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SYSTEMATIC RANK, SYNONYMY AND GEOGRAPHICAL DISTRIBUTION OF *PISIDIUM OBTUSALE*, *P. ROTUNDATUM* AND *P. VENTRICOSUM*

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ABSTRACT. – The systematic rank of the freshwater bivalves *Pisidium obtusale, P. rotundatum* and *P. ventricosum* is discussed. The North American *P. rotundatum* is considered to be specifically identical to the Holarctic *P. obtusale*, and the North American *P. ventricosum* to be a distinct Nearctic species. *Pisidium ventricosum* and *P. obtusale* both have a globose, glossy shell with broad tumid beaks and a so-called pseudocallus in the posterior part of the hinge, which is relatively short. *Pisidium ventricosum* differs from *P. obtusale* by its extreme globosity and its oblique, posteriorly placed beaks. *Pisidium obtusale* lives in small bodies of stagnant water, whereas *P. ventricosum* prefers moving water.

Pisidium japonicum from Japan, *Galileja lapponica cor* from Kamchatka, *P. stoliczkanum* and *P. yarkandense* from western China, and *P. turanicum* from Turkestan are considered to be junior synonyms of *P. obtusale*. A lectotype of *P. scholtzii* var. *lapponicum* from Lapland is designated.

From a distributional point of view, the species of the genus *Pisidium* C. Pfeiffer of Nearctis and those of the western part of Palearctis may be classified into three categories, which are likely to reflect different degrees of systematic affinity. The first category includes the species living either west or east of the Atlantic Ocean dispersal barrier and having no analogous form on the opposite side. This category comprises in Nearctis: *P. adamsi* Stimpson, *P. compressum* Prime, *P. cruciatum* Sterki, *P. equilaterale* Prime, *P. fallax* Sterki, *P. insigne* Gabb, *P. punctatum* Sterki, *P. punctiferum* (Guppy), *P. ultramontanum* Prime, *P. variabile* Prime and *P. walkeri* Sterki; in western Palearctis, *P. annandalei* Prashad, *P. dancei* Kuiper, *P. edlaueri* Kuiper, *P. hinzi* Kuiper, *P. maasseni* Kuiper, *P. moitessierianum* Paladilhe, *P. personatum* Malm, *P. pirothi* Jickeli, *P. pulchellum* Jenyns, *P. pseudosphaerium* Schlesch[1] and *P. tenuilineatum* Stelfox.

[1]For the authorship of *Pisidium pseudosphaerium*, I am following Bowden & Heppell (1968: 258).

The second category includes the species which have an analogous form on the opposite side of the Atlantic Ocean. These are the closely allied Nearctic/Palearctic pairs *Pisidium ferrugineum* Prime + *P. hibernicum* Westerlund, *P. ventricosum* Prime + *P. obtusale* (Lamarck)[2], *P. idahoense* Roper + *P. subtilestriatum* Lindholm and *P. dubium* Say + *P. amnicum* (Müller).

The species of the third category occur in both the Old and the New World (i.e., in both the eastern and western hemispheres). Some of the species are Holarctic, e.g., *Pisidium milium* Held, *P. nitidum* Jenyns, *P. obtusale* (Lamarck) and *P. subtruncatum* Malm; other species are rather circumboreal, e.g., *P. conventus* Clessin, *P. lilljeborgii* Clessin, *P. waldeni* Kuiper; one species, *P. casertanum* (Poli), is cosmopolitan; and three species, *P. amnicum* (Müller), *P. henslowanum* (Sheppard) and *P. supinum* Schmidt, are considered, as long as there is no Nearctic fossil evidence to the contrary, to be recent immigrants in northeastern America.

