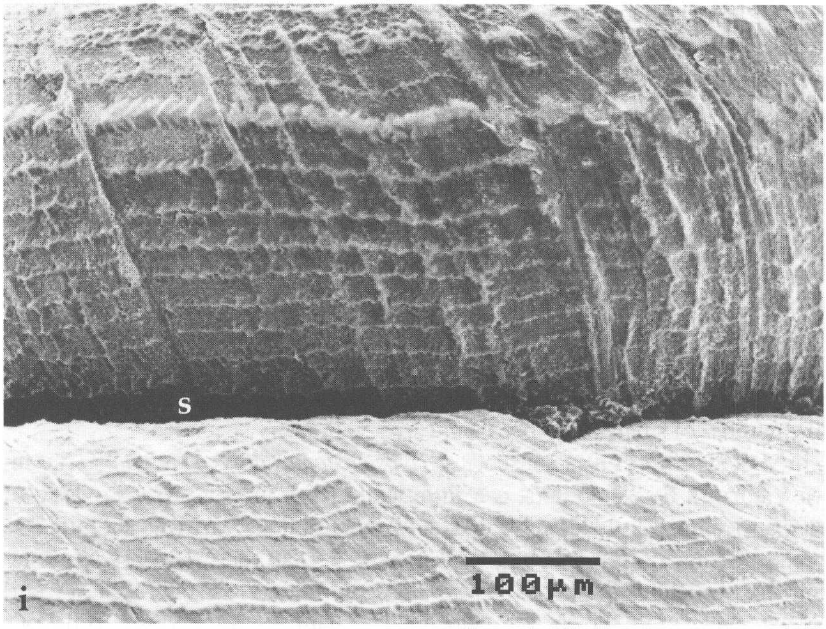

FIG. 6. *Gyliotrachela saraburiensis* (continued). **i**, Surface sculpture and suture (s).

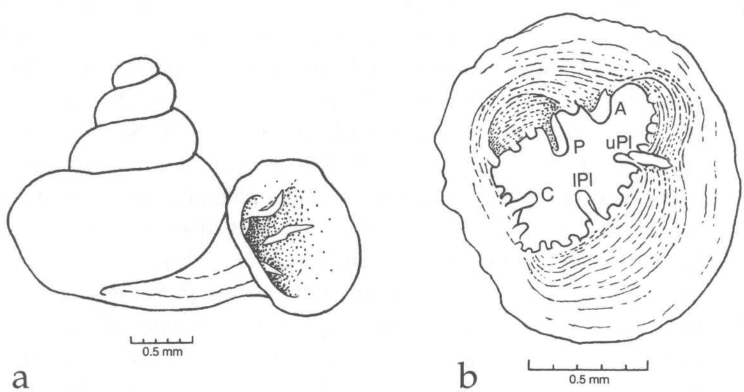

FIG. 7. *Gyliotrachela saraburiensis* n. sp., holotype. **a**, Shell in side view showing the upward tilt of the tuba; **b**, apertural barriers. Lamellae and plicae: A = angular; C = columellar; P = parietal; lPl = lower palatal; uPl = upper palatal.

sulci or carinae. In addition to the five major apertural barriers (angular, parietal, columellar, and lower and upper palatal) there are three infraparietals, two supracolumellar, three subcolumellar, five infrapalatals, three interpalatals, five suprapalatals, two parallels, and an additional barrier between the parietal and angular lamellae deep within the aperture. The apertural barriers are spinose.

Remarks. *Gyliotrachela saraburiensis* is a member of the spirally striate group of *Gyliotrachela* species and, like some of them, it has a short, horizontal tuba. *Gyliotrachela saraburiensis* differs from *G. diarmaidi, G. kohrin* and *G. surakiti* described later in this paper by its more or less horizontal, rather than upwardly directed, tuba. In shell shape, our specimens seem close to *Gyliotrachela crossei* (Morlet) as described and illustrated by Pilsbry (1917, p. 216, pl. 36, figs. 11-13). However, *G. crossei* lacks spiral striae on its teleoconch, its umbilical opening is narrower, its periphery is more sharply angled, and, possibly, the aperture contains fewer barriers. *Gyliotrachela crossei,* like *G. saraburiensis,* has many apertural barriers. Pilsbry showed 17 apertural barriers in the specimen of *G. crossei* he illustrated, but stated that although the major barriers (angular, parietal, columellar, and upper and lower palatal) are constant, "the number of small accessory teeth varies with every specimen."

In Möllendorff's (1901) subspecies "*Hypselostoma*" *crossei endodonta* (northern Vietnam), the "umbilicus is a little wider [than in *G. crossei s.s.*, also of Vietnam], spire a little less elevated, apex more oblique, last whorl a little less free, teeth much more deeply placed. Diam. 3.4, alt. 2.5." (Pilsbry's translation). In Möllendorff's subspecies *brevituba* (northern Vietnam), the "last whorl [is] very much more shortly free, spire higher. Diam. 3.1, alt. 2.5 mm." (Pilsbry's translation). Möllendorff's very brief descriptions contain no details regarding number and characteristics of the apertural barriers. The wider umbilicus in *G. c. endodonta* is closer to our specimens of *G. saraburiensis.* Photographs of Möllendorff's two subspecies in apertural view (but not showing exact detail of apertural dentition) were published by Zilch (1984, pl. 2, figs. 20 and 21)

Gyliotrachela saraburiensis is very similar to *G. catherina* Solem (Australia) in having an obtusely angulated body whorl, and like *G. catherina, G. saraburiensis* lacks a supra-angular sulcus (upper palatal groove). The silhouette of *G. catherina*'s spire is less convex than that of *G. saraburiensis*, and especially the apertural dentition is different. *Gyliotrachela catherina* has the five major apertural barriers characteristic of the genus, plus a basal plica. According to Solem (1981, p. 92), the lower infrapalatal and suprapalatal plicae are absent, and no other barriers are mentioned. [Solem, *loc. cit.,* says that the columellar lamella is also absent, although his fig. 11 shows a columellar lamella.] In contrast to *G. catherina, G. saraburiensis* has, in addition to the five major barriers, numerous supracolumellar, subcolumellar, infracolumellar, infraparietal, suprapalatal, interpalatal and infrapalatal barriers. *Gyliotrachela napierana* Solem (Australia) has a similar shell shape to *G. saraburiensis*, but its tuba is directed upward and the last whorl is more sharply angled, and somewhat obtusely carinated. *Gyliotrachela concreta* Benthem Jutting (Celebes, Indonesia) and *G. saxicola* Benthem Jutting (Malaya) have, like *G. saraburiensis*, short tubas and accessory apertural barriers, but both species are markedly carinate, and the accessory barriers are fewer (only three in *G. saxicola*). In *G. hungerfordiana* Möllendorff (northern Malaysia) and *G. transitans* (Möllendorff) (Samui Island, Thailand) the tuba is longer than that of *G. saraburiensis,* the shells have pronounced carinae, the teleoconch sculpture is granulate, and spiral striae are lacking. *Gyliotrachela everetti* (Smith) (Kalao Island, Indonesia) is also carinate, the carina is high on the whorl, below the carina is a broad, shallow sulcus (the upper palatal groove), and the shell is more widely unbilicate.

Gyliotrachela kohrin Panha & Burch, new species
(Figs. 8, 9)

Description of holotype. Shell depressed planiturbinate, moderately umbilicate, the body whorl produced into an ascending tuba, which rises to about the depressed apex of the shell spire. In cross-section, the tuba is obtusely triangular. The shell is a rather Dark Olive-Buff (Ridgeway) or ca. 4505 C (Pantone) in color, and has 3 3/4 whorls to where the tuba begins. Shell measurements are given in Table 1. Nearing maturity, growth of the last half of the body whorl changes direction greatly, continuing upward at about a 79° angle from the direction of the previous shell growth. The spire is depressed, although the first two whorls are raised above the disproportionately enlarged body whorl. The sutures are well impressed. The body whorl (which makes up most of the shell's outer periphery) is obtusely carinate and shouldered. The umbilicus is deep, and measures less than 1/3 the shell diameter. Nuclear whorls ca. 1 1/3; the protoconch appears smooth under the highest power of a stereoscopic microscope. Teleoconch spirally striate, finely striatulate, and decussate, with radial cordlets.

The angulo-parietal groove is well defined, broad, rather deep. The upper palatal groove is also well defined, and broad, with its beginning at the proximal end of the upper palatal plica. The lower palatal groove is very shallow, hardly perceptible. The columellar groove is shallow. The aperture is subquadrangular. Peristome free, continuous, broadly flared-out. The apertural embayments are as follows: a well-developed, rounded angulo-palatal, a more or less semicircular columellar-parietal, a somewhat triangular basal, and a triangular palatal embayment. There are five prominent barriers in the aperture—the parietal, angular and columellar lamellae, and the upper and lower palatal plicae. All five are rather deep-set and entering, but the angular lamella extends outward (distally) to the flexure of the peristome, and the upper palatal plica extends nearly as far. In addition to the five prominent teeth, there are numerous small accessory lamellae and plicae. On the parietal wall there are two—a very small infraparietal closer to the parietal lamella, and a larger infraparietal closer to the columellar surface. On the inner columellar surface are two very small supracolumellar lamellae and a larger subcolumellar lamella. On the palatal wall there are two infrapalatals, two small interpalatals, and two small suprapalatal plicae [or perhaps one suprapalatal plica and one parallel lamella]. All of the apertural barriers have spinose surfaces, except the angular lamella.

Type locality. On a limestone hill on Kohrin (Rin Island), which is a small island located in the upper Gulf of Thailand, south of Pattya Beach, eastern coast of Thailand, about 25 kilometers from the coast, Satthip District, Chonberi Province, 12° 48' 5" N, 100° 42' 4" E, 30 meters elevation, Thailand.

Etymology. This species is named after Rin Island, on which it was found.

Type material. The holotype (CUMZ 44043) and 28 paratypes (CUMZ 44044) are deposited in the Chulalongkorn University Zoological Museum. Another nine paratypes (UMMZ 300100) have been deposited in the Museum of Zoology, University of Michigan.

Habitat. *Gyliotrachela kohrin* was found on a limestone wall, which supported many plant species. *Gyliotrachela kohrin* lives on the walls and in rock crevices. Three ground snails, the ariophantids *Cryptozona siamensis* and *Sarika* sp., and a subulinid species, were also found here. *Cryptozona siamensis* and an arboreal camaenid snail, *Amphidromus* (*Amphidromus*) *inversus* (Müller), are the dominant snail species on the island.

Diagnosis. *Gyliotrachela kohrin* is a minute gastrocoptine pupillid pulmonate gastropod with depressed spire, a moderately long, upwardly directed tuba that reaches to or near the apex. The teleoconch is spirally striate, and decussate, especially in the upper whorls. The shell is moderately umbilicate, its last whorl weakly carinate. In the shell aperture there are the usual five major apertural barriers (angular, parietal, columellar, and lower and upper palatal), and additionally, numerous small accessory lamellae and plicae: two infraparietals, two supracolumellar lamellae, one subcolumellar lamella, two infrapalatals, two interpalatals, and two suprapalatal plicae. All of the apertural barriers have spinose surfaces, except the angular lamella.

Remarks. Pilsbry (1917) divided his genus *Gyliauchen* (preoccupied, replaced with *Gyliotrachela* by Tomlin, 1930, p. 24) into those species whose shell surface sculpture is "minutely rugose or granulose" and those whose shells are ornamented by "spiral threads or striae." About half of the presently known species of *Gyliotrachela* are spirally striate, including, in this paper, the two preceding species (*G. khaochakan* and *G. saraburiensis*), *G. kohrin* (described above), and the species to follow (*G. diarmaidi*). *Gyliotrachla kohrin* differs from *G. khaochakan* and *G. saraburiensis* by its much more depressed spire, its up-turned tuba, and its median carina. The latter character also differentiates *G. kohrin* from *G. diarmaidi,* which, additionally, has a much longer tuba and a wider umbilicus. In other Thai species, *Gyliotrachela adela* Thompson & Upatham lacks a carina and its aperture and the terminal part of the last whorl is downwardly deflected; *G. khaochongpran* (Panha & Burch) has a higher placed ca-

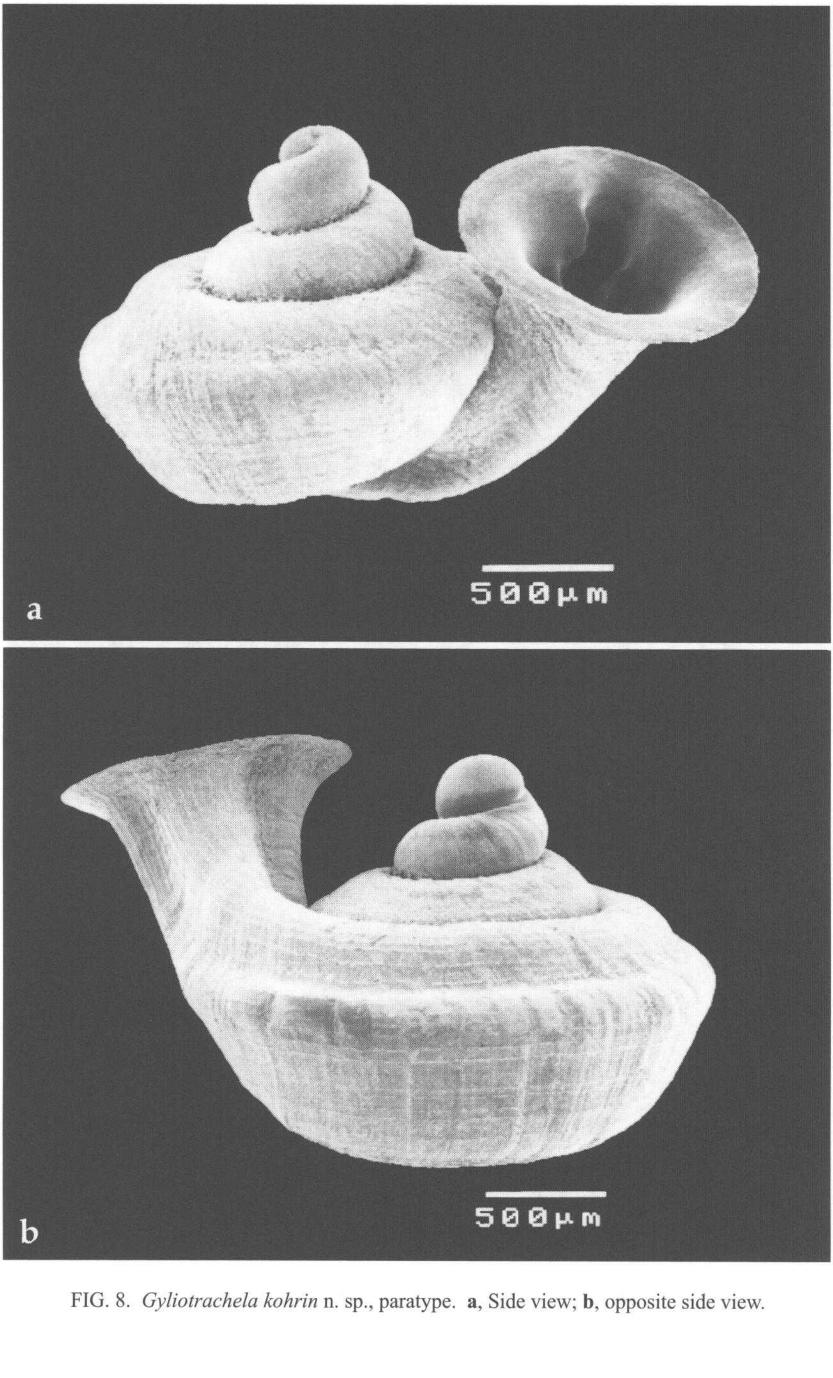

FIG. 8. *Gyliotrachela kohrin* n. sp., paratype. **a**, Side view; **b**, opposite side view.

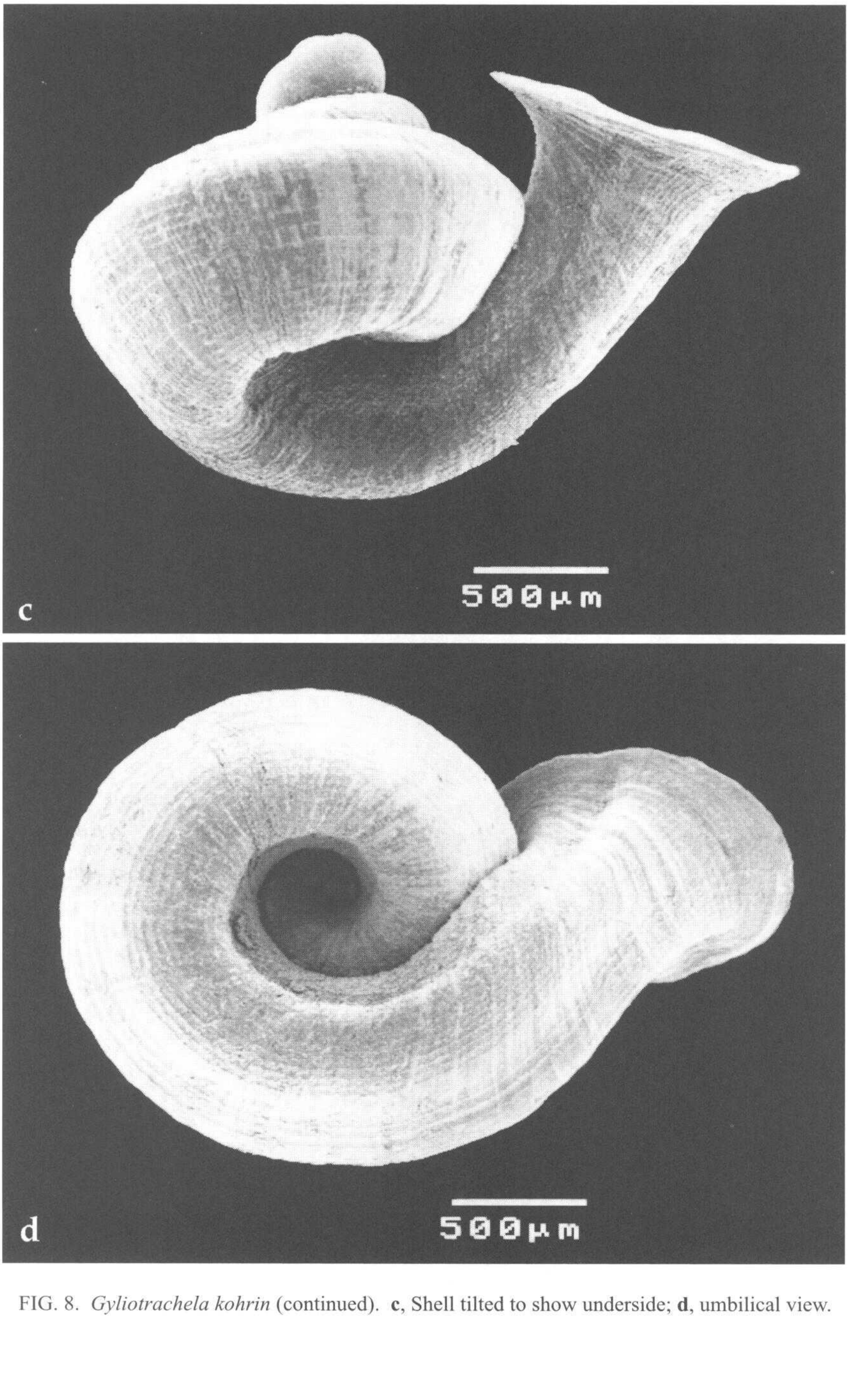

FIG. 8. *Gyliotrachela kohrin* (continued). **c**, Shell tilted to show underside; **d**, umbilical view.

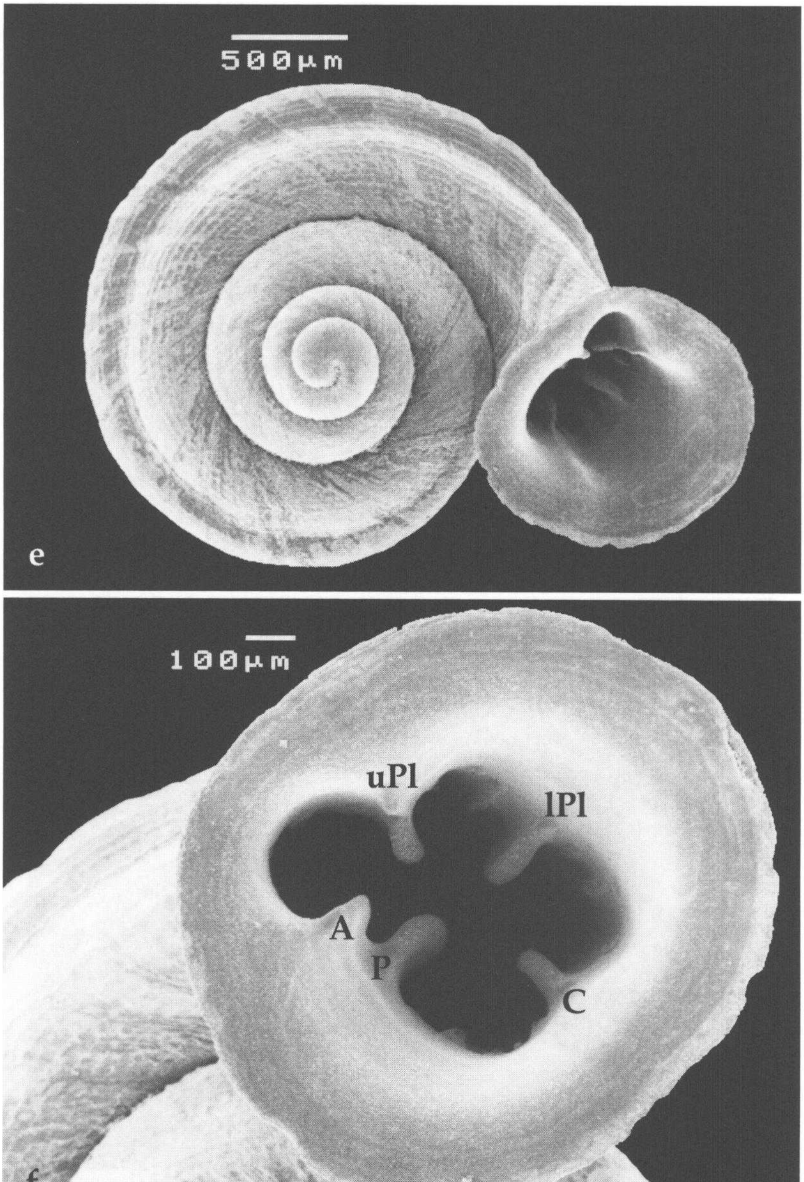

FIG. 8. *Gyliotrachela kohrin* (continued). **e**, Apical (dorsal) view showing aperture; **f**, enlarged view of aperture. A = angular lamella; C = columellar; P = parietal; lPl = lower palatal plica; uPl = upper palatal.

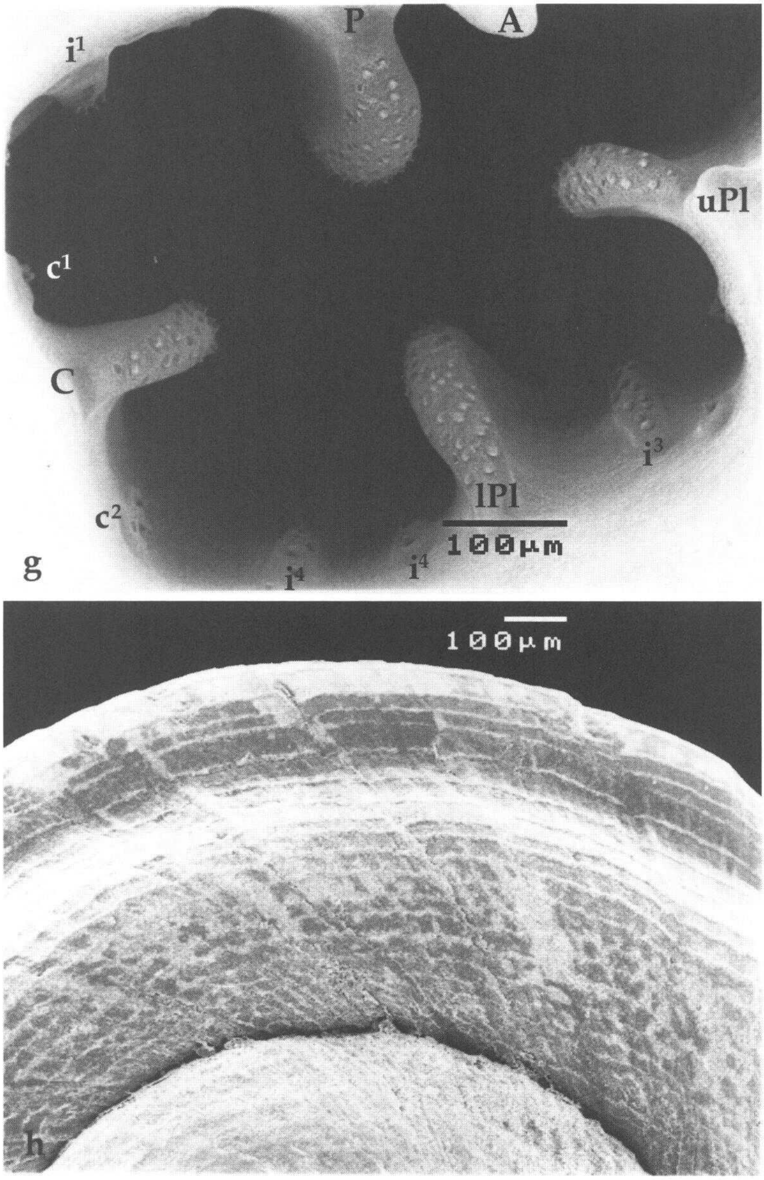

FIG. 8. *Gyliotrachela kohrin* (continued). **g**, Much enlarged view of the aperture (note the spinelets on the barriers); **h**, enlarged view of a portion of the body whorl showing spiral and transverse sculpture. Lamellae and plicae: A = angular; C = columellar; P = parietal; lPl = lower palatal; uPl = upper palatal; i^1 = infraparietal plica; i^3 = interpalatal; i^4 = infrapalatal ; c^1 = supracolumellar; c^2 = subcolumellar.

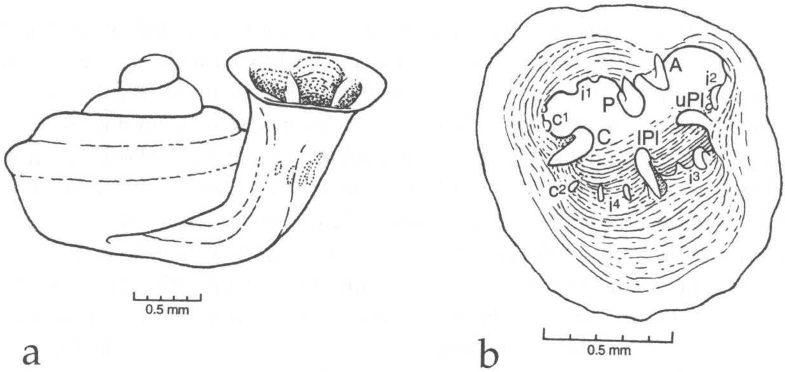

FIG. 9. *Gyliotrachela kohrin* n. sp., holotype. **a**, Shell in side view, showing the upward tilt of the tuba; **b**, apertural barriers. Lamellae and plicae: A = angular; C = columellar; P = parietal; lPl = lower palatal; uPl = upper palatal; c^1 = supracolumellar; c^2 = subcolumellar; i^1 = infraparietal; i^2 = suprapalatal; i^3 = interpalatal; i^4 = infrapalatal.

rina and horizontal tuba; and the shell of *G. surakiti* has granulose surface sculpture.

Exralimitally, other spirally striate and carinate species—*G. everetti* (Smith) (Kalao Island, Indonesia) and *G. torticollis* Benthem Jutting (Cambodia)—have higher placed carinae. *Gyliotrachela khaochongpran* and *G. dohertyi* (Fulton) (Tenimber Island, Indonesia) also have more or less horizontal, rather than upturned, tubas, and *G. torticollis* has a long, down-turned tuba. *Gyliotrachela salpinx* Benthem Jutting (Malaya) and *G. saxicola* Benthem Jutting (Malaya) have more or less median carinae, like *G. kohrin,* but their tubas are horizontal rather than up-turned. *Gyliotrachela napierana* Solem (Australia), *G. catherina* Solem (Australia), *G. concreta* Benthem Jutting (Celebes, Indonesia), *G. fruhstorferi* (Möllendorff) (Java, Indonesia), and *G. ningbingia* Solem (Australia) lack carinae.

Gyliotrachela diarmaidi Panha & Burch, new species
(Figs. 10, 11)

Description of holotype. Shell planiturbinate, base flattened, body whorl produced into a long, ascending tuba, which rises above the depressed apex of the shell spire. In cross-section, the tuba is almost square. Dark Olive-Buff (Ridgeway) or ca. 4505 C (Pantone) in color, with 4+ whorls; the tuba starts at slightly less than 4 whorls. Shell measurements are given in Table 1. Nearing maturity, growth of the last half of the body whorl changes direction greatly, continuing upward at about a 58° angle from the direction of the previous shell growth. Spire strongly depressed, with only the apical whorls raised above the body whorl. Sutures well impressed. The body whorl (which makes up most of the shell's outer periphery) almost flat sided, slightly concave, and rather sharply shouldered; first and second whorls rounded. Umbilicus wide and deep, measuring more than 1/2 the shell diameter (not including the tuba). Nuclear whorls 1 3/4, sculptured with wrinkles, with some wrinkles coalescing to produce roundish shallow pits; a few faint spiral striae (threads) on the first 1 1/2 whorl, becoming a bit more evident on the last 1/4 of the protoconch. After the protoconch the spiral striae become much more evident. Teleoconch spirally striate; lightly striatulate, the radial cordlets intersecting with the spiral ridgelets, giving a decussated appearance. As the last whorl becomes free, a well defined groove (produced where the curvature of the upper part of the whorl meets the curvature of the lower part of the whorl) is evident. This is the *parietal groove,* which continues on the tuba to the expanded apertural lip. The upper palatal groove is well defined, the columellar groove somewhat less so, and the lower palatal groove is hardly distinguishable (but the latter's presumptive location can be identified by the image of the lower palatal fold showing through the shell wall).

Aperture irregularly rounded, peristome free, continuous, broadly dilated, sinuated at the angulo-palatal lip. The apertural embayments are as follows: a well-developed, semi-circular angulo-parietal, an oblong columellar-parietal, a triangular basal, and a rectangular palatal embayment. There are numerous barriers in the aperture, but the most prominent are the parietal, angular, columellar, and upper and lower palatal. All of the barriers are deep-set within the aperture, but the elongate angular lamella extends outwardly (distally) to the reflection of the peristome. The forward extension of the upper palatal plica extends nearly as far. The parietal and angular lamellae are both elongate and close together, nearly merging deep within the aperture. There are two interpalatal plicae, the lower one the largest and easiest seen. The smaller one is deeper within the aperture and its exact position can best be seen from through the shell on the outside. Close to the columellar lamella is a smaller subcolumellar lamella. A single infrapalatal plica occurs between the subcolumellar lamella and the lower palatal plica. There are four very small barriers in the curvature of the inner apertural wall between the angular lamella and the upper palatal plica, the position of which can best be seen from the outer shell surface, showing through the thin and translucent shell. Although their nomenclature might seem rather arbitrary, the two closest to the angular tooth would traditionally be called parallel lamellae, and the two closest the upper palatal plica would be called suprapalatal plicae. Two small lamellae occur in the curvature between the parietal and columellar lamellae. The one closest to the parietal lamella is the infraparietal lamella, and the one closest to the columellar lamella is the supracolumellar. All of the apertural barriers are spinose, except the angular lamella.

Variation. Ten specimens showed very little variation in overall shell shape, color and sculpture. There was a little variation in width of umbilicus, and there

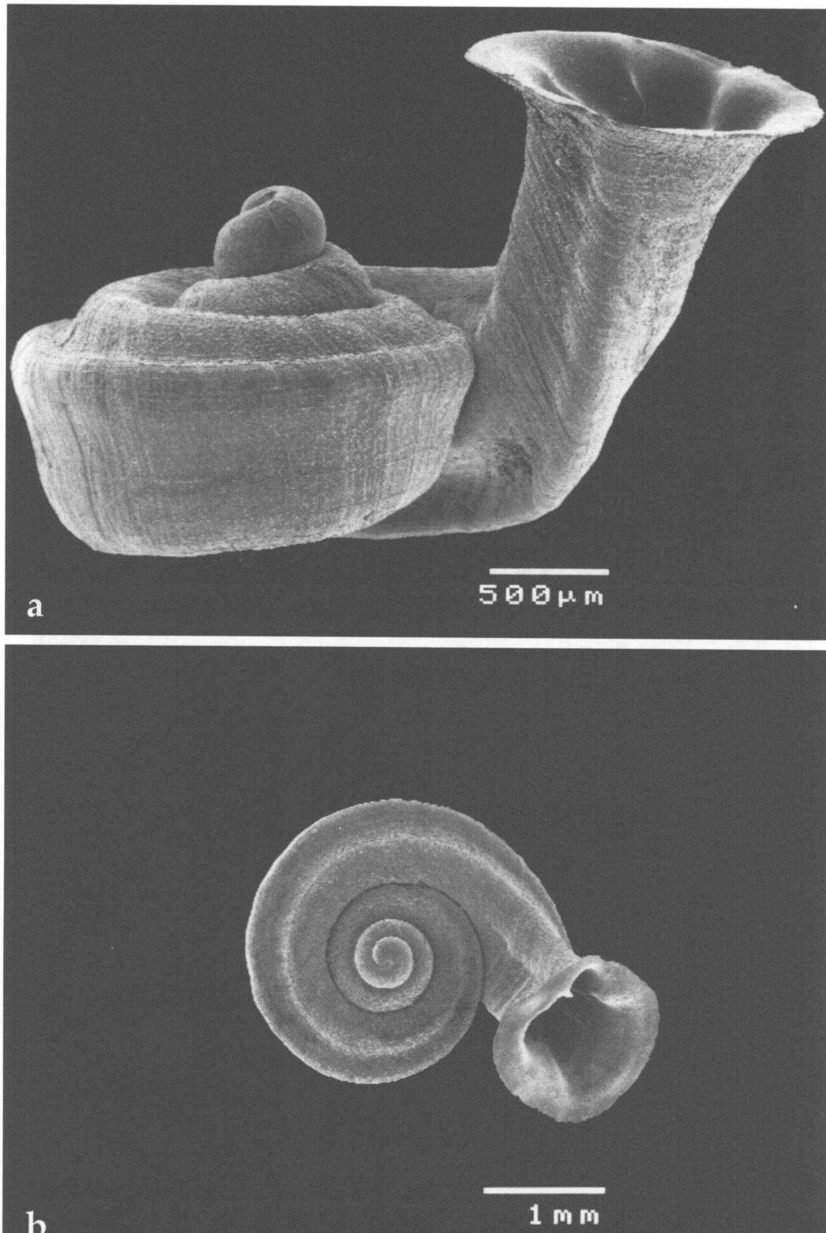

FIG. 10. *Gyliotrachela diarmaidi* n. sp., paratype. **a**, Side view; **b**, dorsal (apical) view.

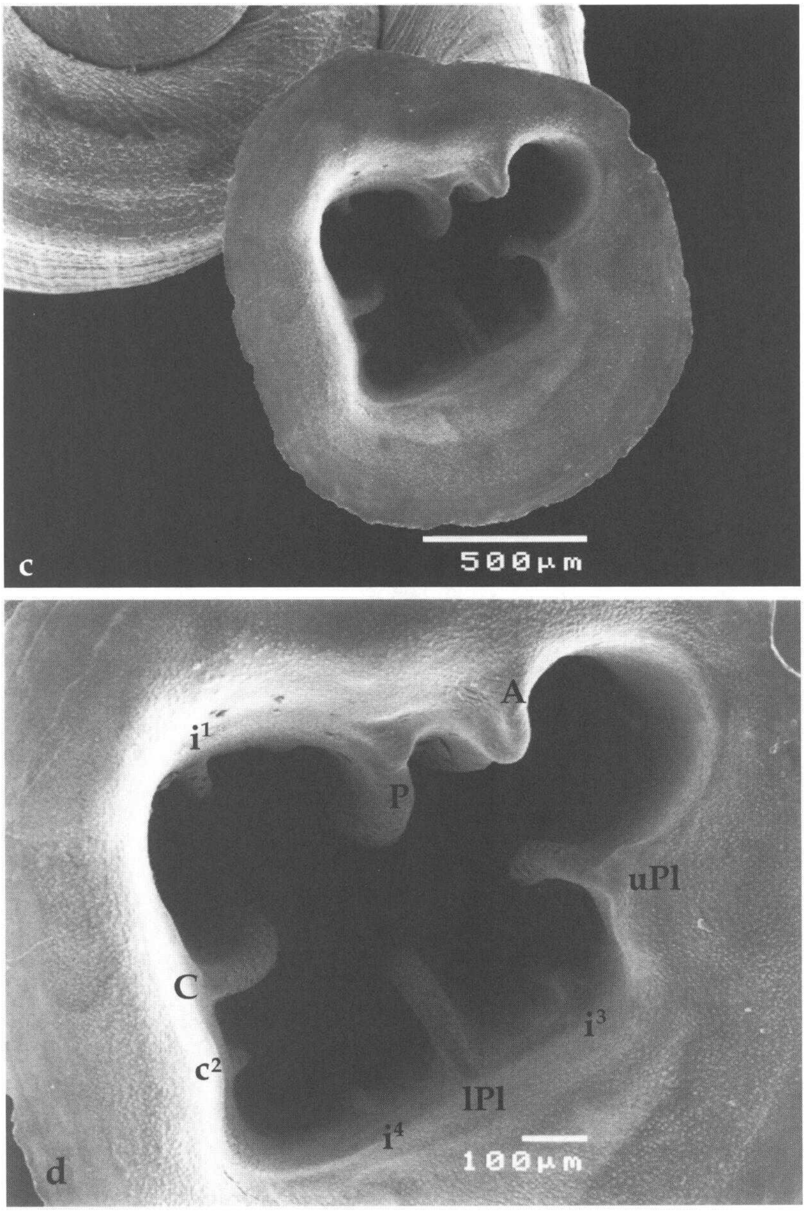

FIG. 10. *Gyliotrachela diarmaidi* (continued). **c**, Apertural view showing barriers ("teeth"); **d**, close-up of aperture. A = angular lamella; C = columellar lamella; P = parietal lamella; lPl = lower palatal plica; uPl = upper palatal plica; i^1 = infraparietal plica; i^3 = interpalatal plica; i^4 = infrapalatal plica; c^2 = subcolumellar lamella.

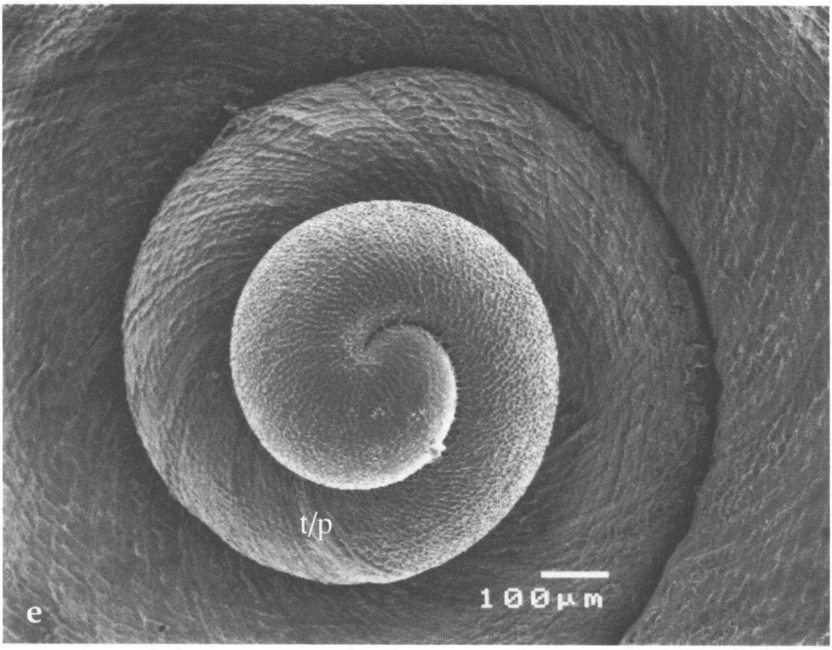

FIG. 10. *Gyliotrachela diarmaidi* (continued). **e**, Apex of the shell showing the protoconch (first 1 3/4 whorls), its rugose sculpture, and the spiral and transverse sculpture of the ensuing teleoconch whorls. t/p = boundary between the teleoconch and the protoconch.

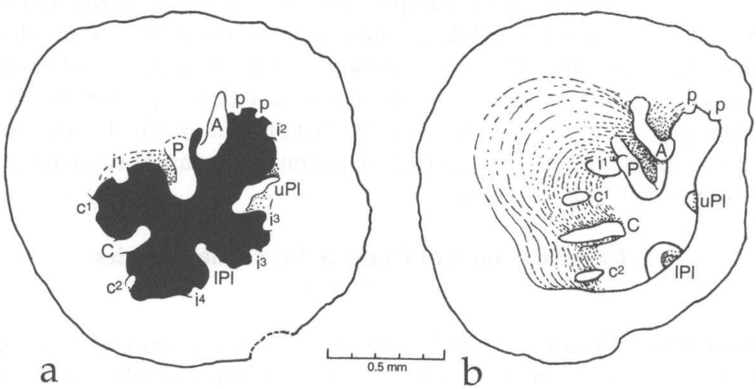

FIG. 11. *Gyliotrachela diarmaidi* n. sp., holotype. **a**, Apertural barriers; **b**, aperture tilted for a better view of the barriers in and on either side of the columellar-parietal embayment and channel. Lamellae and plicae: A = angular; C = columellar; P = parietal; lPl = lower palatal; uPl = upper palatal; c^1 = supracolumellar; c^2 = subcolumellar; i^1 = infraparietal; i^2 = suprapalatal; i^3 = interpalatal; i^4 = infrapalatal.

was some variation in tuba length.

Type locality. Pluangthong Mountain, west of Pluangthong Temple, Botong District, Chonburi Province, 13° 11' 5" N, 101° 34' 59" E, 110 meters elevation, Thailand.

Etymology. The name *diarmaidi* is after Dr. Diarmaid O'Foighil, who has been instrumental in interpreting the molecular data of this and other species of Thai Pupillidae, and in whose laboratory the molecular research was done.

Type material. The holotype (CUMZ 44037) and six paratypes (CUMZ 44038) are deposited in the Chulalongkorn University Zoological Museum. Another nine paratypes (UMMZ 300064) have been deposited in the Museum of Zoology, University of Michigan.

Habitat. This species was found on a limestone wall, with many plant species, dominated by *Spondias pinnata* Kurz and *Pennisetum polystachyom* (Linnaeus) Schult. The giant African snail, *Achatina fulica* (Férussac), and the ariophantid, *Cryptozona siamensis,* were abundant in the area.

Diagnosis. *Gyliotrachela diarmaidi* is a minute gastrocoptine pupillid pulmonate gastropod with a very depressed spire and mammillate apex, and a long, upwardly directed tuba that goes beyond the apex. The teleoconch is spirally striate, decussate, and widely umbilicate. The last whorl has a high, dorsally sulcate carina. In addition to the five major apertural barriers (angular, parietal, columellar, and lower and upper palatal) there is an infraparietal, a supracolumellar, a subcolumellar, an infrapalatal, two interpalatals, two suprapalatals, and two parallel lamellae.

Remarks. *Gyliotrachela diarmaidi* differs from all other known spirally striate congeners by its very depressed spire and long, sharply deflected, up-turned tuba. Excluding the tuba, and the mammillate first several whorls, the shell is almost planate and discoidal. The body whorl of the more depressed variation of *G. everetti* (Smith) from Kalao Island, Indonesia (see Smith, 1896, pl. 10, fig. 9a; Pilsbry, 1917, pl. 37, fig. 10) resembles that of *G. diarmaidi,* but the tuba of *G. everetti* is but little up-turned, and the apertural barriers are fewer (nine shown in Pilsbry's, 1917, pl. 37, fig. 9).

Gyliotrachela surakiti Panha & Burch, new species
(Figs. 12, 13)

Description of holotype. Shell planiturbinate or depressed-conoid, spire elevated, base flattened, body whorl produced into a long, ascending tuba, which rises above the depressed apex of the shell spire. In cross-section, the tuba is more or less square, with rounded corners. The shell is a rather light Dark-Olive Buff (Ridgeway) or ca. a light 4505 C (Pantone) in color. The tuba is Buckthorn Brown (Ridgeway), or ca. OJZI-C (Pantone). The shell has 4 1/3 whorls to where the tuba begins. Shell measurements are given in Table 1. Nearing matu-

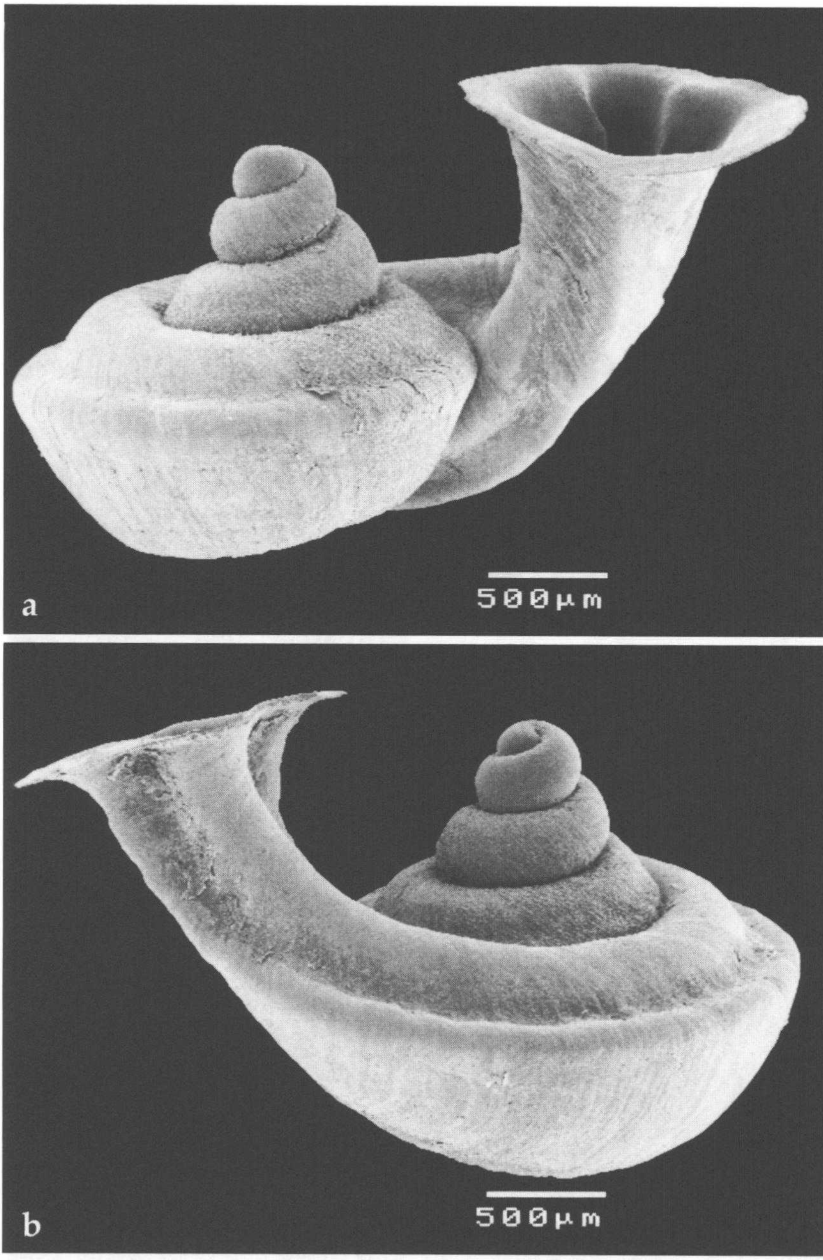

FIG. 12. *Gyliotrachela surakiti* n. sp., paratype. **a**, Side view; **b**, opposite side view.