In the first category, similar variation in sculpture, in gloss of the periostracum or in convexity and general shape between certain species on both sides of the Atlantic barrier may be observed. Such resemblances easily lead to premature conclusions of systematic affinity. This has been the case, for instance, with the Nearctic *Pisidium punctatum* and the Palearctic *P. tenuilineatum* (Herrington, 1954: 135; 1962: 47). I have attempted to point out that *P. punctatum* and *P. tenuilineatum*, as well as the central American *P. punctiferum*, are not only distinct species, each with its own area of distribution, but that they even belong to different subgenera (Kuiper, 1962). The Australian *P. aslini* Kuiper (1983: 37), which is exteriorly similar to *P. punctatum* and *P. tenuilineatum*, but has a basically different hinge structure, therefore, in my opinion, belongs to a distinct subgenus. Cases of parallel variation or convergence like these have sometimes been interpreted in terms of affinity, as did Ellis (1978) in suggesting a close relationship between the European *P. milium* and the Malagasy *P. johnsoni* Smith (l.c., p. 66), the European *P. subtruncatum* and the South African *P. harrisoni* Kuiper (l.c., p. 70), the European *P. moitessierianum* and the North American *P. punctatum* (l.c., p. 82).

Tentatively, I think that in the first category mentioned above, the Old and the New World will each prove to have their own subgenera not

[2] As to whether C. Pfeiffer or Lamarck is the author of *Pisidium obtusale*, I follow Boettger (1961: 243).

represented on the opposite side of the dispersal barrier. The actual use in European literature of the subgeneric name *Cymatocyclas* Dall (1903) for those Palearctic species which anatomically are characterized by two demibranches on each side and two siphonal apertures (Heard, 1966: 87; Bowden & Heppell, 1968: 257; Zeissler, 1971; Dyduch-Falniowska, 1983) seems to me systematically and phylogenetically disputable, in view of the fact that the type species of *Cymatocyclas* is a Nearctic endemic, viz. *Pisidium compressum* Prime.

In the second category, the analogue forms on either side of the dispersal barrier differ at the species level and possibly belong to subgenera with a Holarctic area of distribution. Examples are the Nearctic *Pisidium ferrugineum* and the Palearctic *P. hibernicum*. Herrington's (1962: 52) view of their specific identity introduced the name *P. ferrugineum* into the European fauna (Boettger, 1961: 241; Jaeckel, 1962: 224). I have tried to show that the variation ranges of *P. ferrugineum* and *P. hibernicum* only partially overlap and that therefore, as well as for some other reasons, both have to be considered specifically distinct (Kuiper, 1966). In this connection, some species of the third category, e.g., *P. milium* and *P. nitidum*, merit a closer investigation, especially in view of the possibility that Nearctic subspecies can be distinguished in each of them, based on somewhat diverging ranges of variation.

A subject of controversy for nearly a century and a half is the degree of affinity of the Nearctic *Pisidium ventricosum* Prime and *P. rotundatum* Prime on the one hand, and the Palearctic *P. obtusale* (Lamarck) on the other. Temple Prime, when he was a staff member of the American Legation at The Hague, Netherlands, wrote in a letter dated December 30, 1855, (autograph in the author's archive) to his French correspondent Auguste Baudon, physician in the provincial town of Mouy (France): "Je suis assez convaincu que nous ne possédons aucune des espèces de l'Europe sur notre continent, mais je suis de l'avis que toutes nos espèces ont leur analogue chez vous. Ainsi notre *P. dubium* est le représentant en Amérique du *P. amnicum*, notre *ventricosum* du *obtusale* et ainsi de suite". Baudon (1857: 20), not convinced, noticed: "Le *ventricosum* T. Prime est absolument semblable à notre *P. obtusale*. L'auteur m'a donné des types: je les ai comparés avec le plus grand soin aux nôtres, et il m'a été impossible de constater la plus petite différence . . . je persiste à croire que les *obtusale* et *ventricosum* sont absolument les mêmes". It would, of course, have been interesting to examine Baudon's specimens of *P. ventricosum*. Unfortunately, however, his collection, lodged in the museum of Beauvais (France) after his death, was completely destroyed during World War II.

Clessin (1879: 51) observed, quite rightly, that his *Pisidium scholtzii* (= *P. obtusale*) even in its most globose form, never attains the extraordinary convexity of the American clam, which he therefore refused to identify with any European species. It is evident that Clessin worked with specimens of another origin than Baudon. Clessin's collection, lodged in the museum of Stuttgart (Federal Republic of Germany) was destroyed during World War II.