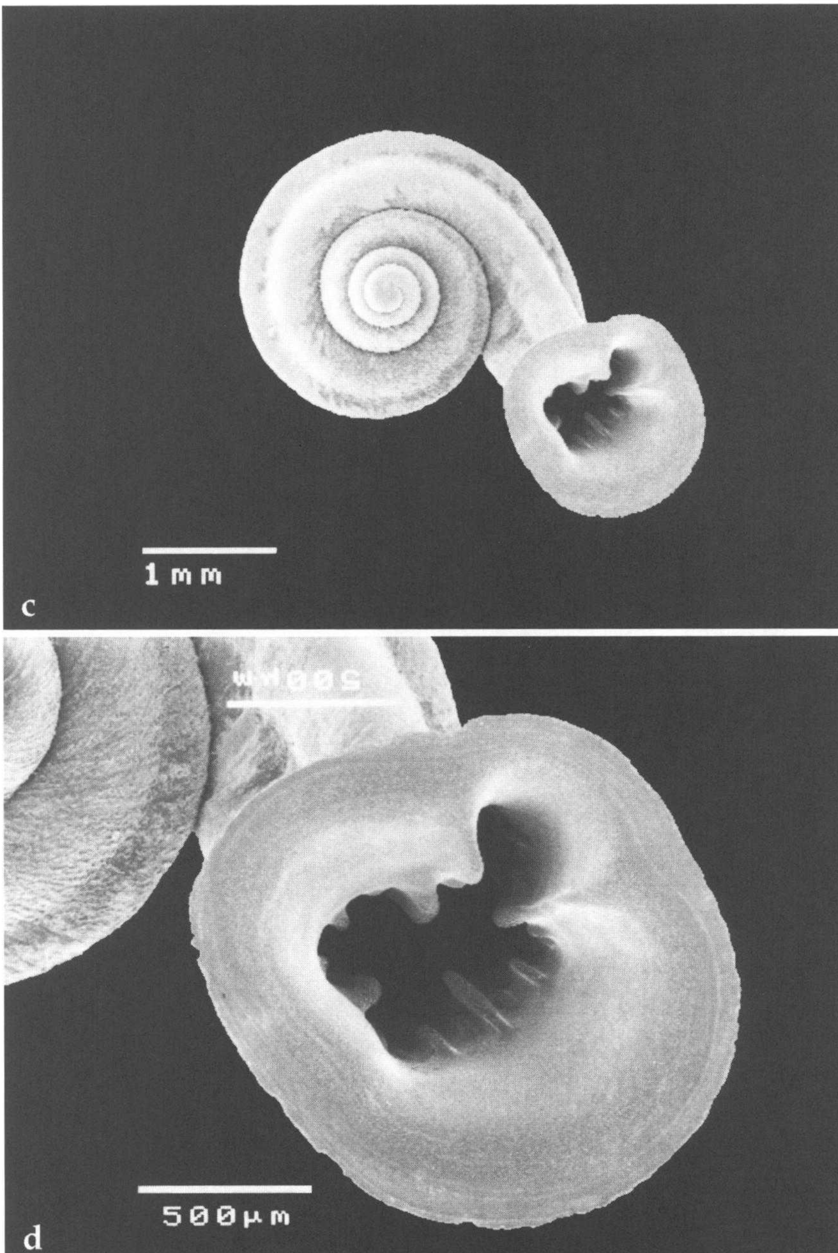

FIG. 12. *Gyliotrachela surakiti* (continued). **c**, Apical (dorsal) view showing the aperture; **d**, enlarged view of the aperture.

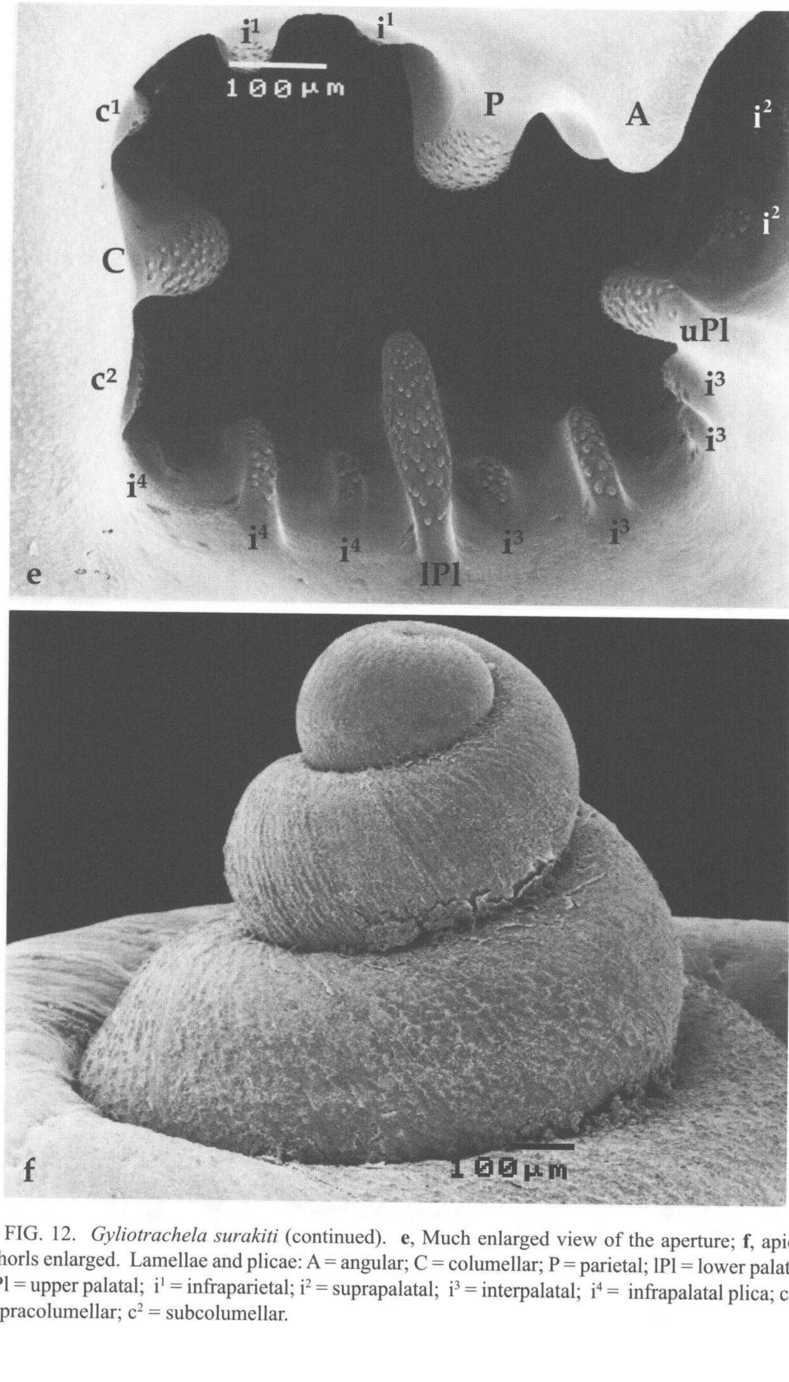

FIG. 12. *Gyliotrachela surakiti* (continued). **e**, Much enlarged view of the aperture; **f**, apical whorls enlarged. Lamellae and plicae: A = angular; C = columellar; P = parietal; lPl = lower palatal; uPl = upper palatal; i^1 = infraparietal; i^2 = suprapalatal; i^3 = interpalatal; i^4 = infrapalatal plica; c^1 = supracolumellar; c^2 = subcolumellar.

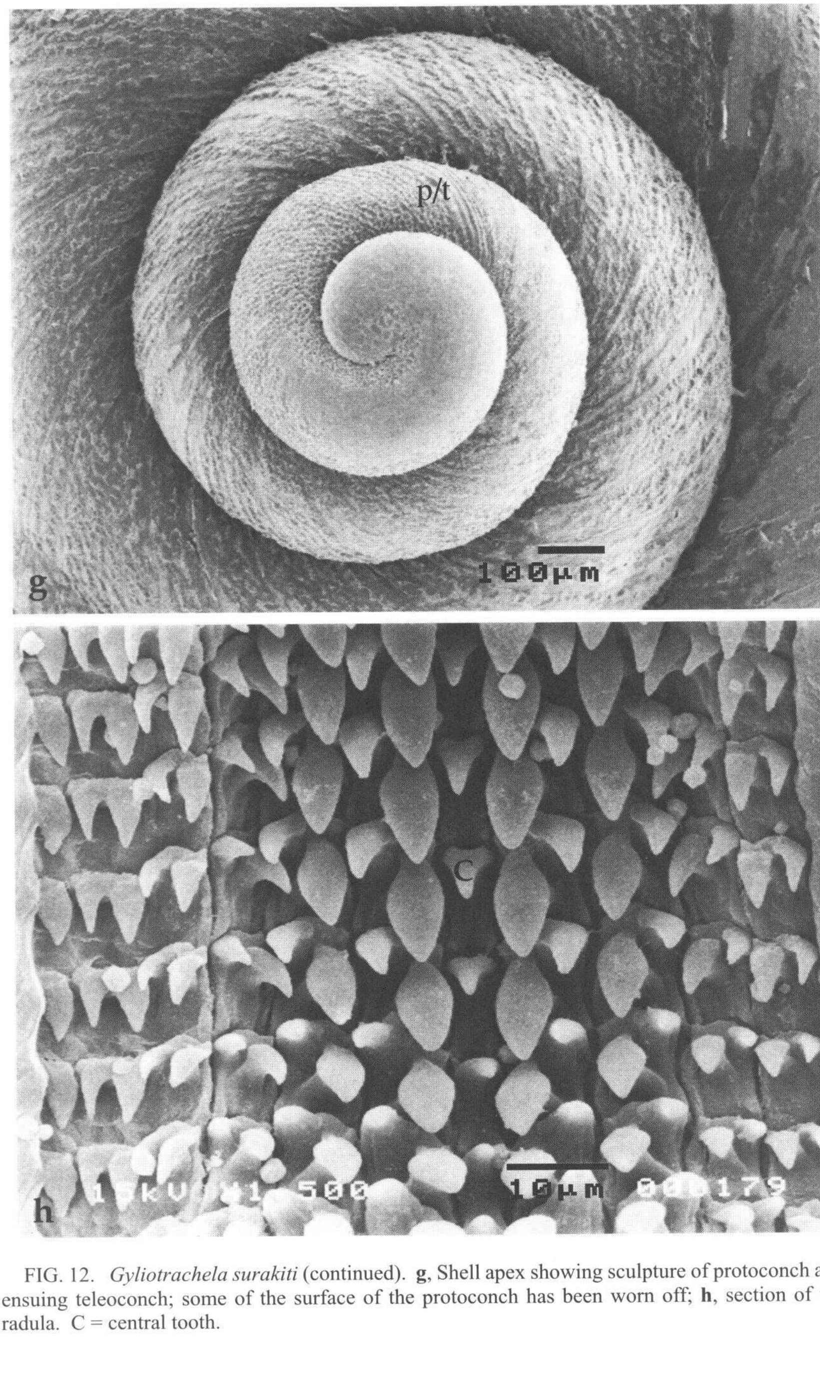

FIG. 12. *Gyliotrachela surakiti* (continued). **g**, Shell apex showing sculpture of protoconch and ensuing teleoconch; some of the surface of the protoconch has been worn off; **h**, section of the radula. C = central tooth.

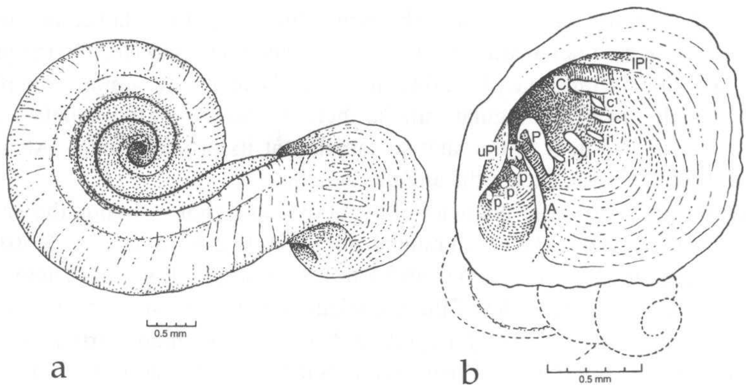

FIG. 13. *Gyliotrachela surakiti* n. sp., holotype. **a**, Umbilical view of shell; **b**, aperture tilted for a better view of the barriers in the columellar-parietal and the angulo-palatal channels. Lamellae and plicae: A = angular; C = columellar; P = parietal; lPl = lower palatal; uPl = upper palatal; c^1 = supracolumellar; i^1 = infraparietal; i^2 = suprapalatal; i^3 = interpalatal; i^4 = infrapalatal; p = parallel; t = twin.

rity, growth of the last half of the body whorl changes direction greatly, continuing upward at about a 49° angle from the direction of the previous shell growth. The spire is depressed, although the first three whorls are rather evenly sloped and raised above the disproportionately enlarged body whorl. The sutures are well impressed. The body whorl (which makes up most of the shell's outer periphery) is flat sided and sharply shouldered. This appearance is caused by the furrow running spirally around the upper part of the whorl. Above the furrow, the whorl is more or less rounded. The umbilicus is wide and deep, measuring nearly 1/2 the shell diameter. Nuclear whorls ca. 1 3/4; sculptured with fine shallow pits. Teleoconch granulose or tuberculate, the tuberculets of the general surface are also on the radial cordlets; striatulate; shell surface lacking spiral striae. The angulo-parietal groove is deep and rather broad. The upper palatal groove is well defined, rather deep and broad, becoming shallow on the expansion of the peristome. The lower palatal groove is very weak and short. The columellar groove is rather well defined, although somewhat shallow along the tuba. It flares out and fades at the beginning of the expansion of the peristome.

The shell aperture is rather trapezoidal in shape. The peristome is free, continuous, broadly dilated, sinuated at the angulo-parietal lip. The apertural embayments are as follows: a semicircular angulo-palatal, a curved columellar-angular, and a rectangular baso-palatal embayment. There are 24 barriers in this specimen. The five major barriers are present—the parietal, angular, columellar, and the upper and lower palatal. The parietal and angular are close together, and both are long and thin. The parietal lamella is more deeply-set, while the angular lamella continues distally to the flexure of the peristome. On the parietal wall there are three additional barriers—the infraparietal lamellae. Next to these, on the columellar wall, are two supracolumellar lamellae. On the palatal wall are three infrapalatal plica, four interpalatals, and three suprapalatal plicae. Additionally, near the angular lamella there are three parallel lamellae and a twin, which lies next to the angular lamella, at its proximal end. All of the barriers are spinose, except the angular lamella.

Variation. The major diameter of the body whorl (not including the tuba) of the seven specimens examined ranged from 2.20 to 2.63 (average = 2.50) mm. The lengths of the tubas varied from 1.0 to 1.8 (average = 1.4) mm. There is also some variation in the width of the umbilicus of the seven specimens. There is little variation in the five major apertural barriers. The minor barriers are basically the same in number and characteristics in the seven specimens, but—as the apertures were not entirely clean—the minor barriers were not scored.

Type locality. South of Puttabanpot Temple, Pajoh Village, Nawang District, Nongbualumpoo Province, 17° 19' 1" N, 102° 7' 3" E, 320 meters elevation, Thailand.

Etymology. This species is named after Mr. Surakit Polkoksung, a technician in the Physics department, Chulalongkorn University.

Type material. The holotype and 10 paratypes (CUMZ ver 078) are deposited in the Chulalongkorn University Zoological Museum. Another six paratypes (UMMZ 300101) have been deposited in the Museum of Zoology, University of Michigan.

Habitat. *Gyliotrachela surakiti* was found on a limestone wall, on which also occurred mosses. Most of the snails were in the rock crevices. The legume, *Senna alata* (Linnaeus) Roxb., was found nearby. The prosobranch land snail, *Cyclophorus volvulus,* was also found at this habitat.

Diagnosis. *Gyliotrachela surakiti* is a minute gastrocoptine pupillid pulmonate gastropod with depressed spire, granulate sculpture, rough, raised transverse striae, and rather wide umbilicus. The last whorl has a well defined carina. In addition to the five major apertural barriers (angular, parietal, columellar, and lower and upper palatal) there are three infraparietals, two supracolumellars, three infrapalatals, four interpalatals, three suprapalatals, three parallels and a twin.

Remarks. *Gyliotrachela surakiti* differs from about half of the described species of its genus by the lack of spiral striae on its shell, having instead a rugose or granulate shell sculpture. Among the non-striate *Gyliotrachela* species, *G. surakiti* is one of three species distinguished by their distinctly upwardly directed tubas. Compared to the other two species, *G. surakiti*'s tuba is noticeably longer than the tubas of both of the Malayan species, *G. depressispira* Benthem Jutting and *G. luctans* Benthem Jutting. *Gyliotrachela depressispira*'s tuba terminates closer to the apex than does *G. surakiti*'s. Also, *G. depressispira,* as its name implies, has a more depressed spire. The tuba of *G. luctans* is the shortest of the three species, and its tuba is directed upward more obliquely than in the other two species. Another striking difference that distinguishes *G. surakiti* from the other two species is the much greater number of barriers in its aperture (24 in the holotype). *Gyliotrachela depressispira* is reported to have 17 (Benthem Jutting, 1949a), and *G. luctans* is illustrated with nine barriers in its aperture (Benthem Jutting, 1949c).

Hypselostoma erawan Panha & Burch, new species
(Figs. 14, 15)

Description of holotype. Shell planiturbinate, base flattened, body whorl with a long tuba, ascending, the peristome about the same level as the shell apex. In cross-section, the tuba is roundly and obtusely triangular. The shell is a light Buffy Brown (Ridgeway) or ca. a light OGZR-C (Pantone) in color, and has 4 1/2 whorls. Shell measurements are given in Table 1. Nearing maturity, growth of the last half of the body whorl changes direction greatly, continuing upward at about an 80° angle from the direction of the previous shell growth. The spire is greatly depressed, although the first several whorls are rather evenly sloped and raised above the disproportionately enlarged body whorl. The sutures are deeply impressed. The body whorl is rather flattened, a little convex, with a well-defined shoulder; the periphery of other whorls is more or less rounded. The umbilicus is deep and very wide, measuring more than 1/2 the shell diameter. Nuclear whorls ca. 1 2/3; the protoconch appears smooth under a light stereoscopic microscope; spiral cordlets start at the beginning of the teleoconch. Teleoconch spirally striate; weakly striatulate; decussate. The angulo-parietal groove is short and shallow, terminating at the flare of the peristome. The upper palatal groove is short and very shallow, and begins at the distal end of the upper palatal plica. There is no lower palatal groove. The columellar groove is very shallow, terminating at the distal end of the columellar lamella.

The aperture is roundly trapezoidal. The peristome is free, continuous, broadly flared-out, strongly sinuated at the angulo-palatal lip, and moderately sinuated at the columellar-parietal lip. The apertural embayments are: a rather oval anguloparietal-palatal, a rounded columellar-anguloparietal, and a broadly rounded, internally rectangular, baso-palatal embayment. There are 11 apertural barriers in this specimen. The noticeably largest barrier is the angulo-parietal lamella. On the parietal wall are two additional very small barriers—infraparietal lamellae. The larger of the two is situated deeper within the aperture. Considerably smaller than the angulo-parietal, but still the second-most prominent of the barriers, is the columellar lamella. On the palatal wall are seven barriers—upper and lower palatal plicae, two infrapalatals, two interpalatals, and a suprapalatal

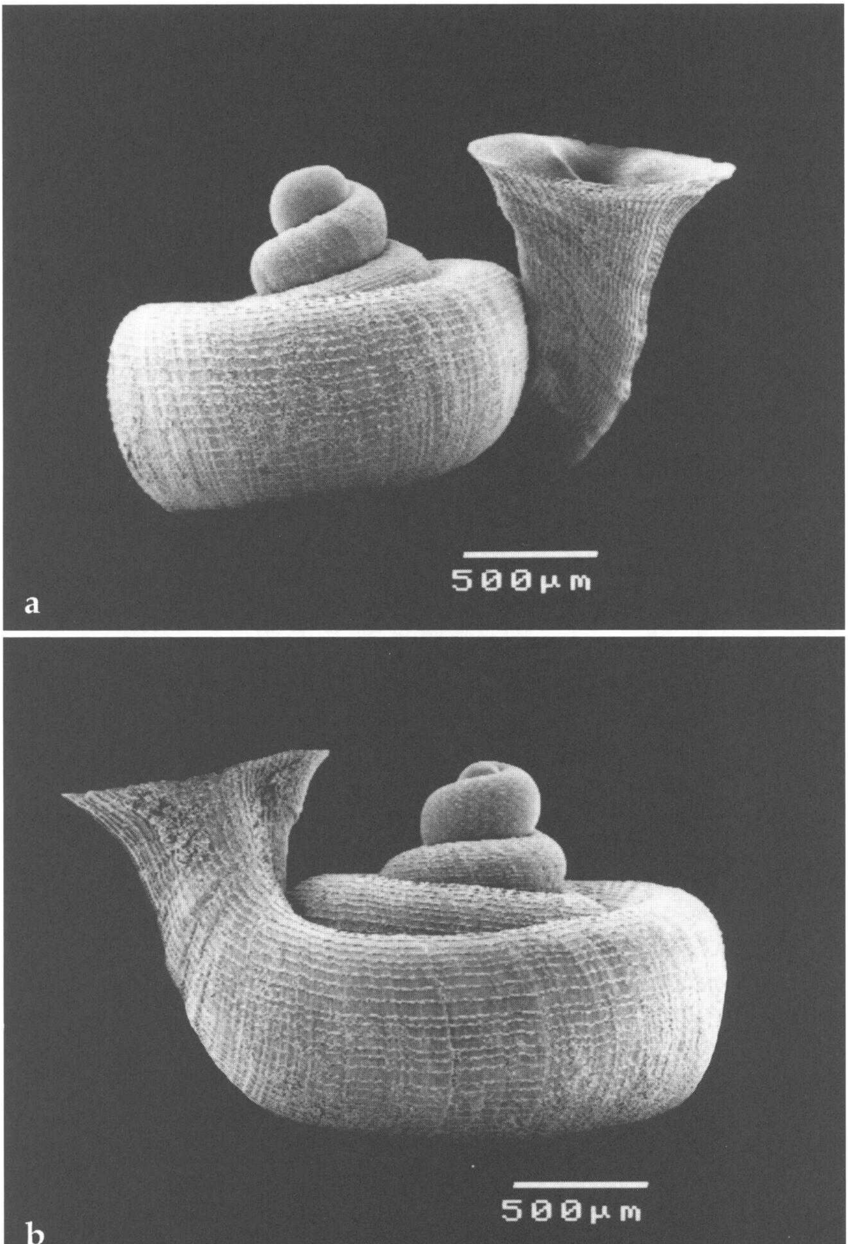

FIG. 14. *Hypselostoma erawan* n. sp., paratype. **a**, Side view; **b**, opposite side view.

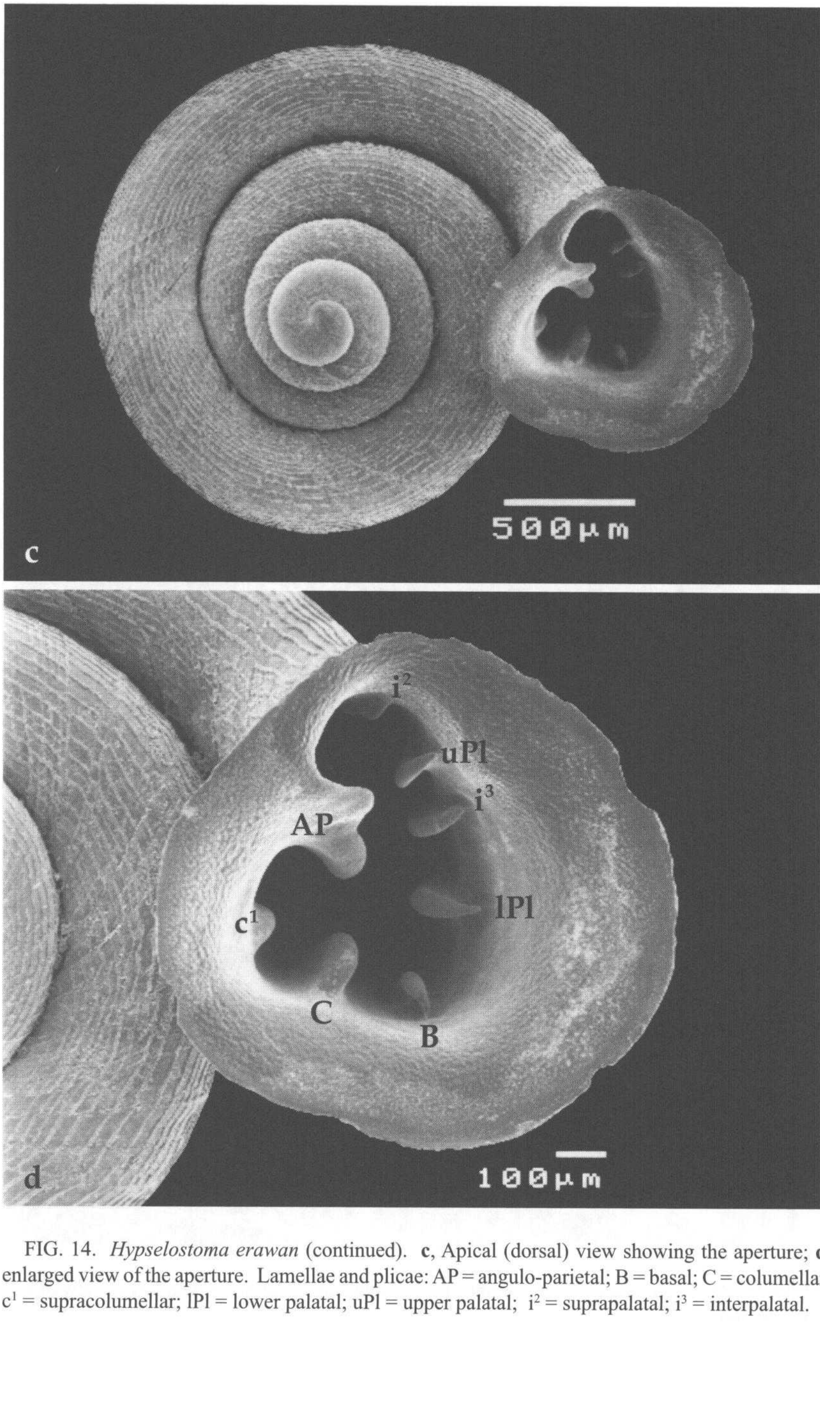

FIG. 14. *Hypselostoma erawan* (continued). **c**, Apical (dorsal) view showing the aperture; **d**, enlarged view of the aperture. Lamellae and plicae: AP = angulo-parietal; B = basal; C = columellar; c^1 = supracolumellar; lPl = lower palatal; uPl = upper palatal; i^2 = suprapalatal; i^3 = interpalatal.

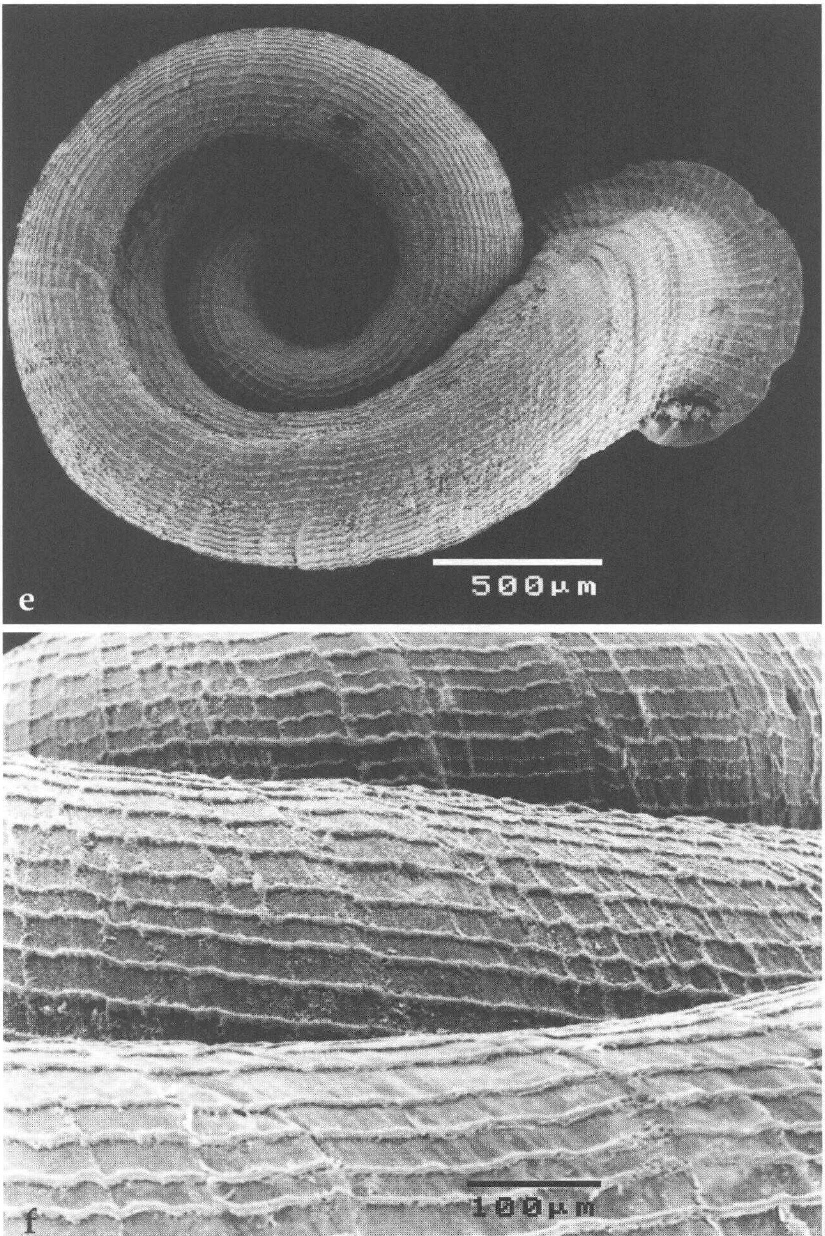

FIG. 14. *Hypselostoma erawan* (continued). **e**, Umbilical (basal) view; **f**, enlarged view of surface sculpture.

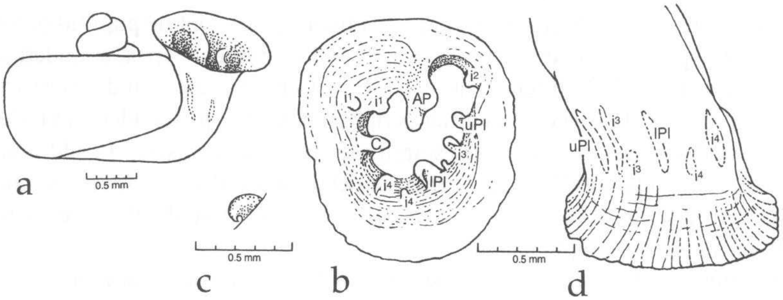

FIG. 15. *Hypselostoma erawan* n. sp., holotype. **a**, Shell in side view, showing the deviation in the coiling of the body whorl, and the upward tilt of the tuba; **b**, apertural barriers; **c**, enlargement of the lower palatal plica in side view, showing its hook-like structure; **d**, outside of the tuba near the peristome showing the outlines of the plicae as seen through the palatal wall of the shell. Lamellae and plicae: AP = angulo-parietal; B = basal; C = columellar; lPl = lower palatal; uPl = upper palatal; i^1 = infraparietal; i^2 = suprapalatal; i^3 = interpalatal; i^4 = infrapalatal.

plica. The largest of the palatal plicae is the lower palatal plica. The upper palatal plica and the interpalatal plica next to the upper palatal plica are about the same size. [Since the barrier here called the upper palatal plica, and the barrier (here called an interpalatal plica) sitting next to it are of nearly the same shape and prominence, it is difficult to discern which should be called the upper palatal plica. The one here so named was chosen because it sits on a mound—however slight—and is situated closer to the peristome.] Several of the palatal plicae end distally in an outwardly pointed hook.

Variation. Of the seven specimens examined, only the holotype has a second infrapalatal plica, and only one other specimen has a second interpalatal plica. On all of the paratype specimens, the upper and lower palatal plicae, and the inter- and infrapalatal plicae, each ends distally in a sharp, outwardly directed point. All of the specimens are (or were) outwardly coated with mud.

Type locality. A limestone mountain in the southern part of Erawan National Park, Triyoke District, Karnchanaburi Province, 14° 12' 15" N, 99° 7' 58" E, 70 meters elevation, Thailand.

Etymology. *Hypselostoma erawan* gets its name from Erawan National Park, where it was found.

Type material. The holotype (CUMZ 44049) and 13 paratypes (CUMZ 44050) are deposited in the Chulalongkorn University Zoological Museum. Another four paratypes (UMMZ 300102) have been deposited in the Museum of Zoology, University of Michigan.

Habitat. *Hypselostoma erawan* was found on a limestone wall, which also supported mosses, and under large rubber trees. All of the *Hypselostoma erawan* specimens were collected on the rock wall. *Cryptozona siamensis*, a larger arionphantid land snail, was abundant in the area.

Diagnosis. *Hypselostoma erawan* is a minute gastrocoptine pupillid pulmonate gastropod with a very depressed spire and mammillate apex, a moderately long, upwardly directed tuba that reaches to or near the apex, and a very wide umbilicus. The last whorl has a flat periphery and strong shoulder and lacks a carina and a sulcus; it is intensely spirally striate, and decussate. In addition to the four major apertural barriers (angulo-parietal, columellar, and lower and upper palatal) there are two infraparietals, one or two infrapalatals, one or two interpalatals, and a suprapalatal.

Remarks. The majority of the species of *Hypselostoma* have high, conical (even turreted), spires. Nearly all of these high-spired species have horizontally directed tubas. *Hypselostoma erawan,* on the other hand, belongs to the small group of *Hypselostoma* species with depressed spires, nearly all of which have upwardly directed tubas. The exception, *H. elephas* Benthem Jutting (Malaya), is distinguished by its exceptionally long (the longest known in the Hypselostoma-Boysidia group), horizontal tuba. *Hypselostoma erawan* can be easily recognized from the other species with depressed spires that have carinate shells (*H. cucumensis* Panha (southern Thailand), *H. piconis* Benthen Jutting (Malaya) and *H. roebeleni* Möllendorff (Philippines)) by its lack of any trace of a carina, and from *H. tuberifum* (Benson) (Burma) by its nearly vertical, almost flat periphery. The whorls of *H. tuberifum* slope strongly basally.

***Hypselostoma taehwani* Panha & Burch, new species**
(Figs. 16, 17)

Description of holotype. Shell pyramidal, with a long tuba, descending at about the same angle as the first three whorls. In cross-section, the tuba is roundly triangular. The shell is Hay's Russett or Morocco Red (Ridgeway) or ca. 478 C (Pantone) in color, and has 4 1/3 whorls to where the tuba begins. Shell measurements are given in Table 1. Nearing maturity, growth of the last half of the body whorl changes direction a little, continuing upward at about an 11° angle from the direction of the previous shell growth. Then, when the whorl becomes free, it again changes direction of growth, resuming about the original angle of coiling. The spire is somewhat elongated, and rather evenly sloped. The spire angle is 57°. The sutures are well impressed. The body whorl has a well defined, broad, obtuse carina, the penultimate whorl is weakly angular, and the first and second whorls are rounded. The umbilicus measures about 1/2 the shell diameter (not including the tuba). Nuclear whorls 1 3/4, sculptured with fine, spiral, periostracal threads (Fig. 17a). Teleoconch sculpture: spirally striate; weakly striatulate, with some more prominent transverse (radial) striae occurring at irregular, more widely spaced, intervals. The angulo-parietal groove is deep and

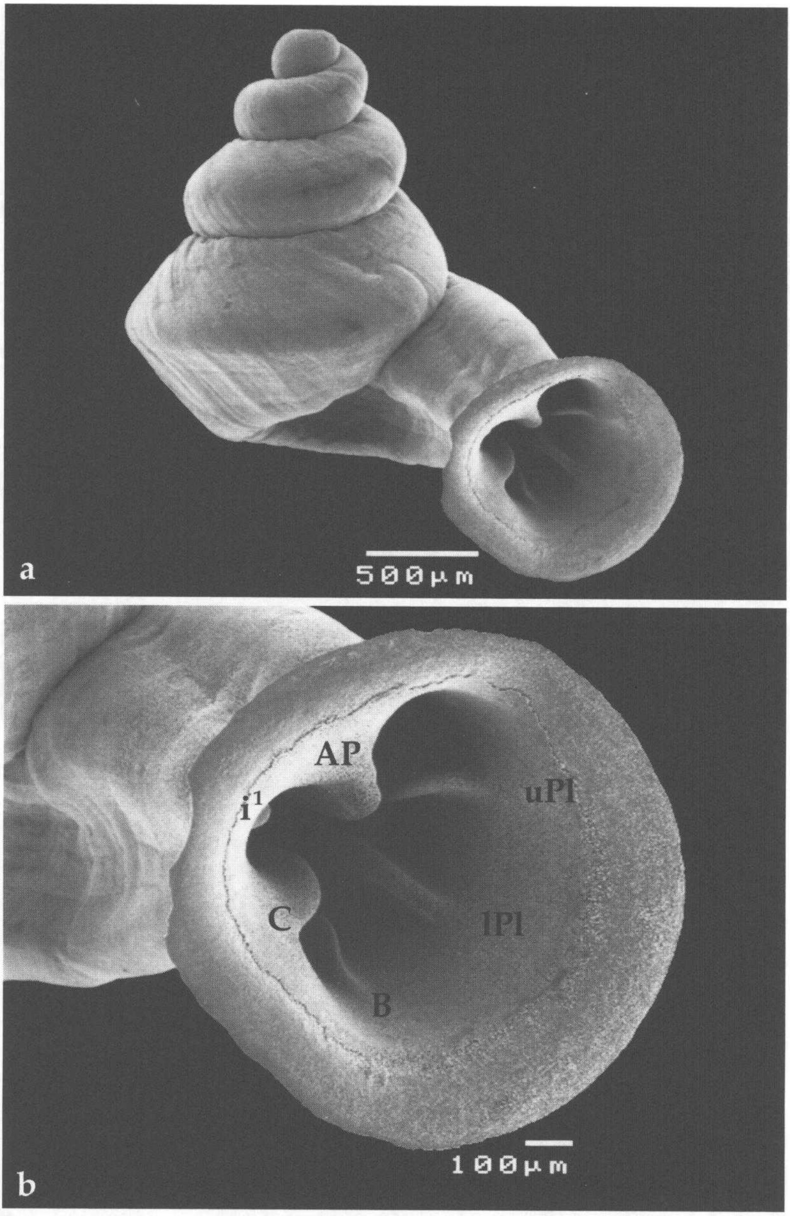

FIG. 16. *Hypselostoma taehwani* n. sp., paratype. **a**, Side view; **b**, enlarged view of aperture. Lamellae and plicae: AP = angulo-parietal; B = basal; C = columellar; lPl = lower palatal; uPl = upper palatal; i^1 = infraparietal.

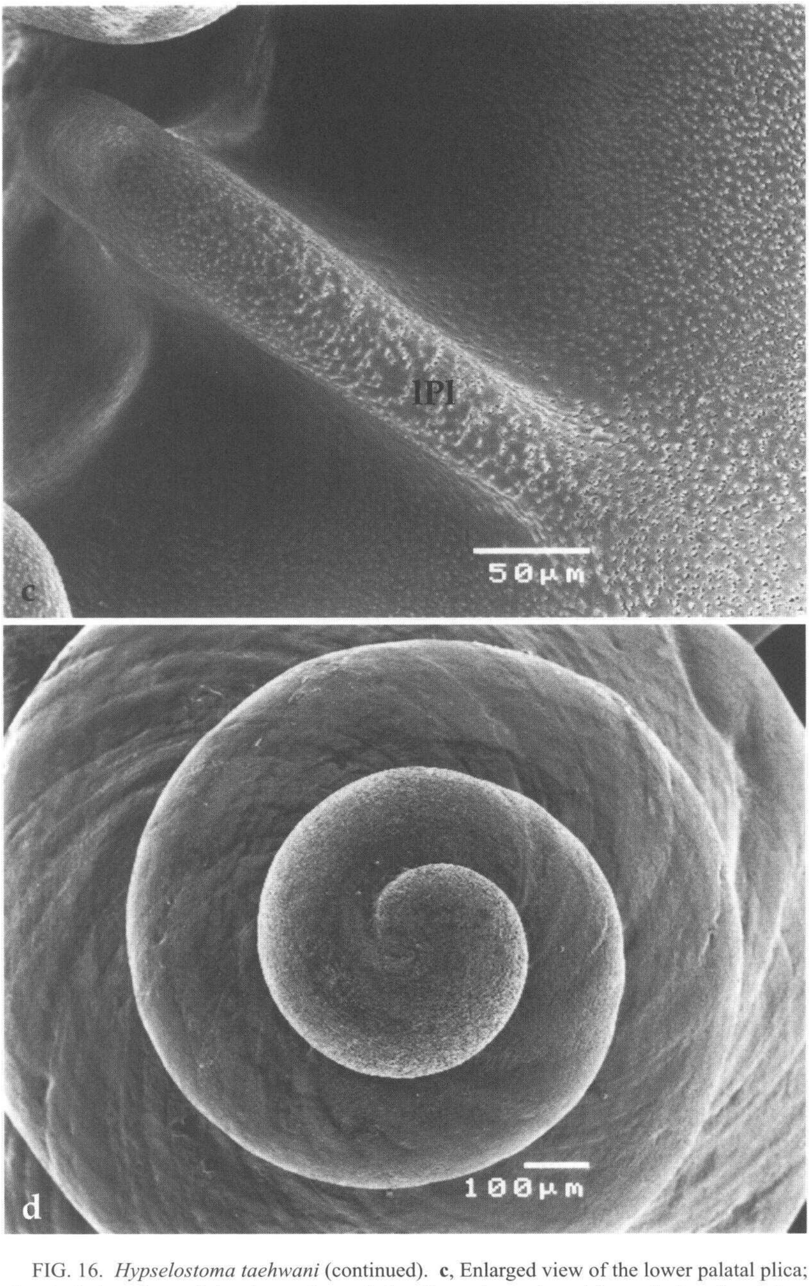

FIG. 16. *Hypselostoma taehwani* (continued). **c**, Enlarged view of the lower palatal plica; **d**, apical view; the sculpture is mostly eroded on the protoconch, and the periostracal sculpture was brushed off when cleaning the shell. lPl = lower palatal plica.

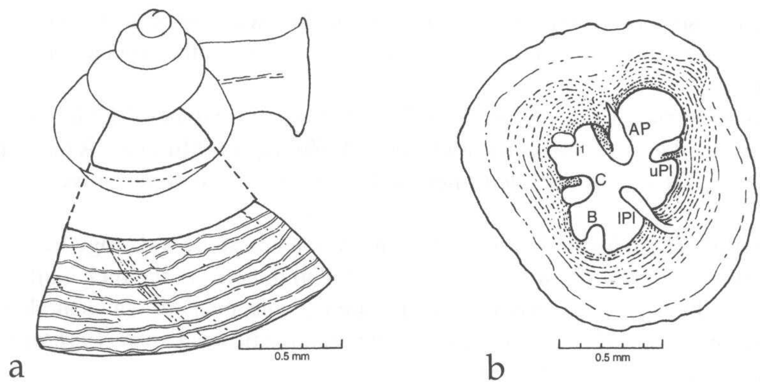

FIG. 17. *Hypselostoma taehwani* s. sp., holotype. **a**, Portion of the shell surface showing the periostracal spiral striae (cordlets); these delicate periostracal structures were inadvertently brushed off when cleaning the shell for the SEM pictures in Fig. 16; **b**, apertural barriers. Lamellae and plicae: AP = angulo-parietal; C = columellar; B = basal; lPl = lower palatal; uPl = upper palatal; i^1 = infraparietal.

well defined along the entire length of the tuba. The upper palatal groove, which begins about halfway up the tuba, is very shallow. The lower palatal groove is hardly distinguishable, but its presumptive position can be determined by the image of the lower palatal plica showing through the shell wall. The columellar groove is rather shallow, but well-defined.

Aperture subquadrangular or somewhat roundly quadrangular. Peristome free, continuous, broadly expanded, sinuated at the angulo-palatal lip. The apertural embayments are: a well-developed rounded anguloparietal-palatal, a squarish columellar-anguloparietal, and a triangular basal embayment, which continues as a somewhat rounded palatal embayment. The aperture contains six barriers, of which the four most prominent are the cross-forming angulo-parietal, columellar, and upper and lower palatal. The strongest of these are the angulo-parietal and columellar lamellae, followed by the lower palatal plica, and then the upper palatal plica. Smaller, but well developed, are the basal plica and the infraparietal lamella. The apertural barriers, and the apertural wall surfaces, are densely and minutely granulose.

Variation. The shell height in four specimens ranged from 2.15 to 2.59 (avg. = 2.33) mm. The lengths of the tuba in these specimens ranged from 1.00 to 1.33 (avg. = 1.14) mm. There is some minor variation in peristome shape and size, and spire angle, but there is very little variation in shell color and sculpture.

Type locality. Central area of Tamrong Temple, Muang Petchburi District, near the main Petchkasem artery of the Asian Highway to southern Thailand, Petchaburi Province, 13° 01' 32" N, 99° 55' 11" E, 10 meters elevation, Thailand.

Etymology. The name *taehwani* is after Dr. Taehwan Lee, who has been instrumental in analyzing the molecular data of this and other species of Thai Pupillidae.

Type material. The holotype (CUMZ 44052) and 12 paratypes (CUMZ 44053) are deposited in the Chulalongkorn University Zoological Museum. A paratype (UMMZ 300103) has been deposited in the Museum of Zoology, University of Michigan.

Habitat. *Hypselostoma taehwani* occurred on a limestone wall, together with some moss species. Most specimens were found in holes in the rock wall surface. The habitat is on a smooth hill with some plants, many of which are leguminous species, such as *Senna alata.* The ariophantid land snail, *Cryptozona siamensis,* is common in the area.

Diagnosis. *Hypselostoma taehwani* is a minute gastrocoptine pupillid pulmonate gastropod with a high spire and a long, downwardly directed tuba. The teleoconch is sculptured with fine, delicate, spiral, raised, periostracal striae, crossed by fine growth lines; beneath the periostracum are fine, spiral incised lines. The shell is somewhat moderately umbilicate; the last whorl is rather sharply angular, with an obtuse carina. In addition to the four major apertural barriers (parietal, columellar, and lower and upper palatal) there is a basal plica, and an infraparietal lamella.

Remarks. Most species assigned to *Hypselostoma* have shells with solute, non-adnate apertures that are placed at the end of short or long detached extensions (tubas) of the terminal whorl. Most of the species have high-spired shells, and nearly all are reported to be sculptured with spiral striae. *Hypselostoma taehwani* meets these criteria. It differs from all of the known Hypselostomas by its long, downwardly directed tuba. Fine, closely-spaced spiral striae are readily seen with a stereoscopic microscope using reflected light, but these striae are not seen on the SEM pictures (Fig. 16) because the striae are periostracal (not part of the ostracum), very delicate, and, during the cleaning process in preparation for the SEM pictures, were inadvertently rubbed off. [Pilsbry (1917, p. 179), regarding the Burmese *H. tubiferum* (Benson), referred to the feeble nature of the striae: "When cleaned with sufficient care (and not too much), delicate spiral striae may be seen in places on the second and third whorls, but they are easily removed." And, on p. 183, regarding the Japanese *H. insularum* Pilsbry: "The very fine and delicate spiral striae seem to be of cuticular substance."] Impressed spiral lines (minute, narrow, shallow grooves) can be seen on the cleaned ostracum devoid of periostracum.

Hypselostoma panhai Burch & Tongkerd, new species

(Fig. 18)

Description of holotype. Shell high-spired, elongate-heliciform, its shape approaching oval. It is a lighter shade of Dark Olive-Buff (Ridgeway) or ca. a

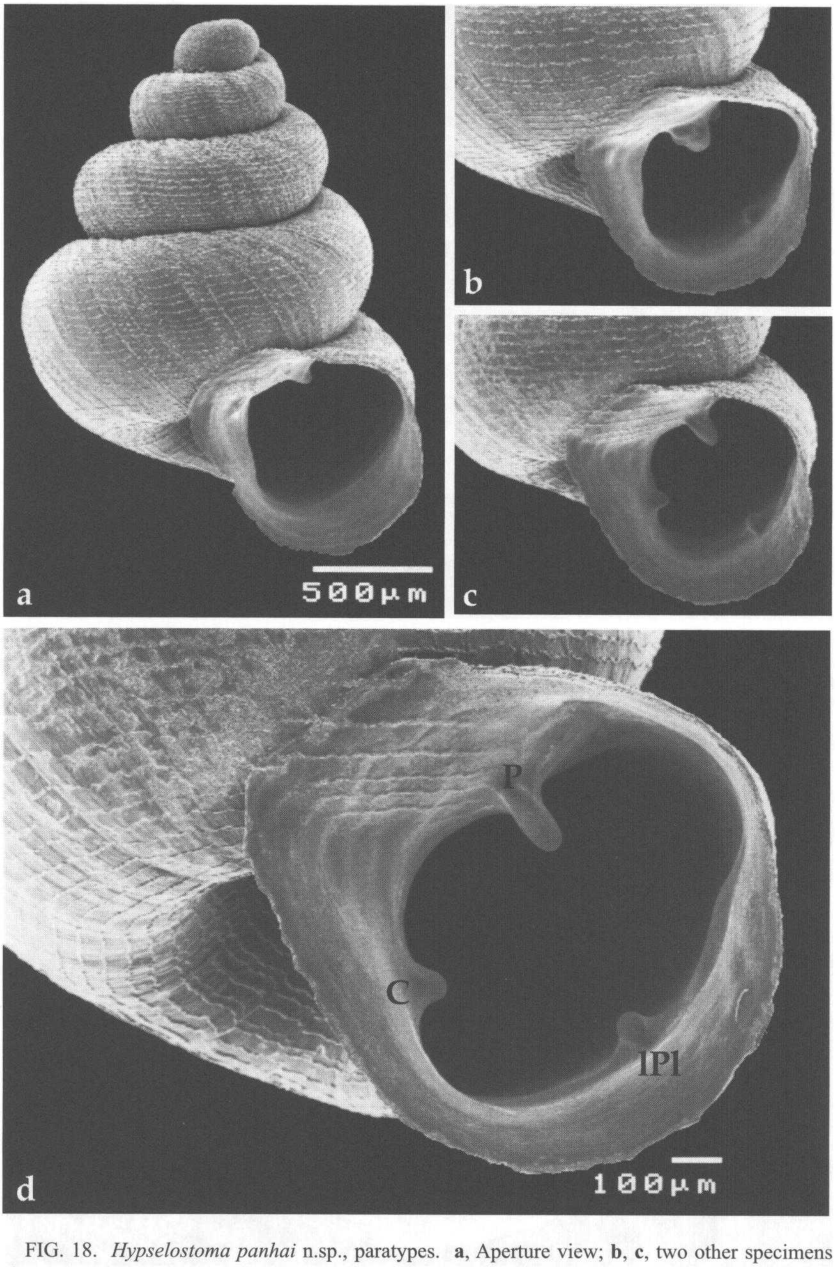

FIG. 18. *Hypselostoma panhai* n.sp., paratypes. **a**, Aperture view; **b**, **c**, two other specimens showing variations in apical barriers; **d**, enlargement of the shell in Fig. c. Lamellae and plicae: C = columellar; P = parietal (or angulo-parietal?); lPl = lower palatal.

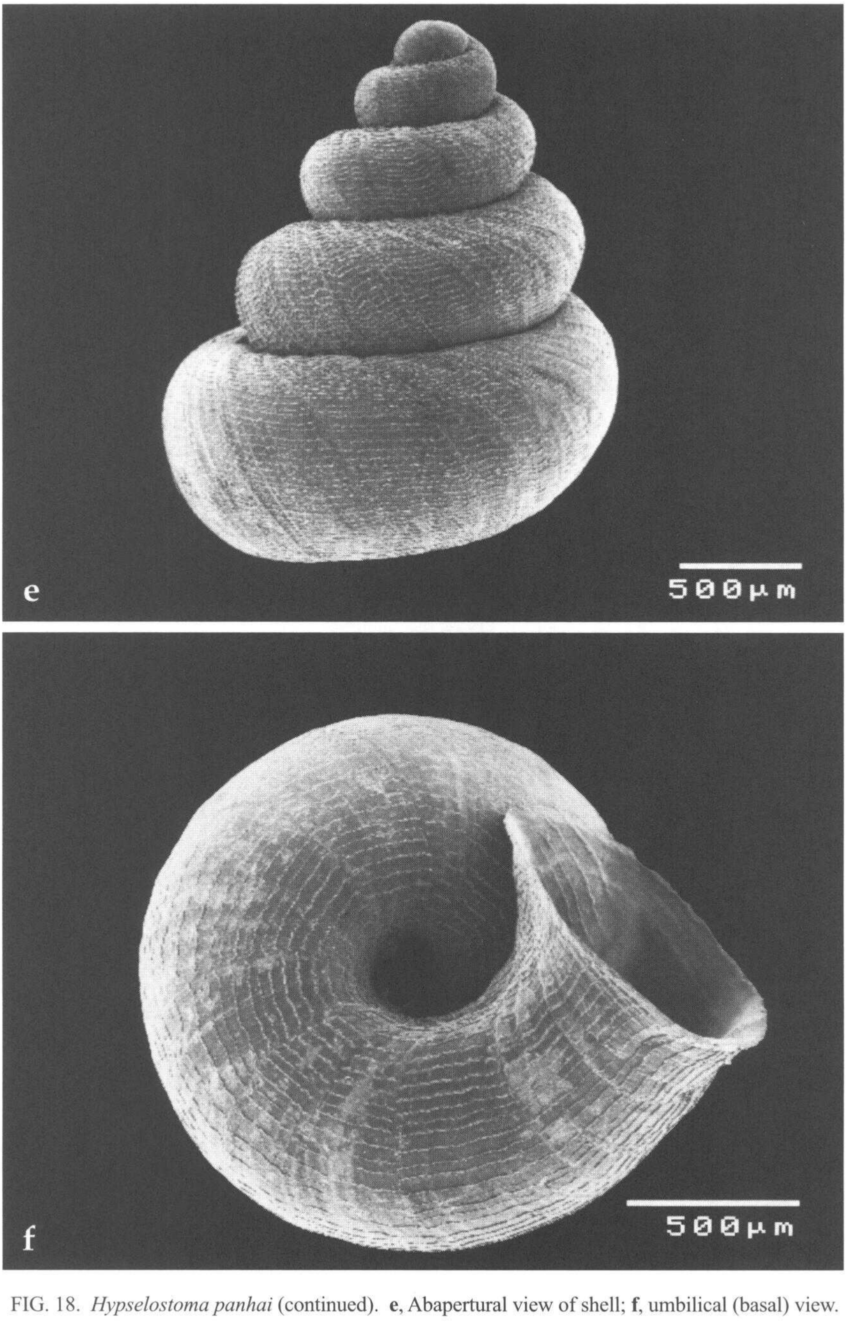

FIG. 18. *Hypselostoma panhai* (continued). **e**, Abapertural view of shell; **f**, umbilical (basal) view.

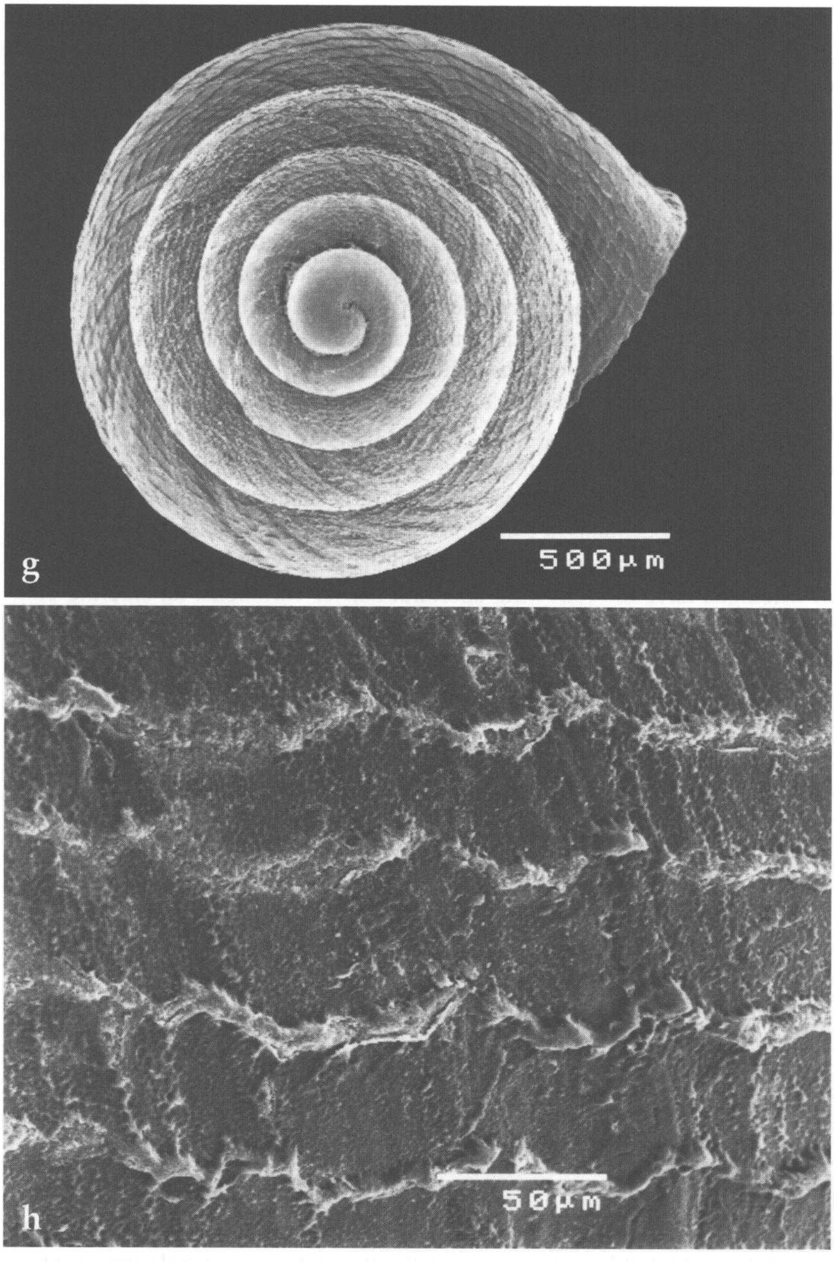

FIG. 18. *Hypselostoma panhai* (continued). **g**, Apical view; **h**, enlarged view of shell surface showing sculpture.

light 4505 C (Pantone) in color, and has 5 1/3 whorls. Shell measurements are given in Table 1. Nearing maturity, growth of the last half of the body whorl changes direction slightly, continuing upward at about a 7° angle from the direction of the previous shell growth. Spire raised, rather broad, evenly sloped. Sutures well impressed; whorls rounded; umbilicus narrow, except for that part influenced by the last 1/4 whorl. Nuclear whorls ca. 1 1/2; rugose; spiral cordlets start where the teleoconch begins. Teleoconch sculpture with wavy spiral striae, rather evenly parallel; weakly striatulate. There is no tuba. On the last quarter-whorl begins a broad, very shallow depression below (basal to) the shoulder of the whorl. This depression continues to the flare of the peristome.

Aperture roundly triangular, peristome adnate, expanded along the palatal and basal margins, more so along the columellar margin, very little expanded along the outer parietal and sinulus margins, sinuated at the angulo-palatal lip. The type specimen has only one tooth, a small tubercle on the parietal wall. However there is some variation in apertural dentition (see below).

Variation. There is some variation in apertural dentition. Figure 18a,b,c shows three paratype specimens at Chulalongkorn University which have two or three similarly degenerative barriers. An additional five paratypes at the University of Michigan have the following apertural barrier variations: an entering elongate, small but well developed parietal lamella and a very low, hardly noticable, columellar lamella; a small weakly developed parietal and a very low vestigal columellar; a well developed parietal, a low, underdeveloped columellar, and a small but distinct lower palatal; same as the previous, but additionally with a very low vestige of the upper palatal; one barrier only, a very small, poorly developed parietal lamella.

All of the specimens collected are young adults, so with age added calcium deposition on the aperture walls might have made the barriers better developed and more prominent.

These same five UMMZ paratype specimens, all apparently in about the same stage of development, vary in shell height from 2.06 cm to 2.50 cm. The spire angles vary from 54° to 68°, *i.e.,* from subovately conic to subglobosely conic (see Burch & Jung, 1992). All specimens have adnate peristomes, but there is some variation in the degree of reflection of the peristomes.

Type locality. Chongkhaokad, west of the World War II museum, near the famous bridge of the now abandoned railroad of World War II, Triyoke District, Karnchanaburi Province, 14° 24' 8" N, 98° 53' 23" E, 140 meters elevation, Thailand.

Etymology. The name *panhai* is after Dr. Somsak Panha, the leader of the Thai micro snail project, and who supported the research and helped collect the material on which this and other recent Southeast Asian malacological publications were based.

Type material. The holotype (CUMZ 44055) and 15 paratypes (CUMZ 44056) are deposited in the Chulalongkorn University Zoological Museum. Another five paratypes (UMMZ 300069) have been deposited in the Museum of Zoology, University of Michigan.

Habitat. *Hypselostoma panhai* was found in the grass and leaf litter area below a limestone wall. Two plant species are dominant in this area, *Chromolaena odoratum* and *Euphorbia heterophylla* Linnaeus. *Cryptozona siamensis* is a dominant snail species here. The shells of *Hypselostoma panhai* in nature are coated with mud and tiny sand grains.

Diagnosis. *Hypselostoma panhai* is a minute gastrocoptine pupillid pulmonate gastropod with a high spire, adnate aperture, narrow umbilicus, and evenly rounded last whorl that lacks a carina and a sulcus. The teleoconch is sculptured with fine, spiral cordlets crossed by irregular growth lines. Apertural barriers are depauperate in size and number, ranging from one (parietal, or angulo-parietal?), two (a parietal with an additional columellar lamella), or three (parietal and columellar lamellae, and a lower palatal plica).

Remarks. By shell characters, this species does not readily fit into an already named and described generic group. We are assigning the species to the genus *Hypselostoma* because of its close association with *H. erawan* as shown by analysis of DNA data (Tongkerd *et al.,* 2003). *Hypselostoma panhai* differs from the other species described in this paper by its aperture—by an adnate peristome and reduced number of apertural barriers—and the lack of a free portion (tuba) to the last whorl. In this way it resembles various species of, *e.g., Gastrocopta* and *Bothriopupa.* However, *H. panhai'*s spire shape is not pupoid, but rather pyramidal, as is characteristic of species of the Boysidia-Hypselostoma group.

DISCUSSION

The Pupillidae are one of the few land snail families with a worldwide distribution. Its species are all small to minute, and a great many of them have an oblong, rather cylindrical shell with dome-shaped apex, reminiscent of many insect pupae, a shape from which the famly name is derived. The dominant pupillid taxa in Southeast Asia comprise a group of species that characteristically have shells with more tapering and conical ("pyramidal") apices. Pilsbry referred to this assemblage as the Hypselostoma-Boysidia group, using the names of two of the common genera. Our paper includes three genera of the Hypselostoma-Boysidia group.

A characteristic of the shell of all of the species described in our paper is that, on nearing maturity, growth of the last half of the body whorl changes direction, and thereby changes the angle of new whorl growth in relation to the shell axis. This occurs even if—with continued growth—a portion of the last whorl becomes free and assumes the normal direction of growth, as in *Hypselostoma taehwani,* where the tuba is directed downward.

Another characteristic of eight of these new species is the cross arrangement of the four (or four of the) major apertural barriers (angular and parietal [or angulo-parietal], columellar, and lower and upper palatal). Such a cross arrangement in this group of pupillid snails was observed as early as 1863 by Blanford (for the Burmese *Hypselostoma bensonianum*). This persistent apertural barrier configuration alone would suggest a common ancestry for the group.

Thompson & Dance (1983) erected *Dasypupa* (type species *Boysidia (Dasypupa) salpinx* Thompson & Dance) as a new subgenus in the genus *Boysidia* to include three new species from Borneo (Sarawak). To this new subgenus, they also referred four Malayan species, Tomlin's (1939) *Hypselostoma terae,* and three of Benthem Jutting's (1949c) species—*H. elephas, H. megaphonum* and *H. perigyra.* In species of Thompson and Dance's new subgenus "the columella lamella is tubercular and deeply recessed within the aperture..., not blade-like as in *Boysidia* Ancey or *Paraboysidia* Pilsbry. The parietal-angular lamellae are concrescent into a short, flexed, bilobed blade... The shell is conical, spire depressed-conical to elongate-conical, with minute rough periostracal finbriations parallel to the lines of growth... Spiral striations are absent in contrast to *Hypselostoma,* in which some of the species of *Dasypupa* have been placed. Occasional raised spiral threads may be present due to fusion of short segments of granular sculpture. The peristome may be adnate to or solute from the previous whorl." We have not yet evaluated this generic-group category within the framework of Asian pupillid systematics.

There are undoubtedly more, perhaps many, additional species of the Hypselostoma-Boysidia assembledge to be discovered in Asia. Hopefully this paper will set a standard for future species descriptions in this group of fascinating gastropods.

ACKNOWLEDGEMENTS

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STATUS SURVEY OF THE FRESHWATER MUSSELS (BIVALVIA: UNIONIDAE) IN THE NEW RIVER DRAINAGE, VIRGINIA

Michael J. Pinder[1], Eric S. Wilhelm[2] and Jess W. Jones[3]

ABSTRACT

Although the Kanawha-Ohio River mussel fauna has been extensively studied, little is known about the status and distribution of species in the upper New River, Virginia. Eleven species have been documented from relatively few surveys. In 1997-1998, we conducted a drainage-wide survey to determine the current status and distribution of freshwater mussels in the New River, Virginia. We collected eight species, represented by 1,181 individuals from 50 of 134 survey sites. The mainstem New River contained the greatest species richness and abundance, although most sites had low numbers. The two most common and widely distributed species were purple wartyback, *Cyclonaias tuberculata*, and spike, *Elliptio dilatata*. The rarest species were elktoe, *Alasmidonta marginata*, at one site and green floater, *Lamigona subviridis*, at three sites. The most unique find was the discovery of the Tennessee heelsplitter, *Lasmigona holstonia*, a species usually found in the adjacent Tennessee River drainage. Based on the presence of relic shell material and a limited number of live individuals, the New River mussel fauna has demonstrated a marked loss in species richness and abundance. With known threats such as sedimentation, water withdrawal, and nutrification, additional declines of mussel populations are likely before conservation measures can be implemented.

Key words: Freshwater mussels, New River, Virginia, status, distribution, threats.

INTRODUCTION

The New River is reported to be the oldest, large river in the eastern United States (Jenkins & Burkhead, 1994). Together with its receiving stream, the Kanawha River, they comprise a major tributary of the Ohio River basin. Although the Ohio River is known for its high diversity of mollusks, fishes, and crayfishes, the New River, despite its age and size, has historically maintained a low diversity of aquatic fauna (Neves, 1983; Jirka & Neves, 1987; Jenkins & Burkhead, 1994). Less than 56% of fish and 35% of mussel species known from the Kanawha River are found in the New River drainage. This disparity is likely the result of unique geologic features (e.g., New River Gorge & Kanawha Falls), and the effects of glaciation that prevented faunal dispersal since the late Pliocene and early Pleistocene (Neves, 1983).

[1]Wildlife Diversity Division, Virginia Department of Game and Inland Fisheries, 2206 South Main Street, Suite C, Blacksburg, Virginia 24060.

[2]U.S. Department of Agriculture, Animal Plant Health Inspection Services - Wildlife Services, 105 B Ponderosa Drive, Christiansburg, Virginia 24073.

[3]Virginia Cooperative Fish and Wildlife Research Unit, U.S. Geological Survey, Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

Even though most drainages in the Ohio River basin have been extensively studied (Ortmann, 1913; Turgeon *et al.*, 1998; Parmalee & Bogan, 1998), very little is known of the freshwater mussels in the Virginia portion of the New River. Most previous surveys in the New River drainage have been in West Virginia or limited to the lower portions in Virginia (Bates, 1979; Markham *et al.*, 1980; USFWS, 1984). Of the mussel surveys in Virginia, none have comprehensively determined status or distribution of species throughout the entire drainage.

Among the few surveys on freshwater mussels of the New River drainage in Virginia, 11 species have been identified (Table 1). These include: elktoe, *Alasmidonta marginata* (Say 1818); spike, *Elliptio dilatata* (Rafinesque 1820), green floater, *Lasmigona subviridis* (Conrad 1835), purple wartyback, *Cyclonaias tuberculata* (Rafinesque 1820), pistolgrip, *Tritogonia verrucosa*, (Rafinesque 1820), pocketbook, *Lampsilis ovata* (Say 1817), wavy-rayed lampmussel, *Lampsilis fasciola* (Rafinesque 1820), Tennessee heelsplitter, *Lasmigona holstonia* (Lea 1938), and mucket, *Actinonaias ligamentina*; (Lamarck 1819)

TABLE 1. Mussel species collected in the New River Drainage of Virginia. Collection records by Ortmann (1913), Stansbery & Clench (1966-1969 *in* Clarke 1981 & 1985), Dillon (1977), Markham *et al.* (1980), Neves & Moyer (1988), Dr. David Stansbery (personal communication), Dr. Matt Winston (personal communication, 1997, and this paper, 2003). RS = relic shell material only.

	Reference date						
Species	1913[1]	1966-69[2]	1977[3]	1980[4]	1988[5]	1997[6]	2003
Actinonaias ligamentina				X			
Alamindonta marginata	X	X	X/RS			RS	X
Cyclonaias tuberculata			X	X			X
Elliptio dilatata	X	X	X				X
Lampsilis fasciola							X
Lampsilis ovata			X				X
Lasmigona holstonia		X					X
Lasmigona subviridis	X	X	X/RS		X		X
Tritogonia verrucosa			X	X			X
Total number of species (9)	3	4	6	3	1	1	8

[1]Sites were surveyed at New River mainstem, Pearisburg and Reed Creek.
[2]Sites were surveyed at Walker Creek, Giles Co., Wolf Creek (Bland Co.), and Little River, Floyd Co.
[3]Sites were surveyed at New River mainstem at Radford, Montgomery Co. upstream to state boundary including tributaries.
[4]Sites were surveyed at New River mainstem, between Glen Lyn and VA/WV
[5]Site at New River mainstem at McCoy, Montgomery Co.
[6]Site at Sinking Creek, Giles Co.

(Ortmann, 1913; Stansbery & Clench 1966-1969 *in* Clarke 1981 & 1985; Dillon, 1977; Markham *et al.*, 1980; Dr. David Stansbery, Ohio State University, personal communication; Dr. Richard Neves, Virginia Polytechnic Institute and State University, personal communication). Two additional species, the paper pondshell, *Utterbackia imbecillis* (Say 1828) and giant floater, *Pyganodon grandis* (Say 1829), are known from Claytor Lake reservoir (Dr. Richard Neves, personal communication).

Several factors linked to mussel declines throughout the United States, such as dam construction, water pollution, and exotic species introductions, are present in the New River drainage of Virginia (Neves *et al.*, 1997). Since Ortmann's initial surveys in the early 1900's, three dams have been built on the New River, Virginia. Dams affect mussel populations by inhibiting the movement of fishes that are hosts to their larval life stage. Dams also alter seasonal flow regimes, decrease oxygen levels, and increase depth and sedimentation rates that can negatively affect mussels adapted to riverine environments. Point source pollution from industrial and wastewater discharges is prevalent throughout the mainstem and some tributaries in the drainage. Chlorine, the primary disinfectant used in the treatment of wastewater, is detrimental to aquatic organisms (Brungs, 1973). Nonpoint pollution such as siltation dates to the mid-1800's from wide-scale deforestation and agriculture throughout the drainage (USDA, 1992). Siltation can harm freshwater mussels by clogging gills and reducing feeding efficiency (Neves *et al.*, 1997). Lastly, exotic species such as the Asian clam (*Corbicula fluminea* Müller 1774) are abundant throughout the drainage and can compete for food and space with native bivalves (Sickel, 1986; Yeager *et al.*, 2000).

A comprehensive mussel survey was initiated because much of the New River drainage has not been sampled for mussels or investigated for immediate threats to their populations. The objective of this study was to determine the distribution and status of freshwater mussels in the mainstem and tributaries of the New River drainage in Virginia. This paper summarizes the survey effort, collections, habitat, and observed threats to mussels in the drainage. In addition, management recommendations are provided for the mussel fauna.

STUDY AREA

The New River originates in the Blue Ridge Mountains of North Carolina, and flows northward through the Valley and Ridge Province of Virginia, and the Appalachian Plateaus of West Virginia (Fig. 1). It becomes the Kanawha River at the confluence of the Gauley River in southcentral West Virginia. The Virginia portion of the New River extends for 249 km and drains an area of 7,927 km^2. Mean annual discharge is 143 m^3/sec at Glen Lyn, near the West Virginia border. High flows occur during late winter and early spring, and low baseflows

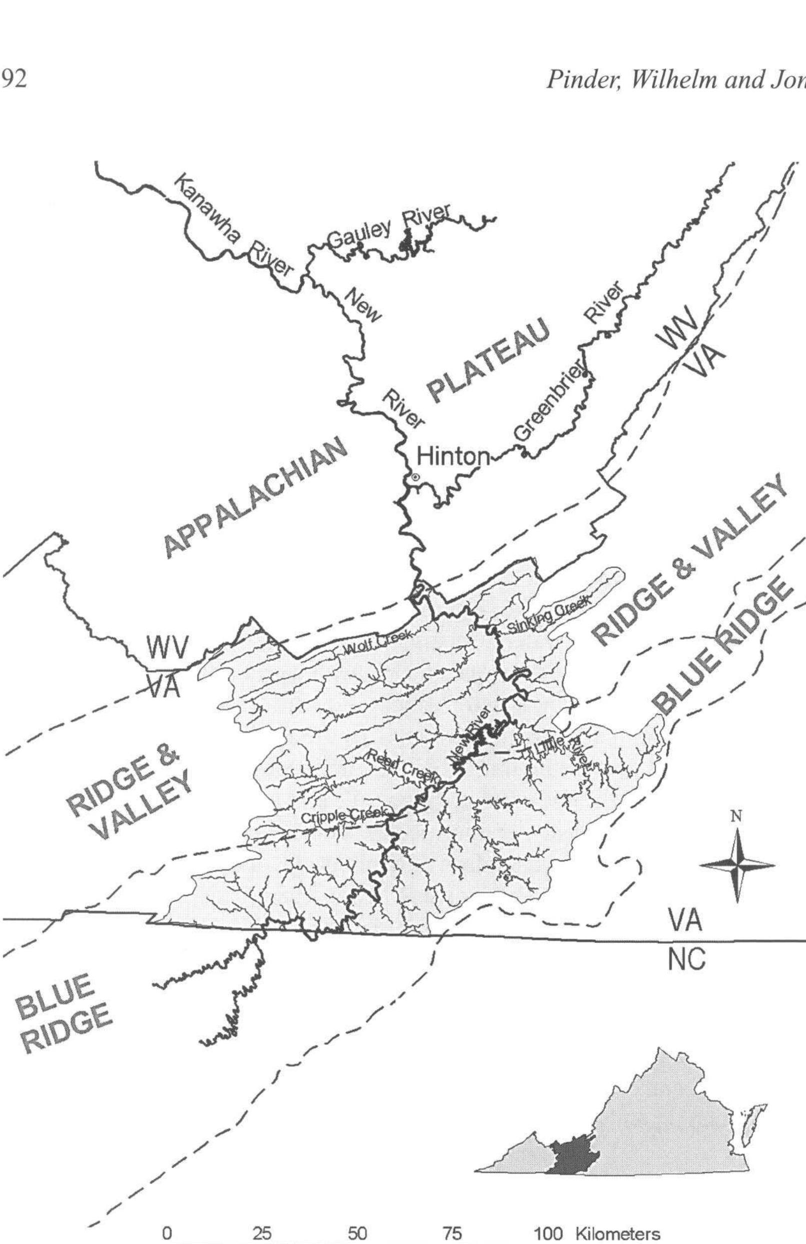

FIG. 1. Basinwide map of the New-Kanawha River drainage, including physiographic provinces and tributaries.

are summer and early fall.

The chemical and physical characteristics of the New River in Virginia are directly influenced by the two physiographic provinces from which it drains

(Fig. 1). Highly resistant igneous and metamorphic rock underlies 3,550 km^2 of the Blue Ridge Province in the upper basin. Most of Grayson, Carroll, and Floyd counties are within this province (Fig. 2). In this region, the mainstem and its tributaries contain low levels of water hardness and alkalinity in high to moderate gradient fluvial morphology. Sedimentary rocks of limestone, dolomite, shale, and sandstone comprise the Ridge and Valley Province, which drains 4,377 km^2 of the lower basin. Layers of sandstone cap the ridges in this region and produce streams with similar water quality and physical characteristics to those in the Blue Ridge Province (USDA, 1992). Valley streams have relatively high to moderate hardness and alkalinity and moderate to low gradients. In several areas streams disappear underground because of the karst geology that characterize the region. The majority of Wythe, Pulaski, and Montgomery counties, and all of Craig, Giles and Bland counties drain the Ridge and Valley province (Fig. 2). Foster's Falls in Wythe County represents the division between the two provinces on the mainstem river. Elevations range from 427 to 1,743 m above sea level. The forest composition of the New River drainage is 75% oak-hickory and 10% white pine-hemlock, with the remaining in a mix of pine and associated deciduous trees (USDA, 1992).

Land-use in the New River Drainage

The New River drainage in Virginia is 58% forested, 37% agriculture, and 5% urban (DCR, 2000). Because of its steep topography, most agriculture is confined to the valleys and along the floodplain of the mainstem. The towns of Wytheville, Bluefield, Christiansburg, Blacksburg, Radford, and Galax are the major urban centers in the drainage. Industrial centers include furniture manufacturers in Carroll and Pulaski counties, the Radford Army Ammunition Plant in Pulaski County, and the Hoechst Celanese Plant and American Electric Power Plant in Giles County (USDA, 1992). Claytor Lake, directly upstream of the town of Radford, is the largest impoundment (1810 ha) on the New River and is popular for boating and fishing (Fig. 2). This reservoir is used to demarcate the upper and lower sections of the mainstem because of its location approximately midway along the Virginia portion of the New River. Two smaller mainstem impoundments are Buck and Byllseby reservoirs, which are 27 ha and 96 ha, respectively. Other small impoundments also occur on the mainstem and the tributary streams of Reed Creek in Wythe County, Peak Creek in Pulaski County, and Little River in Floyd County.

METHODS

Mussels were sampled at 134 sites in the New River basin between June 1997 and October 1998 (Fig. 3; Appendix A). Sites were sequentially numbered based on sampling order. Stream order

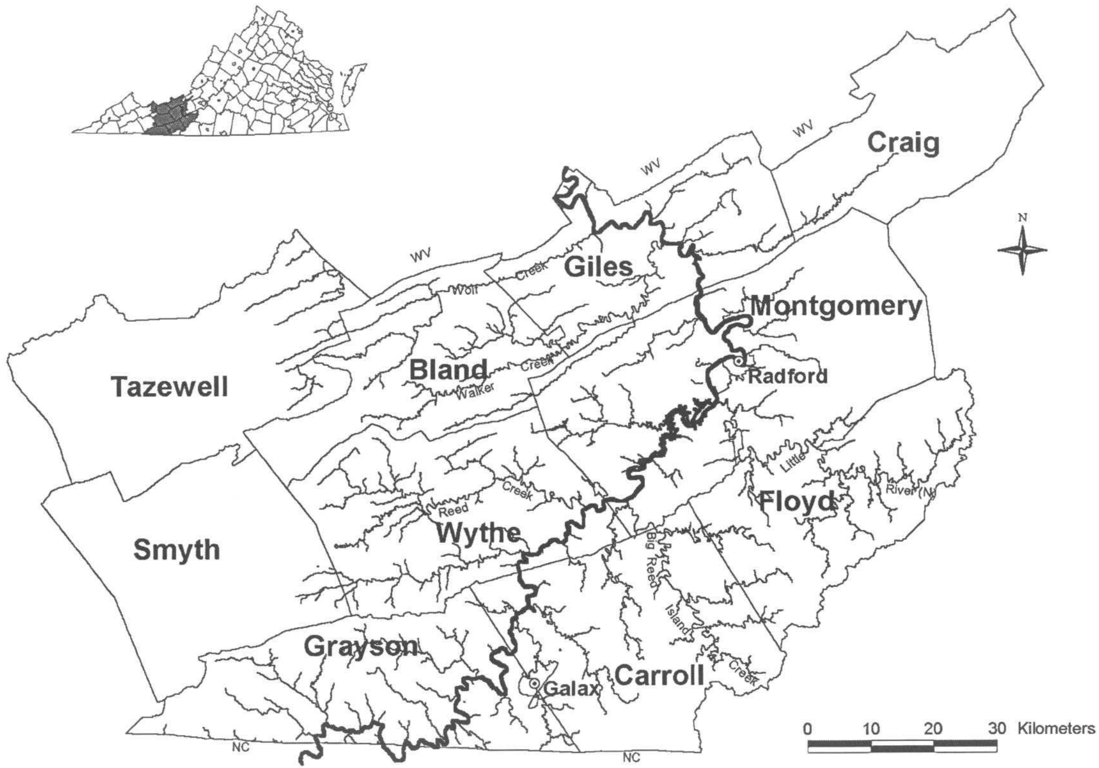

FIG. 2. Counties and major towns in the New River drainage, Virginia.

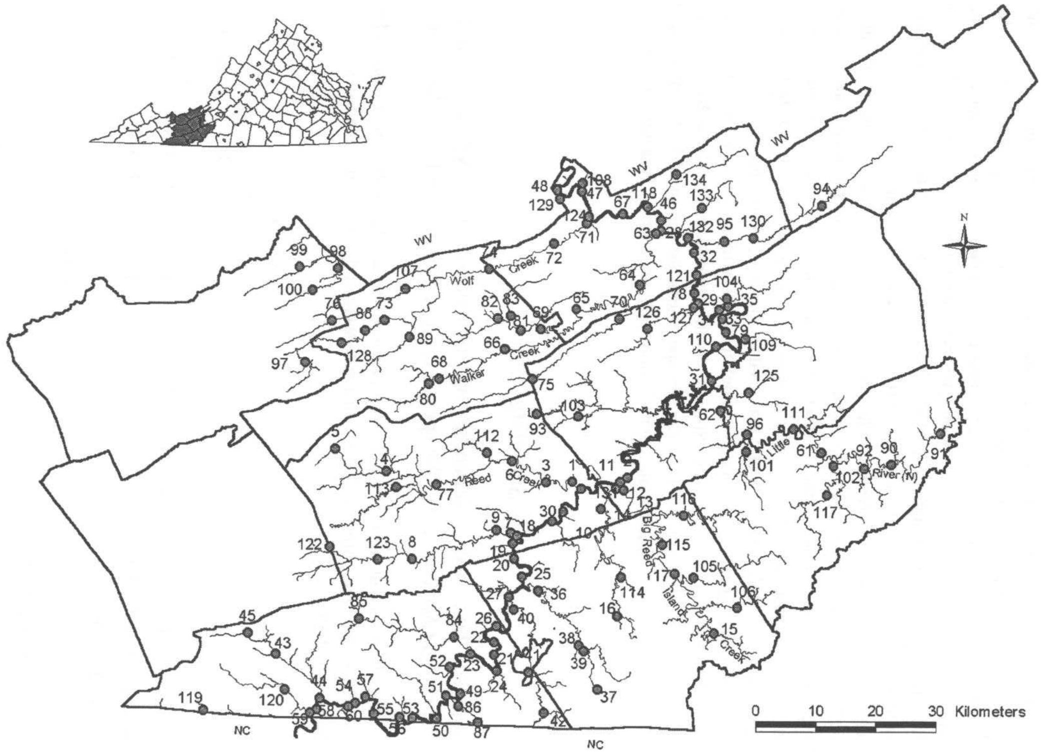

FIG. 3. Survey sites in 1997-1998 for freshwater mussels in the New River drainage, Virginia. Sites are numbered sequentially based on sampling order.

(Strahler, 1957) was defined as blue-lines on a 1:100,000-scale map. We sampled forty-six 4th order mainstem sites, nineteen 3rd order stream sites, thirty-three 2nd order stream sites, and thirty-six 1st order stream sites. Site selection was determined by habitat suitability, accessibility, and historical species records (Ortmann, 1913; Stansbery & Clench 1966-1969 *in* Clarke 1981 & 1985; Neves & Moyer, 1988). Sampling was conducted in summer and early fall during low flow and clear stream conditions. Depending on stream size, field crews ranged from one to eight individuals. Most sites were snorkeled by moving upstream, scanning the stream bottom and lifting small boulders for mussels. A distance of 500 m on mainstem and 250 m on most tributary sections was sampled using these techniques. In streams too shallow to snorkel, we used viewscopes and hand-picked mussels from the substrate. At one deep section, we used SCUBA equipment to sample. We also examined the shoreline to search for mussel shells in muskrat (*Ondatra zibethicus*) middens.

General characteristics including stream width, substrate composition, habitat type (pool, riffle, run), and depth were recorded at each site. In addition, direct impacts and threats to mussels (siltation, nutrification, channelization), obvious water pollution (water discoloration, foam, bacteria growth), and potential causes of impacts (cattle in streams, nearby factories, or roadways) were documented. A Magellan NAV 5000 GPS unit was used to obtain UTM coordinates.

Most live mussels were checked for gravidity. Shell material (with and without lustrous nacre) was collected and recorded at the survey site. Species identifications were confirmed by Dr. David H. Stansbery, Ohio State University (OSU). Voucher specimens are deposited in the Museum of Biological Diversity at OSU. Common and scientific nomenclature follows Turgeon *et al.* (1998).

RESULTS

Sampling Effort

Effort in person-hours varied depending on stream size, habitat type, and number of mussels present (Appendix B). We spent a total of 500 person-hours during the

TABLE 2. Number of sites and abundance (in parentheses) of freshwater mussels by stream order in the New River drainage, Virginia. All 4th order sites were in the New River mainstem. Species codes are in brackets.

	Stream order				
Species	1	2	3	4	Total sites
Elliptio dilatata [EDIL]	1 (16)	2 (28)	2 (13)	24 (316)	29
Cyclonaias tuberculata [CTUB]	–	–	2 (27)	24 (674)	26
Lampsilis ovata [OVA]	–	–	–	12 (27)	12
Lampsilis fasciola [LFAS]	–	–	1 (4)	6 (15)	7
Lasmigona holstonia [LHOL]	4 (20)	–	–	–	4
Tritogonia verrucosa [TVER]	–	–	–	4 (15)	4
Lasmigona subviridis [LSUB]	1 (9)	1 (8)	–	1 (7)	3
Alasmidonta marginata [AMAR]	–	–	–	1 (2)	1
Total Mussel Abundance	45	36	44	1056	50 (1181)

survey, averaging 3.79 person-hours/site. Mean sampling effort varied from 2.4 person-hours on 1st order streams to 5.8 person-hours on 4th order streams.

Species Richness and Diversity

A total of 1,181 live mussels representing eight species from 50 sites, were collected during this study (Table 2). Eighty-nine percent of the mussels were from the mainstem and 11% were from tributaries. Species richness ranged from 0-4 species/site (Fig. 4). The highest species richness was recorded on the New River between Reed and Cripple Creeks, Wythe County, and one site near Rich Creek, Giles County. Most mainstem sites with mussels had from 1 to 3 species. Most 3rd order tributaries had ≤ 2 species, and most 1st and 2nd tributary streams had ≤ 1 species.

The following paragraphs summarize the species, distribution, habitat, and life history characteristics of mussels collected in this survey. Species are listed in order of number of sites where they were found.

Elliptio dilatata (Rafinesque 1820), Spike

Elliptio dilatata was the most widely distributed and second most abundant species found in the survey (Table 2). We found 85% (316) of all individuals in the mainstem. The remaining specimens occurred in headwater streams and large tributaries (Fig. 5). This species was common to abundant at sites in the Blue Ridge Province near the North Carolina border. Relic shell material was found throughout the drainage. Cripple and Walker creeks contained an abundance of shell material but lacked live individuals. We found seven live specimens in Reed Creek, Wythe County, a historical site for this species (Ortmann, 1913). Spike mussels were found in shallow runs dominated by cobble substratum. Gravid specimens were observed in late June and early July, 1997; and again in early August, 1998.

Cyclonaias tuberculata (Rafinesque 1820), Purple Wartyback

Cyclonaias tuberculata was the most abundant species, with 701 individuals comprising 59% of total number collected (Table 2). This species was found at 24 mainstem and two tributary sites (Fig. 6). The largest aggregations (>60 individuals) were found above and below Claytor Lake. *Cyclonaias tuberculata* was found in a wide variety of habitats that included shallow runs, riffles, and moderately deep pools with gravel, boulder or bedrock substrate. Many individuals were found partially buried and covered with an unidentified aquatic moss. Relic shell material was found throughout the mainstem (Fig. 6). Individuals were found gravid in late June, 1997. We observed a female releasing conglutinates during this same time period.

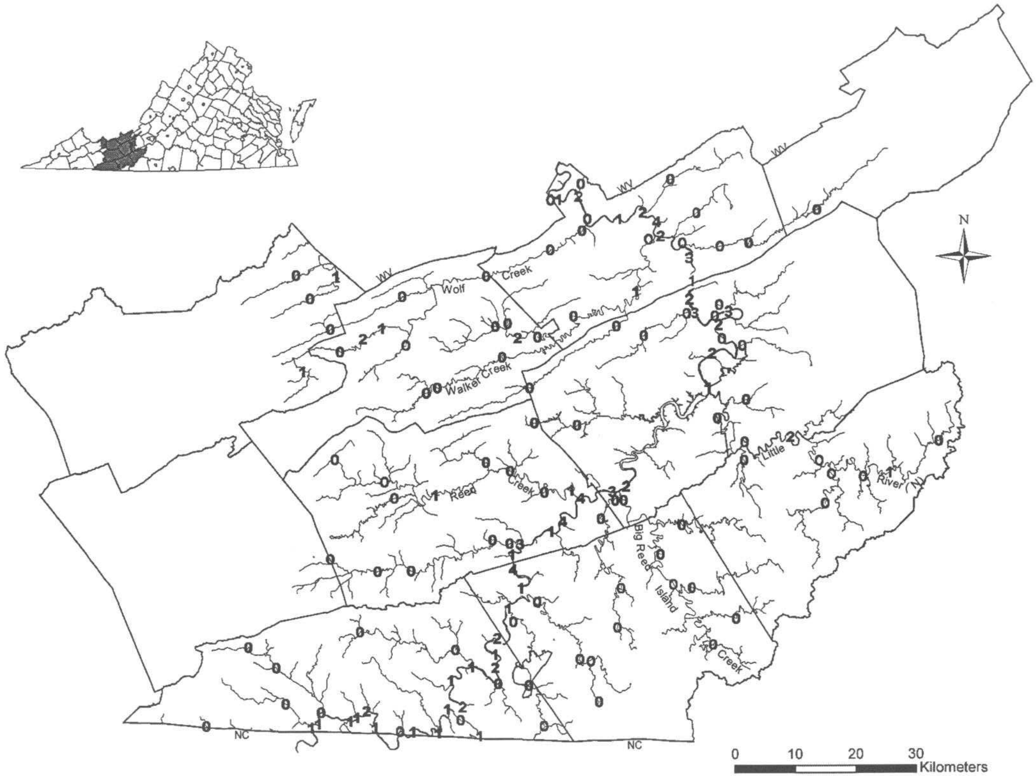

FIG. 4. Number of freshwater mussel species at each sampling site in the New River drainage, Virginia.

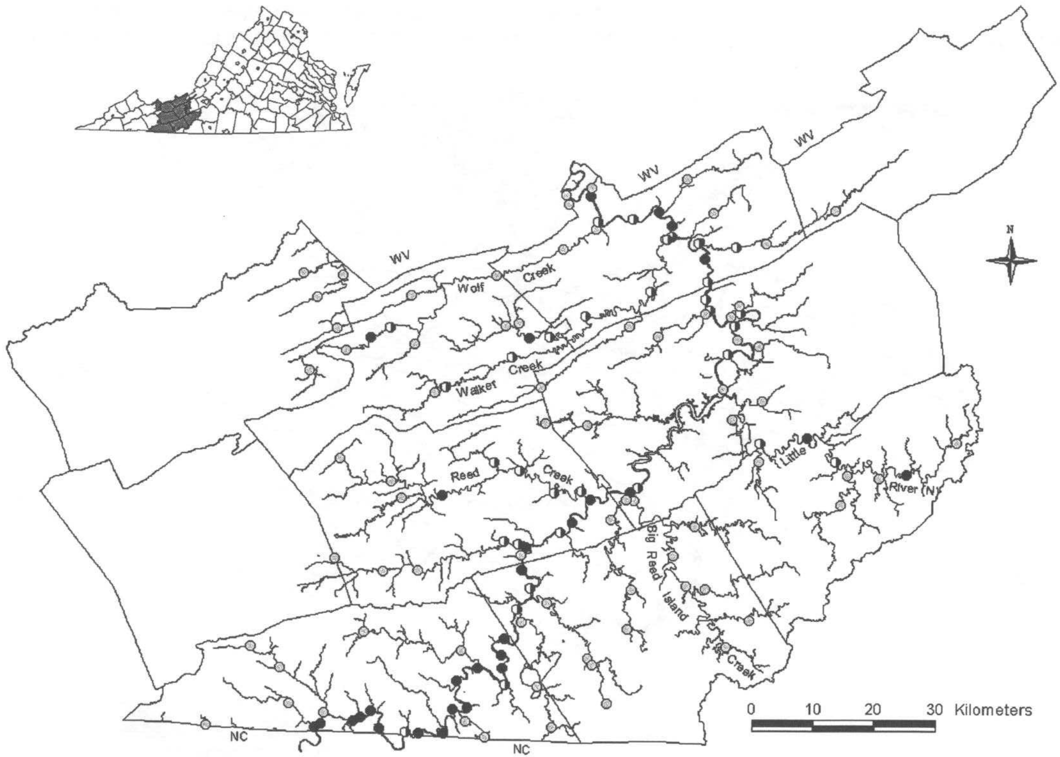

FIG. 5. Distribution of *Elliptio dilatata* (Rafinesque) – live specimens (closed circles), relic shells (half circles), and no live specimens or relic shells (open circles) in the New River drainage, Virginia.

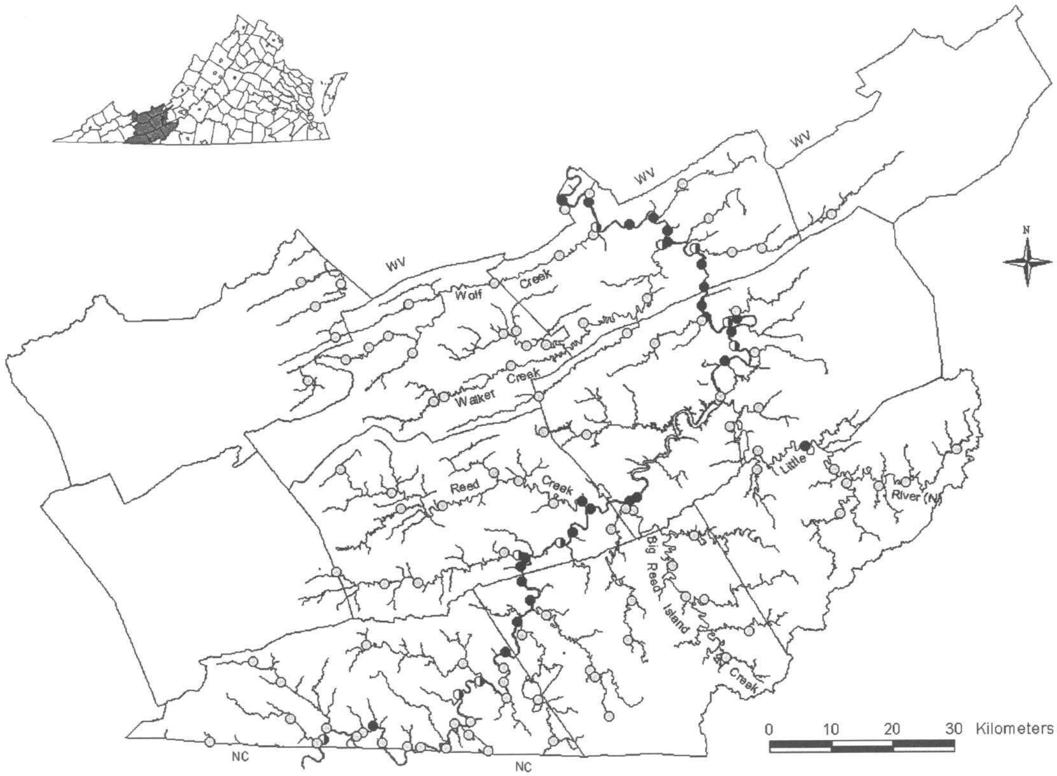

FIG. 6. Distribution of *Cyclonaias tuberculata* (Rafinesque) – live specimens (closed circles), relic shells (half circles), and no live specimens or relic shells (open circles) in the New River drainage, Virginia.

Lampsilis ovata (Say 1817), Pocketbook

Lampsilis ovata was found at 12 mainstem sites, totally 27 individuals (Table 2). Relic shell material was found in Reed Creek. In the mainstem, shell material was uncommon but widely distributed from Giles to Carroll counties. Only one live individual was found in the Blue Ridge province. This species was found in runs with sand, pebble, and gravel substratum. In late June, 1997, we observed a male releasing what appeared to be sperm through its excurrent aperture. Gravid females were found in late June, September, and October, 1998.

Lampsilis fasciola (Rafinesque 1820), Wavy-rayed Lampmussel

Lampsilis fasciola was collected at seven sites, totaling 19 individuals (Table 2). This species was limited to sites below Claytor Lake (Fig. 8). We found 15 individuals in the mainstem, and an additional four specimens in the lower reach of Walker Creek. We found specimens in shallow runs with large gravel and cobble substrate, and observed gravid individuals in July, 1997.

Lasmigona holstonia (Lea 1838), Tennessee Heelsplitter

Lasmigona holstonia were found at four sites, totaling 20 individuals (Table 2). Three sites were in the upper Wolf Creek system, Bland County, and at one site in the Bluestone River, Tazewell County (Fig. 9). In the Wolf Creek system, this species was found from Burkes Garden to approximately 23.4 km downstream in moderate to low gradient reaches. In Burkes Garden, we found eight specimens in a small, heavily-silted, pasture stream (< 2.5 m wide and 35 cm depth). We were unable to find live specimens at historical sites in upper Walker Creek, but several relic shells were present (Dr. David Stansbery, personal communication). Most specimens were found in small, low gradient streams containing clean gravel and cobble. Gravid specimens were found in late August, 1998.

Tritogonia verrucosa (Rafinesque 1820), Pistolgrip

Tritogonia verrucosa was found at four sites, totaling 15 individuals (Table 2). All sites were on the mainstem New River, from above Claytor Lake to just upstream of Fosters Falls, Carroll County (Fig. 10). Except for relic shell material found near the Grayson and Carroll County line, this species was absent from the upper-most portions of the New River. Only relic shells were found below Claytor Lake. At Foster's Falls, we found several individuals in moderately deep runs containing sand, pebble, gravel, and boulder substratum. We found no gravid specimens during our survey.

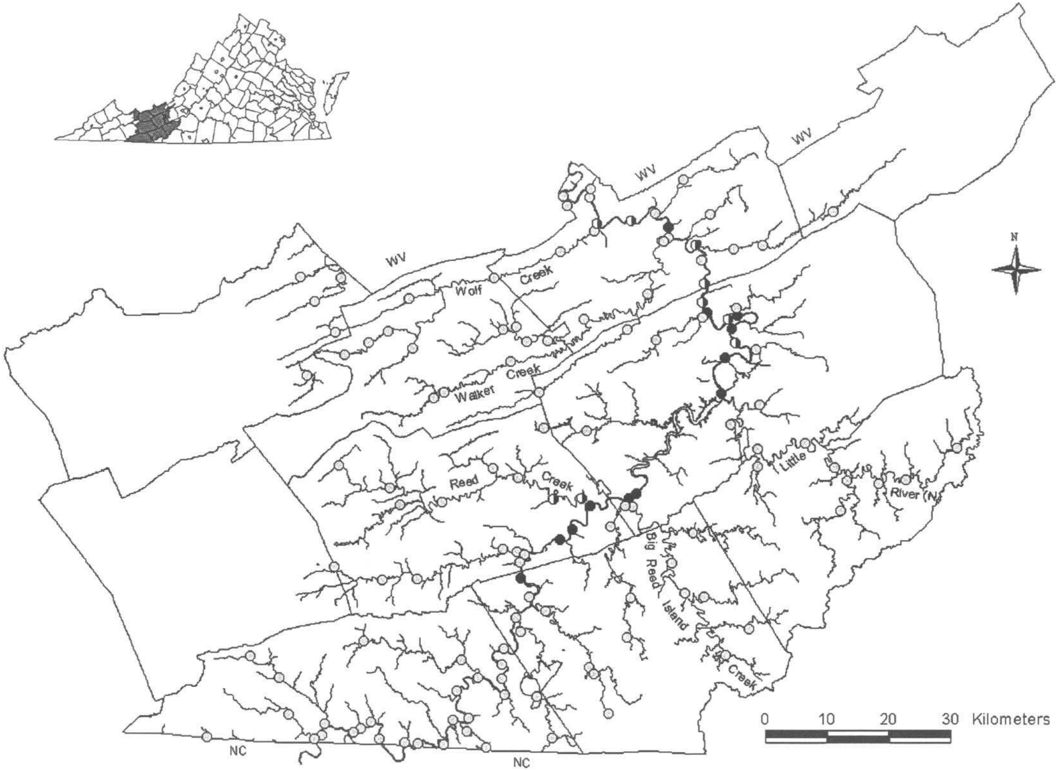

FIG. 7. Distribution of *Lampsilis ovata* (Say) – live specimens (closed circles), relic shells (half circles), and no live specimens or relic shells (open circles) in the New River drainage, Virginia.

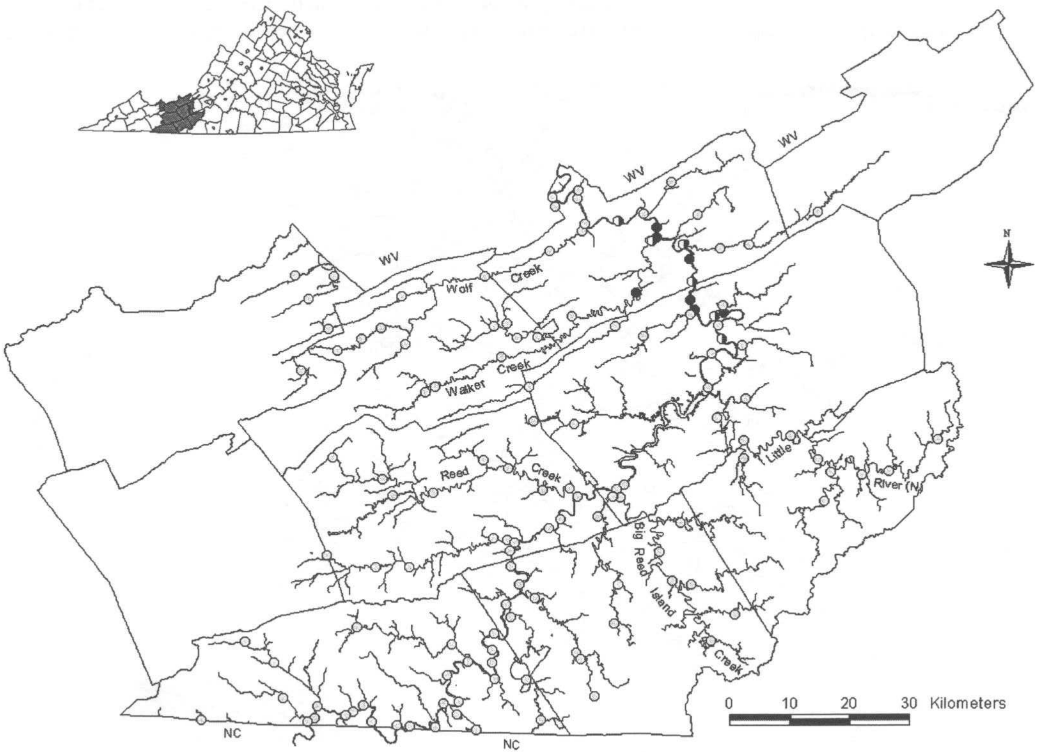

FIG. 8. Distribution of *Lampsilis fasciola* Rafinesque – live specimens (closed circles), relic shells (half circles), and no live specimens or relic shells (open circles) in the New River drainage, Virginia.

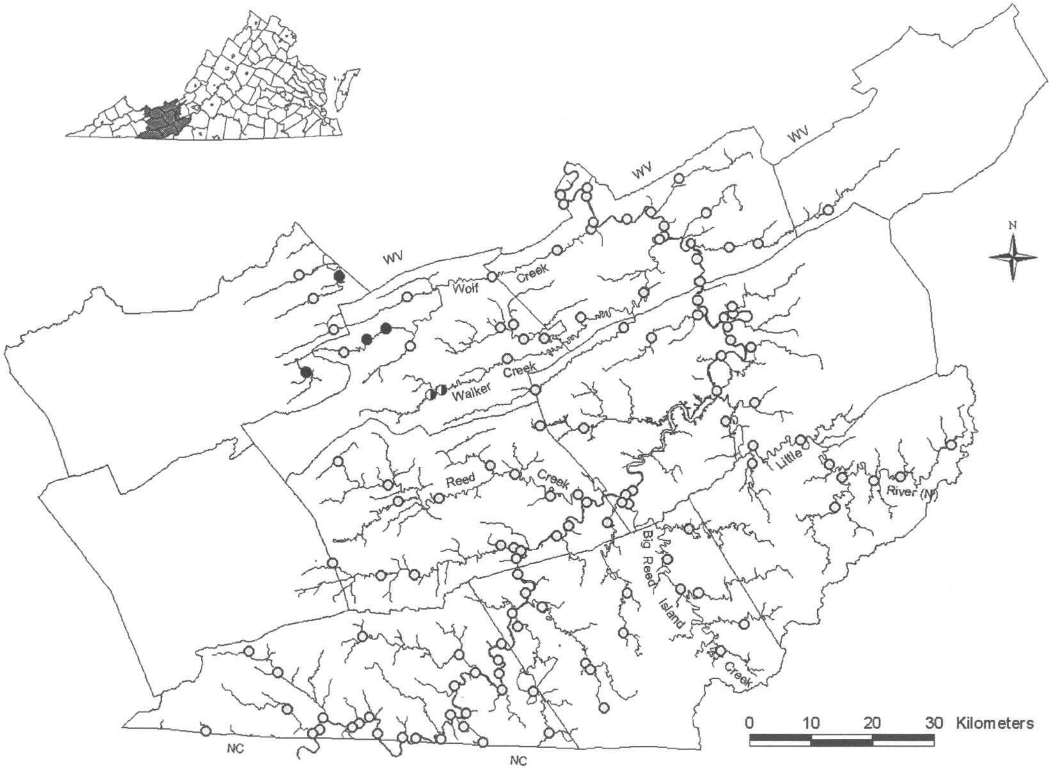

FIG. 9. Distribution of *Lasmigona holstonia* (Lea) – live specimens (closed circles), relic shells (half circles), and no live specimens or relic shells (open circles) in the New River drainage, Virginia.

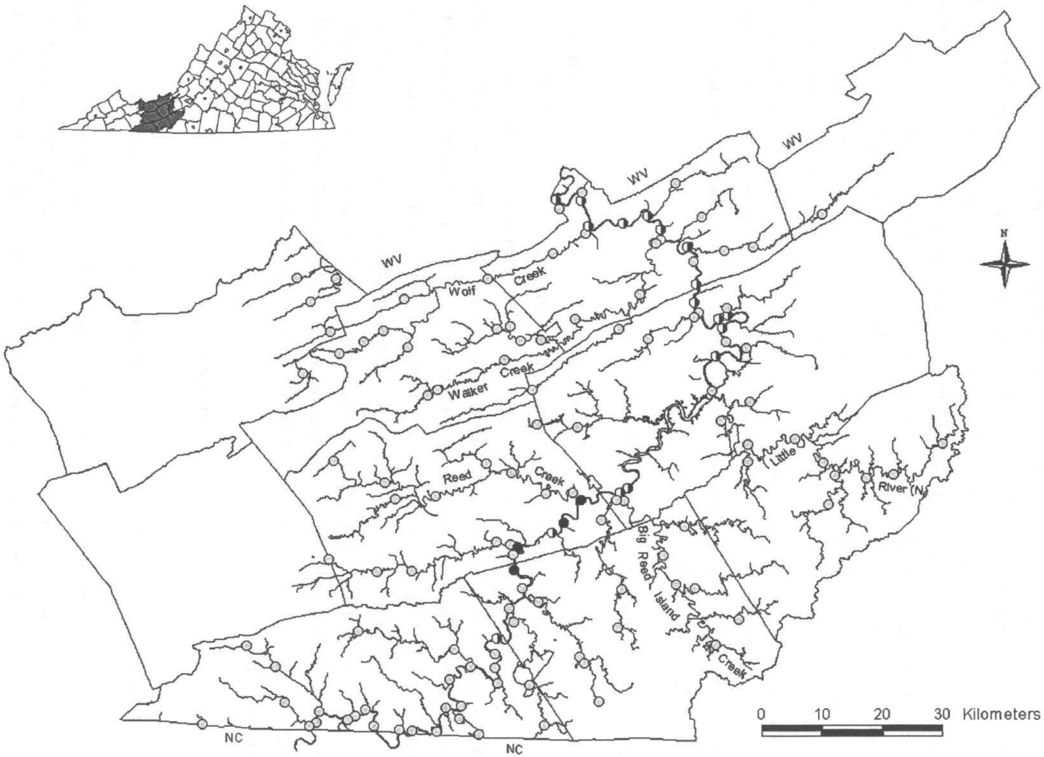

FIG. 10. Distribution of *Tritogonia verrucosa* (Rafinesque) – live specimens (closed circles), relic shells (half circles), and no live specimens or relic shells (open circles) in the New River drainage, Virginia.

Lasmigona subviridis (Conrad 1835), Green Floater

Lasmigona subviridis was found at three sites, totaling 24 individuals (Table 2). Live specimens were found in Kimberling Creek, Bland County; Little River, Grayson County; and New River above Rt.58/221 bridge, Grayson County (Fig. 11). Relic shell material was collected at three mainstem sites below and one site above Claytor Lake. Among historical sites that contained this species, we failed to find live mussels in the Little River, Floyd County (Stansbery & Clench, 1968 *in* Clarke 1985), Reed Creek, Wythe County (Ortmann, 1913), or the mainstem New River, Montgomery County (Neves & Moyer, 1988). In Little River, Grayson County, the habitat was a single shallow run (< 35 cm depth) with gravel and sand substrate. In Kimberling Creek, we found eight specimens in a shallow run with gravel and silt substratum interspersed among large boulders. Sand deposits behind bedrock and boulders in shallow runs characterized habitat for the seven individuals found in the mainstem site. Gravid individuals were collected in August, 1998.

Alasmidonta marginata Say 1818, Elktoe

Alasmidonta marginata was found at one site, totaling only two live individuals (Table 2). Specimens were found at one mainstem river site in Carroll County in early July, 1997 (Fig. 12). Habitat was a shallow run with pebble substrate, and neither was gravid. We failed to find this species in the mainstem river near Pearisburg, Giles County (Ortmann, 1913); Wolf Creek, Bland County (Stansbery & Clench, 1968 *in* Clarke 1981); Reed Creek, Wythe County (Ortmann, 1913); and Walker (Stansbery & Clench, 1968 *in* Clarke 1981) and Sinking creeks (Dr. Matt Winston, Virginia Polytechnic Institute and State University, personal communication), Giles County where the species was known historically. Relic shells were found at one mainstem river site above Claytor Lake and in the upper Wolf Creek system, Bland County.

DISCUSSION

Distribution and Status of Mussels in the New River Drainage

Our findings indicate that freshwater mussels in the New River of Virginia have declined in abundance and diversity, and are now patchy in distribution. Based on the relative abundance of the eight species collected in our survey, the purple wartyback and spike were common, the pocketbook was uncommon, the wavy-rayed lampmussel, Tennessee heelspitter, green floater, and pistolgrip were rare, and the elktoe was extremely rare. The dominance of purple wartyback concurred with results of earlier surveys (Markham *et al.*, 1980; USFWS, 1984).

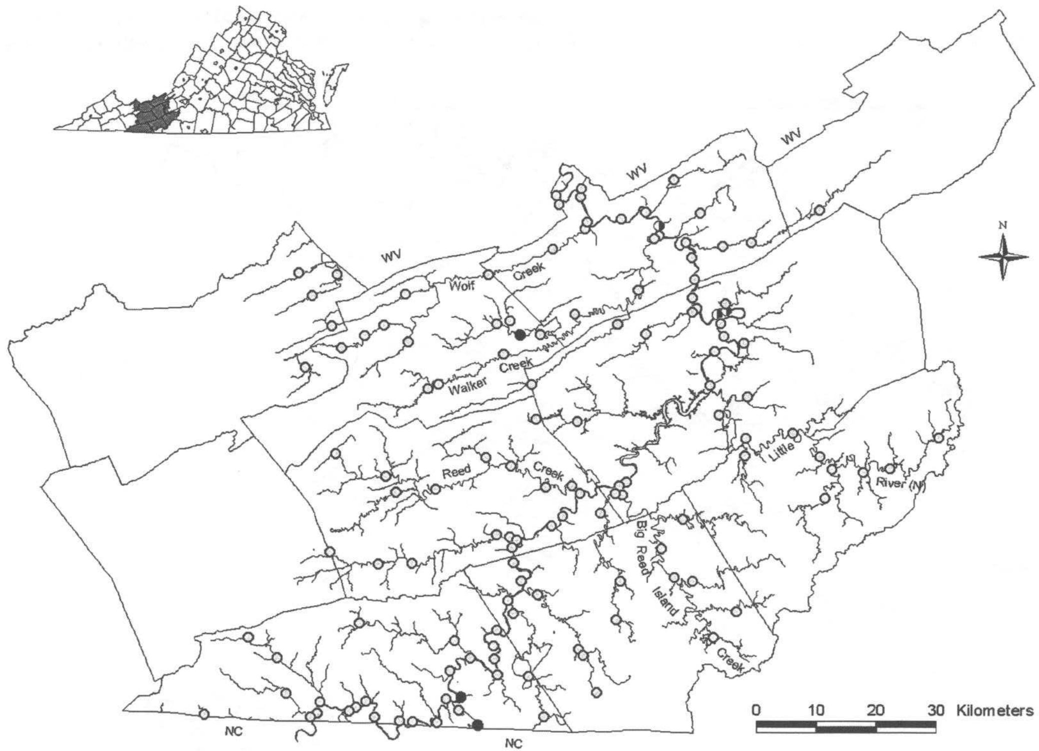

FIG. 11. Distribution of *Lasmigona subviridis* (Conrad) – live specimens (closed circles), relic shells (half circles), and no live specimens or relic shells (open circles) in the New River drainage, Virginia.

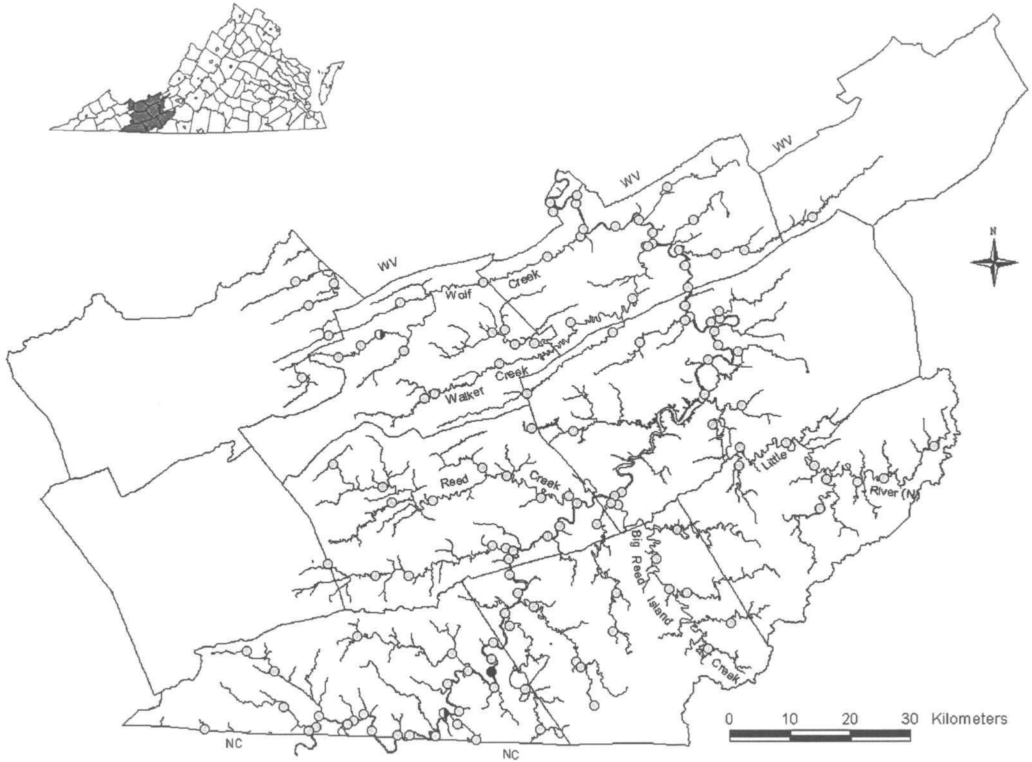

FIG. 12. Distribution of *Alasmidonta marginata* Say – live specimens (closed circles), relic shells (half circles), and no live specimens or relic shells (open circles) in the New River drainage, Virginia.

The only species that occurred historically in the New River that was not collected was the mucket (*Actinonaias ligamentina*). Markham *et al.* (1980) found five specimens in Giles County, Virginia near the West Virginia border in 1979. Two other mussel species, the paper pondshell and giant floater, also occur in the New River, but were not collected in our survey. These species are usually associated with lakes and ponds, locations that we did not sample. Both species are known from Claytor Lake reservoir and other lentic systems in the New River drainage (Dr. Richard Neves, personal communication).

Because of insufficient survey effort, the historic distribution of many mussel species in the New River of Virginia is unknown. Ortmann (1913) did not report the presence of pistolgrip, purple wartyback, wavy-rayed lampmussel, or pocketbook in the Virginia portion of the New River, although he did find most of these species in downstream sections of the New River in West Virginia. Archeological evidence from a Late Woodland village site at the Radford Army Ammunition Plant, Montgomery County location found large numbers of purple wartyback valves dated to 1120 A.D. (Benthall, 2000). The abundance and wide distribution of live individuals and relic shells of purple wartyback and pistolgrip indicates that these species were once well-established in the drainage. Host fish native to the New River drainage of Virginia include flathead catfish (*Pylodictis olivaris*) and channel catfish (*Ictalurus punctatus*) for purple wartyback and flathead catfish for pistolgrip (Hove *et al.*, 1994b; Howells, 1996; Hove, 1997). These fish species are primarily found in mainstem and large tributaries of the New River drainage (Jenkins & Burkhead, 1994), habitats associated with the presence of both mussel species.

In contrast to the pistolgrip and purple wartyback, the pocketbook and wavy-rayed lampmussel may be recent introductions based on their restricted distributions in the New River drainage, Virginia. The New River has the largest number and proportion (42 of 89) of introduced fish species of any system in the eastern United States (Jenkins, 1987). None of the presently known host fishes for either species are native to the New River drainage of Virginia (Jenkins & Burkhead, 1994), even though extensive fish host research has been conducted (Table 3). Mussel introductions have occurred in other areas as a result of stocking infested host fishes. For example, the pocketbook mussel was probably introduced to the Shenandoah River in 1889 via glochidia attached to stocked game fishes (Johnson, 1970). The smallmouth bass (*Micropterus dolomieu*), a nonnative centrarchid that is host to both species (Watters, 1994), was first stocked in the New River tributaries of Virginia in 1877 (Jenkins & Burkhead, 1994). Because the initial and subsequent bass stock originated from the Holston River drainage, where both the wavy-rayed lampmussel and pocketbook are native, these two species may derive from those introduced fish.

TABLE 3. List of brooding periods and fish hosts for freshwater mussels in the New River drainage, Virginia. Original citations are presented in Watters (1994) and Parmalee & Bogan (1998) unless otherwise noted. Fish species status is reported in Jenkins & Burkhead (1994).

Species	Brooding period	Known fish hosts	
Actinonaias ligamentina	August – May[1]	bluegill[2] (I)	*Lepomis macrochirus*
		black crappie[2] (I)	*Pomoxis nigromaculatus*
		green sunfish[2] (N)	*Lepomis cyanellus*
		largemouth bass[2] (I)	*Micropterus salmoides*
		smallmouth bass[2] (I)	*Micropterus dolomieu*
		rockbass[2] (I)	*Ambloplites rupestris*
		white bass[2] (I)	*Morone chrysops*
		white crappie[2] (I)	*Pomoxis annularis*
		yellow perch[2] (I)	*Perca flavescens*
Alasmidonta marginata	July – June[1]	northern hogsucker[2] (N)	*Hypentelium nigricans*
		rockbass[2] (I)	*Ambloplites rupestris*
		warmouth[2] (I)	*Lepomis gulosus*
		white sucker[2] (N)	*Catostomus commersoni*
Cyclonaias tuberculata	May – August[1]	black bullhead[1] (IP)	*Ameiurus melas*
		channel catfish[1] (N)	*Ictalurus punctatus*
		flathead catfish[1] (N)	*Pylodictis olivaris*
		yellow bullhead[1] (IP)	*Ameiurus natalis*
Elliptio dilatata	May – August[1]	banded sculpin[1] (N)	*Cottus carolinae*
		black crappie[1] (I)	*Pomoxis nigromaculatus*
		flathead catfish[1] (N)	*Pylodictis olivaris*
		gizzard shad[1] (I)	*Dorosoma cepedianum*
		rainbow darter[1] (NI)	*Etheostoma caeruleum*
		rockbass[1] (I)	*Ambloplites rupestris*
		yellow perch[1] (I)	*Perca flavescens*
Lampsilis fasciola	September – June[3]	largemouth bass[3] (I)	*Micropterus salmoides*
		smallmouth bass[2] (I)	*Micropterus dolomieu*
Lampsilis ovata	August – July[1]	bluegill[1] (I)	*Lepomis macrochirus*
		largemouth bass[1] (I)	*Micropterus salmoides*
		smallmouth bass[1] (I)	*Micropterus dolomieu*
		white crappie[1] (I)	*Pomoxis annularis*
		yellow perch[1] (I)	*Perca flavescens*
Lasmigona holstonia	September – May[4]	banded sculpin[4] (N)	*Cottus carolinae*
		rock bass[4] (I)	*Ambloplites rupestris*
Lasmigona subviridis	August – May[5]	mottled sculpin[3] (N)	*Cottus bairdi*
Tritogonia verrucosa	April – August[1]	flathead catfish[1] (N)	*Pylodictis olivaris*
		yellow bullhead[1] (IP)	*Ameiurus natalis*

I – Introduced
N – Native
NI – Regarded as native, possibly introduced
IP – Regarded as introduced, possibly native

(1) Parmalee & Bogan, 1998
(2) Watters, 1994
(3) Jones & Neves, pers. comm.
(4) Stegg, 1998
(5) Ortmann, 1919

Lasmigona subviridis (Conrad 1835), Green Floater

The population of green floaters in the Kanawha-New River drainage is unique because it is one of the few interior distributions of the species (Clarke, 1985), and is suspected to be where the species evolved (Ortmann, 1913). It is generally found in the Atlantic slope from the St. Lawrence-Hudson River system of New York, to the Cape Fear River system in North Carolina. Dillon (1977) reported the green floater to be uncommon above Claytor Lake, finding relic shells and a few live individuals. Ortmann (1919) indicated that the green floater is found in quiet pools and eddies with gravel and sand substratum of small streams, typically absent from strong currents and large rivers. We also found specimens in similar substrate types but found individuals in both small tributary and large mainstem river sections.

The decline of green floater in the New River is perplexing. During his survey in the early 1900's, Ortmann (1913) reported that this species was "extremely abundant" in the Kanawha River system (Greenbrier & New rivers). In the mid-1980s, it was common at several sites at McCoy, Montgomery County (Neves & Moyer, 1988). Except for a few isolated sites, the green floater has recently disappeared from the New River drainage in Virginia. Because of declining populations throughout its range, the U.S. Fish and Wildlife Service is currently investigating the green floater as a candidate for federal listing (Roble, 1998). Presently it is listed as threatened in New York and endangered in North Carolina. In Virginia, the green floater is listed as a species of concern, rare but widespread in most Atlantic slope drainages.

Alasmidonta marginata Say 1818, Elktoe

The elktoe is widely distributed in North America from the St. Lawrence River system, Canada, to the Ouachita River drainage, Arkansas (Clarke, 1981). It is typically known from gravel substrate in riffle habitat of large to moderate sized streams (Clarke, 1981b). Our one site with live individuals is similar to its habitat of gravel substrate in large to moderate size streams (Clarke & Berg, 1959).

The northern hogsucker (*Hypentelium nigricans*) and white sucker (*Catostomus commersoni*), both native to the drainage, serve as hosts for the elktoe [Table 3] (Watters, 1994). White suckers inhabit small creeks to medium-sized rivers, while northern hogsuckers are found primarily in large creeks and large rivers (Jenkins & Burkhead, 1994). Because both sucker species are common in the New River, the rarity of the elktoe mussel is not related simply to the lack of host fishes.

Williams *et al.* (1993) rank the elktoe as a species of special concern throughout its range. It is listed as endangered in Kansas, threatened in Minnesota, and of special concern in New York, Tennessee, and Michigan. In Virginia, the elktoe occurs in the New and upper Tennessee River drainages, and is listed as a species of special concern. Historical records indicate that this species was once widely distributed in New River tributaries draining the Ridge and Valley and the Blue Ridge provinces (Clarke, 1981). Dillon (1977) reported specimens at two Reed Creek sites and at one mainstem site above Claytor Lake; however, it is unclear if these samples were of live individuals or relic shells. In 1997, Dr. Matt Winston (personal communication) found relic valves in Sinking Creek, Giles County. Since this survey was conducted, senior author found one live elktoe at the Wolf Creek, Bland County site. Due to its extreme rarity, we suspect that the elktoe may be on the verge of extripation from the Virginia portion of the New River drainage.

Tritogonia verrucosa (Rafinesque 1820), Pistolgrip

In Virginia, the pistolgrip is confined to the mainstem New River where it is becoming increasingly rare. Dillon (1977) reported that it was uncommon to very common from Claytor Lake to Foster's Falls. We found it to be rare above Claytor Lake and absent in our survey below the reservoir. The species is adapted to a wide variety of habitats, from deep pools to shallow runs with gravel, sand, and silt substratum (Parmalee & Bogan, 1998). The pistolgrip is widely distributed in the Mississippi River drainage, from Pennsylvania, west to southern Minnesota, Oklahoma, and Texas (Ortmann, 1919). Williams *et al.* (1993) listed this species as currently stable throughout its range. In Minnesota and Wisconsin, where it occurs at the periphery of its range, the pistolgrip has received additional protection. The pistolgrip is at the extreme edge of its range in Virginia, but it is not protected.

Lasmigona holstonia (Lea 1838), Tennessee Heelsplitter

The Tennessee heelspitter is listed as a state-endangered species in Virginia and primarily occurs in tributaries of the Clinch, Powell, and Holston drainages (Neves, 1991). It is known from the Tennessee River basin and in the headwaters of the Coosa River drainage, Alabama (Parmalee & Bogan, 1998). Its distribution in the Coosa River drainage and now in the New River drainage clearly classifies it as trans-divide headwater species. The New River distribution includes upper Walker Creek (Dr. David Stansbery, personal communication), upper Wolf Creek including Burkes Garden, and upper Bluestone River above Bluefield, Virginia, it appears well established and distributed in upper Wolf Creek, Tazewell and Bland counties. Based on the abundance of relic shell material and the lack of live individuals, this species may be extirpated from Walker Creek, Bland County.

How the Tennessee heelspitter became established in the New River system is unknown. Possible explanations include stream capture, infected host fish movement via subterranean streams, and the inter-drainage transfer of infected host fish by humans. The Tennessee heelsplitter is found in cool, headwater streams, which may increase the likelihood of establishment in the headwaters of adjacent drainages. Both the upper Wolf Creek and Bluestone River systems contain fish species, such as the snubnose darter (*Etheostoma simoterum*), whitetail shiner (*Cyprinella galactura*) and banded sculpin (*Cottus carolinae* sp.) that are native to the Tennessee River basin. Banded sculpin occupy the same habitat as the heelsplitter and is a known host fish (Stegg, 1998). Geological evidence indicates that Wolf Creek captured a tributary of Burkes Garden that once drained into the North Fork Holston River (Ross & Carico, 1963). The "Old Bluestone River" once flowed into the Clinch River, but now drains into the New River (Ross, 1972). Although there is no documented evidence of stream capture on Walker Creek, the divide from the North Fork Holston River is less than one kilometer wide in a flat, karst valley. Further investigation is needed to determine whether stream capture may have occurred between these two drainages.

Threats to Mussels in the New River Drainage

Sedimentation and excessive nutrients were the most obvious impacts to streams in our survey. These factors are considered the primary pollutants to lentic and lotic ecosystems in the United States (Neves *et al.*, 1997). According to the Virginia Department of Conservation and Recreation's Biennial Nonpoint Source Pollution report (2000), nonpoint impairment sources within the New River drainage are from urban (185 km), agriculture (117 km), mineral extraction (13 km), and other/unknown (40 km) sources. During field sampling, we observed heavy silt in the stream bottoms of many tributaries draining agricultural valleys. The most obvious source of siltation was unrestricted access by livestock to creeks and rivers. Because juvenile mussels are associated with surface sediments, they are highly susceptible to sever sedimentation and contaminants when compared to adults (Yeager *et al.*, 1994). Streams containing high levels of silt include Little River in Floyd County, upper Cripple Creek in Wythe County, upper Wolf Creek in Tazewell and Bland counties, and Walker Creek in Giles and Bland counties. The mainstem New River appears less impacted by sedimentation, except during high flows when the river becomes highly turbid.

Nutrient enrichment in the mainstem New River below Claytor Lake was evident by the presence of dense beds of *Elodea* and large mats of filamentous algae that cover the river bottom during the summer. Possible nutrient sources include fertilizer runoff from agricultural and residential plots, and discharge by wastewater treatment plants. Monitoring data from the Virginia Department of Environmental Quality indicates that levels of phosphorus and total nitrogen are generally fair to good, although some watersheds below Claytor Lake are rated poor because of high nutrient loading (DCR, 2000).

Wastewater treatment plants that use chlorine for disinfection occur throughout the New River drainage. Goudreau *et al.* (1993) reported that *Villosa iris* glochidia responded to harmful levels of total residual chloride and ammonia below a wastewater treatment plant by closing their valves, and thus inhibiting reproduction. In addition to chlorine, bacteria and protozoans that proliferate below wastewater discharges may attack the eggs in the gill marsupium of female mussels (Fuller, 1974). The negative effects of chlorine on aquatic biota may prevent mussels from recolonizing suitable habitat of the New River drainage, even if reproducing populations occur upstream.

Biological interactions between exotic species and native fauna may also contribute to the decline of mussels in the New River drainage. The Asian clam is a nonindigenous species that is abundant and widely distributed in the mainstem and in most tributary streams. These highly prolific filter feeders may compete with native bivalves for space and food (Sickel, 1986; Yeager *et al.*, 2000). Interestingly, Asian clams were rare or absent in Kimberling Creek in Bland County, Little River in Grayson County, and upper Wolf Creek in Bland and Tazewell counties, sites that still have rare mussels. An abundance of Asian clams would serve as a food source and an attraction to muskrats, which could predate on native mollusks. Muskrats can intensively feed on small mussels and can affect species abundance at a local level (Neves & Odum, 1989). Neves and Moyer (1988) found significant muskrat predation on green floaters in a previous study in the New River. Because of their small size, adult mussels of the elktoe, spike, Tennessee heelsplitter, green floater, or juveniles of any species would be especially susceptible to muskrat predation.

RECOMMENDATIONS

Because of the rarity of certain species in the New River and throughout Virginia, we strongly recommend listing the green floater and elktoe under the Commonwealth's endangered species law. Specifically, we support listing the elktoe as endangered and the green floater as threatened. The presence of several green floater populations in other Virginia watersheds precludes us from recommending endangered status. The rarity of the pistolgrip may be an artifact of the sampling methods that avoided deeper areas where the species may still persist. Until such sampling can occur, we propose listing the pistolgrip as a state species of special concern.

Because the New River is an expansive system that makes intensive sampling difficult, future mussel surveys should be concentrated on the Little River in Floyd County, Kimberling Creek in Bland County and upper Wolf Creek in Bland

and Tazewell counties. To maximize sampling efficiency, efforts should be concentrated in river reaches that contain high mussel densities, species diversity, or both. We recommend intensive sampling in the mainstem New River between Reed and Cripple Creeks to reveal additional sites with the green floater and elktoe. We also recommend concentrating survey efforts on the river section between Glen Lyn and the West Virginia border, which may harbor the mucket.

Restoring riparian vegetation and restricting cattle access to these waters would significantly improve water quality by reducing siltation and nutrient enrichment. As with most aquatic restoration efforts, obtaining support of riparian landowners is critical (Neves *et al.*, 1997). The headwaters of Wolf Creek, including Burkes Garden, is one area that needs immediate attention. Waters draining Burkes Garden are a significant sediment source in the New River drainage. We failed to observe any trees or buffer vegetation along the creeks in this area. One of the best green floater populations in Virginia occurs in a section of Little River, which is downstream of the town of Sparta, North Carolina. The North Carolina Wildlife Resource Commission and the Division of Environmental Management could provide additional protection to this green floater population.

From 1980 to 2000, New River Valley has increased its human population from 244,983 to 268,393, an 8.7% growth rate (U.S. Census, 2001). As the population increases so will additional demands on the river for water withdrawal and effluent discharge. In rivers and streams with significant mussel resources, other less harmful alternatives such as ozonation and ultra-violet radiation should be considered to disinfect discharges. Water quality monitoring for heavy metals, pathogens, and organic enrichment will also be necessary to document sources of impacts to mussels in the New River.

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APPENDIX A. Location of 134 sampling sites in the New River drainage, Virginia.

Site	Stream Name	Order	UTM X	UTM Y
1	Reed Creek	3	514329	4087457
2	New River	4	523467	4088155
3	Reed Creek	3	509818	4087241
4	Reed Creek	1	483161	4089035
5	Reed Creek	1	474768	4092804
6	Reed Creek	3	504112	4090818
7	Cripple Creek	4	503999	4078719
8	Cripple Creek	3	487543	4074222
9	Cripple Creek	3	501706	4079148
10	New River @ Foster Falls	4	512800	4082373
11	New River at Big Reed Island Creek	4	522246	4087429
12	Little Reed Island Creek	2	521600	4086194
13	Big Reed Island Creek	3	522858	4085983
14	Little Reed Island Creek	2	519148	4082806
15	Big Reed Island Creek	1	538030	4061832
16	Little Reed Island Creek	2	521908	4064719
17	Big Reed Island Creek	2	531360	4071888
18	New River near Ivanhoe	4	505130	4078259
19	New River @ Ivanhoe	4	504384	4076908
20	New River near Ivanhoe	4	504564	4074376
21	New River @ Galax	4	501476	4058059
22	New River Below Galax	4	501427	4060249
23	New River off Rt. 274	4	497540	4058181
24	New River @ Rt. 94	4	501964	4055410
25	New River Below Byllseby Dam	4	505870	4071305
26	New River Below Fries Dam	4	501839	4062934
27	New River @ Rt. 606	4	503741	4067890
28	New River @ Big Walker Creek	4	528637	4129908
29	New River @ Parrot	4	534992	4117638
30	New River @ Rt. 52	4	510883	4080713
31	New River Below Rt. 81	4	537318	4104570
32	New River @ Rt. 730	4	534122	4126237
33	New River @ RAAP	4	539060	4115086
34	New River @ RAAP	4	538468	4116595
35	New River @ RAAP	4	539990	4117229
36	Crooked Creek	2	508602	4068976
37	Crooked Creek	1	518727	4052384
38	Crooked Creek	2	515568	4059793
39	Crooked Creek	2	516361	4058761
40	Chestnut Creek	2	504580	4065711
41	Chestnut Creek	2	507140	4055111
42	Chestnut Creek	2	509654	4048367
43	Fox Creek	2	464994	4058149
44	Fox Creek	2	472334	4050698
45	Fox Creek	1	460308	4061599
46	New River @ Ripplemead	4	528613	4131641
47	New River @ Rich Creek	4	515578	4136518

APPENDIX A (continued).

Site	Stream Name	Order	UTM X	UTM Y
48	New River @ Glen Lynn	4	511368	4136716
49	New River Above Rt. 52/221	4	495921	4051507
50	New River @ Rt. 629	4	491919	4047249
51	New River @ Rt. 715	4	493426	4051211
52	New River @ Rt. 274	4	493995	4055981
53	New River @ Rt. 700	4	487754	4047382
54	New River @ Rt. 601	4	478345	4049842
55	New River @ Rt. 708	4	481456	4048145
56	New River @ Rt. 21/221	4	485621	4047523
57	New River @ Rt. 711, Saddle Creek	4	480001	4050919
58	New River Above Rt. 93	4	471876	4048806
59	New River @ Rt. 716	4	470709	4048166
60	New River @ Rt. 711, VDGIF Launch	4	477204	4049266
61	Little River	3	555665	4092485
62	Little River	3	538829	4099541
63	Walker Creek	3	527806	4129370
64	Walker Creek	3	525237	4120698
65	Walker Creek	3	514700	4116602
66	Walker Creek	2	502807	4109800
67	New River @ Rt. 680, 640	4	522410	4132770
68	Big Walker Creek	2	491890	4104715
69	Kimberling Creek	2	508778	4113144
70	Little Walker Creek	2	521889	4114939
71	Wolf Creek	3	516389	4131102
72	Wolf Creek	3	510908	4127645
73	Wolf Creek	1	482765	4114625
74	Wolf Creek	3	500161	4123332
75	Little Walker Creek	2	507420	4104665
76	Clear Fork	2	474076	4114505
77	Reed Creek	3	491503	4086798
78	New River @ McCoy Falls	4	534226	4119448
79	New River @ Peppers Ferry Bridge	4	539640	4112810
80	Walker Creek	1	490099	4103842
81	Kimberling Creek	2	505470	4112978
82	Wilderness Creek	1	501677	4114951
83	Nobusiness Creek	1	503779	4115410
84	Elk Creek	2	494779	4061090
85	Elk Creek	1	478897	4064073
86	Little River	1	495616	4049369
87	Little River	1	498838	4046742
88	Wolf Creek	1	479539	4112868
89	Hunting Camp Creek	1	486799	4111826
90	Little River	2	567349	4090448
91	Little River	1	575443	4095722
92	Pine Creek	1	562932	4089795
93	Peak Creek	1	508206	4098815
94	Sinking Creek	1	555409	4134278

APPENDIX A (continued).

Site	Stream Name	Order	UTM X	UTM Y
95	Sinking Creek	1	539333	4128192
96	Little River	3	543366	4095569
97	Spring Creek @ Burkes Garden	1	469536	4107476
98	Bluestone River	1	474992	4123314
99	Mud Fork	1	468438	4123538
100	Bluestone River	1	470727	4119620
101	Indian Creek	2	543265	4092543
102	West Fork Little River	3	557673	4090225
103	Peak Creek	1	515197	4098422
104	Tom's Creek	2	539814	4118449
105	Burk's Fork	1	534531	4071299
106	Laurel Fork	1	541891	4066170
107	Clear Fork	2	486185	4119948
108	Rich Creek	1	515706	4137911
109	Crab Creek	1	543013	4111669
110	New River @ Radford	4	538018	4110305
111	Little River	3	551010	4096421
112	Cove Creek	2	500008	4092264
113	South Fork Reed Creek	1	484798	4086351
114	Little Reed Island Creek	2	522550	4071228
115	Big Reed Island Creek	2	529223	4076854
116	Greasy Creek	1	532802	4081771
117	West Fork Little River	2	556609	4085348
118	New River @ Big Stony Creek	4	526415	4133882
119	Helton Creek	1	453122	4048511
120	Big Wilson Creek	2	466530	4052149
121	New River Below McCoy Falls	4	534613	4122445
122	Trib. of Cripple Creek	1	473947	4076181
123	Cripple Creek	3	481957	4074139
124	New River @ Narrows	4	516800	4132284
125	Meadow Creek	2	543628	4102634
126	Back Creek	1	526542	4113314
127	Back Creek	2	534217	4117009
128	Wolf Creek	1	475671	4110759
129	East River	1	511839	4135157
130	Sinking Creek	1	544132	4128761
131	New River @ Reed Creek	4	515760	4086206
132	New River Below Eggleston	4	533054	4128758
133	Little Stony Creek	2	535493	4133769
134	Stony Creek	2	531056	4139385

APPENDIX B. Number of live mussel species found at 134 sampling sites in the New River drainage, Virginia. Species codes are indicated in Table 2.

Site	EDIL	CTUB	LOVA	LFAS	LHOL	TVER	LSUB	AMAR	Total/site	Mussels/hr effort
1	—	23	—	—	—	—	—	—	23	3.8
2	—	59	1	—	—	—	—	—	60	10
3	—	—	—	—	—	—	—	—	0	0
4	—	—	—	—	—	—	—	—	0	0
5	—	—	—	—	—	—	—	—	0	0
6	—	—	—	—	—	—	—	—	0	0
7	—	—	—	—	—	—	—	—	0	0
8	—	—	—	—	—	—	—	—	0	0
9	—	—	—	—	—	—	—	—	0	0
10	6	86	7	—	—	11	—	—	110	6.4
11	1	70	2	—	—	—	—	—	73	12.1
12	—	—	—	—	—	—	—	—	0	0
13	—	—	—	—	—	—	—	—	0	0
14	—	—	—	—	—	—	—	—	0	0
15	—	—	—	—	—	—	—	—	0	0
16	—	—	—	—	—	—	—	—	0	0
17	—	—	—	—	—	—	—	—	0	0
18	4	38	—	—	—	1	—	—	43	5.7
19	—	3	—	—	—	—	—	—	3	0.7
20	6	15	2	—	—	2	—	—	25	6.2
21	26	—	—	—	—	—	—	2	28	4.7
22	3	—	—	—	—	—	—	—	3	1.5
23	9	—	—	—	—	—	—	—	9	1.8
24	—	—	—	—	—	—	—	—	0	0
25	—	1	—	—	—	—	—	—	1	0.5
26	2	115	—	—	—	—	—	—	117	26
27	—	15	—	—	—	—	—	—	15	10
28	—	10	—	2	—	—	—	—	12	2
29	—	3	1	2	—	—	—	—	6	1.5
30	—	—	3	—	—	—	—	—	3	0.7
31	—	—	1	—	—	—	—	—	1	0.3
32	3	50	—	1	—	—	—	—	54	10.8
33	—	1	1	—	—	—	—	—	2	0.3
34	—	—	—	—	—	—	—	—	0	0
35	—	1	1	2	—	—	—	—	4	0.3
36	—	—	—	—	—	—	—	—	0	0
37	—	—	—	—	—	—	—	—	0	0
38	—	—	—	—	—	—	—	—	0	0
39	—	—	—	—	—	—	—	—	0	0
40	—	—	—	—	—	—	—	—	0	0
41	—	—	—	—	—	—	—	—	0	0
42	—	—	—	—	—	—	—	—	0	0
43	—	—	—	—	—	—	—	—	0	0
44	—	—	—	—	—	—	—	—	0	0
45	—	—	—	—	—	—	—	—	0	0

APPENDIX B (continued).

Site	EDIL	CTUB	LOVA	LFAS	LHOL	TVER	LSUB	AMAR	Total/site	Mussels/hr effort
46	4	49	1	2	—	—	—	—	56	9.3
47	2	60	—	—	—	—	—	—	62	15.5
48	—	2	—	—	—	—	—	—	2	0.5
49	1	—	—	—	—	—	7	—	8	1.8
50	78	—	—	—	—	—	—	—	78	22.3
51	3	—	—	—	—	—	—	—	3	1.2
52	3	—	—	—	—	—	—	—	3	1.5
53	8	—	—	—	—	—	—	—	8	2.7
54	1	—	—	—	—	—	—	—	1	0.33
55	50	—	—	—	—	—	—	—	50	20
56	—	—	—	—	—	—	—	—	0	0
57	13	1	—	—	—	—	—	—	14	4.6
58	6	—	—	—	—	—	—	—	6	1.5
59	64	—	—	—	—	—	—	—	64	21.3
60	20	—	—	—	—	—	—	—	20	6.7
61	—	—	—	—	—	—	—	—	0	0
62	—	—	—	—	—	—	—	—	0	0
63	—	—	—	—	—	—	—	—	0	0
64	—	—	—	4	—	—	—	—	4	1
65	—	—	—	—	—	—	—	—	0	0
66	—	—	—	—	—	—	—	—	0	0
67	—	3	—	—	—	—	—	—	3	0.5
68	—	—	—	—	—	—	—	—	0	0
69	—	—	—	—	—	—	—	—	0	0
70	—	—	—	—	—	—	—	—	0	0
71	—	—	—	—	—	—	—	—	0	0
72	—	—	—	—	—	—	—	—	0	0
73	—	—	—	—	1	—	—	—	1	0.2
74	—	—	—	—	—	—	—	—	0	0
75	—	—	—	—	—	—	—	—	0	0
76	—	—	—	—	—	—	—	—	0	0
77	7	—	—	—	—	—	—	—	7	0.8
78	—	22	—	6	—	—	—	—	28	0.9
79	—	—	—	—	—	—	—	—	0	0
80	—	—	—	—	—	—	—	—	0	0
81	26	—	—	—	—	—	8	—	34	9.7
82	—	—	—	—	—	—	—	—	0	0
83	—	—	—	—	—	—	—	—	0	0
84	—	—	—	—	—	—	—	—	0	0
85	—	—	—	—	—	—	—	—	0	0
86	—	—	—	—	—	—	—	—	0	0
87	—	—	—	—	—	—	9	—	9	1.6
88	16	—	—	—	3	—	—	—	19	6
89	—	—	—	—	—	—	—	—	0	0
90	2	—	—	—	—	—	—	—	2	0.5
91	—	—	—	—	—	—	—	—	0	0

APPENDIX B (continued).

Site	EDIL	CTUB	LOVA	LFAS	LHOL	TVER	LSUB	AMAR	Total/site	Mussels/hr effort
92	—	—	—	—	—	—	—	—	0	0
93	—	—	—	—	—	—	—	—	0	0
94	—	—	—	—	—	—	—	—	0	0
95	—	—	—	—	—	—	—	—	0	0
96	—	—	—	—	—	—	—	—	0	0
97	—	—	—	—	14	—	—	—	14	12
98	—	—	—	—	2	—	—	—	2	0.7
99	—	—	—	—	—	—	—	—	0	0
100	—	—	—	—	—	—	—	—	0	0
101	—	—	—	—	—	—	—	—	0	0
102	—	—	—	—	—	—	—	—	0	0
103	—	—	—	—	—	—	—	—	0	0
104	—	—	—	—	—	—	—	—	0	0
105	—	—	—	—	—	—	—	—	0	0
106	—	—	—	—	—	—	—	—	0	0
107	—	—	—	—	—	—	—	—	0	0
108	—	—	—	—	—	—	—	—	0	0
109	—	—	—	—	—	—	—	—	0	0
110	—	3	3	—	—	—	—	—	6	0.6
111	6	4	—	—	—	—	—	—	10	2.1
112	—	—	—	—	—	—	—	—	0	0
113	—	—	—	—	—	—	—	—	0	0
114	—	—	—	—	—	—	—	—	0	0
115	—	—	—	—	—	—	—	—	0	0
116	—	—	—	—	—	—	—	—	0	0
117	—	—	—	—	—	—	—	—	0	0
118	2	13	—	—	—	—	—	—	15	1.5
119	—	—	—	—	—	—	—	—	0	0
120	—	—	—	—	—	—	—	—	0	0
121	—	4	—	—	—	—	—	—	4	0.5
122	—	—	—	—	—	—	—	—	0	0
123	—	—	—	—	—	—	—	—	0	0
124	—	—	—	—	—	—	—	—	0	0
125	—	—	—	—	—	—	—	—	0	0
126	—	—	—	—	—	—	—	—	0	0
127	—	—	—	—	—	—	—	—	0	0
128	—	—	—	—	—	—	—	—	0	0
129	—	—	—	—	—	—	—	—	0	0
130	—	—	—	—	—	—	—	—	0	0
131	1	50	4	—	—	1	—	—	56	10.2
132	—	—	—	—	—	—	—	—	0	0
133	—	—	—	—	—	—	—	—	0	0
134	—	—	—	—	—	—	—	—	0	0

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