Sterki (1903: 43) identified some Pisidia from Indiana as *Pisidium obtusale*, but he did not list this species in his Preliminary Catalogue (Sterki, 1916). Curiously, Sterki (1926, 1928) did not even mention the problem of the affinity of *P. obtusale* and *P. ventricosum* in his papers on the Nearctic and the Palearctic Sphaeriidae.

It was Odhner (1939: 82) who for the first time reported *Pisidium obtusale* from the American continent, namely from Port Clarence, Alaska. His figure (l.c., pl. 6, fig. 2) unmistakably represents *P. obtusale*. Subsequently, Ellis (1940: 64) noticed: *P. obtusale* "occurs in Alaska, and it is practically identical with *P. ventricosum* Prime, and closely allied to *P. rotundatum* from North America", an opinion which he later (Ellis, 1962: 48) formulated as follows: *P. obtusale* "also occurs in North America, extending North to Alaska".

Herrington & Taylor (1958: 16) thought that *Pisidium obtusale* "occurs in North America in two ecologic forms, *rotundatum* Prime and *ventricosum* Prime". Herrington (1962: 46) maintained this viewpoint in his monographic revision and some European authors (Ellis, 1962: 64, 1978: 64; Zeissler, 1971: 491; Stelfox et al., 1972: 192) followed him, like Heard (1962a: 195; 1962b: 142; 1966: 87) did in North America. However, Herrington (1965: 195; Henson & Herrington, 1965: 79) changed his mind in stating that the Nearctic *P. obtusale* as he had interpreted it (1962: 46, 47) should be called *P. ventricosum*, and that *P. rotundatum* is only a form of the latter. Clarke (1973: 203) adopted this view, as did Burch (1975: 40) in his well-known key to the North American Sphaeriidae, and Mackie (1981: 51) in his list of sphaeriacean species found in North America. Clarke (1981: 170, 174) treated *P. rotundatum* and *P. ventricosum* again, quite like Temple Prime (1865: 72), as distinct species and dropped *P. obtusale* from his list of the Canadian fauna.

In view of this taxonomic and nomenclatorial confusion, I have tried to shape my own opinion. Basic for me was the known variability of the Palearctic *Pisidium obtusale*. When I then, in 1973, had the opportunity to examine Prime's type specimens of *P. rotundatum* and *P.*

ventricosum (Johnson, 1959), I was struck by the fact that *P. rotundatum* (Figs. 14a-e), as far as characters like outline, convexity, thickness of the shell and details of the hinge are concerned, perfectly fits within the margins of variation of the Palearctic *P. obtusale*, but that, on the contrary, *P. ventricosum*, although indubitably closely allied to the latter, ranges mostly beyond these limits. My next step was verification of these findings on other materials of both forms. In the 1950s, Rev. Herrington had been so kind as to send me fine series of both *P. rotundatum* and *P. ventricosum* collected by himself in Canada. In 1973, I also studied series in the American Museum of Natural History, New York, the Museum of Comparative Zoology at Harvard University, Cambridge, Massachusetts, and the Academy of Natural Sciences, Philadelphia, Pennsylvania. Finally, in 1985, J.B. Burch enabled me to go through the extensive materials in the Museum of Zoology, The University of Michigan, Ann Arbor, where, among others, are lodged the important sphaeriid collections of Bryant Walker, H.B. Herrington and A.W. Stelfox. All this has confirmed my earlier expressed opinion (Kuiper, 1968: 31; 1972: 202) that *P. rotundatum* and *P. obtusale* have to be considered specifically identical and that *P. ventricosum* is a distinct, typical North American species. Subordinate and not yet solved is the question as to whether the Nearctic *P. obtusale* (= *P. rotundatum*) represents a smaller, statistically demonstrable, geographical subspecies.

The shells of *Pisidium rotundatum* which I have seen generally do not exceed 2.5 mm in length. This is also true for most of the European populations of *P. obtusale*, but specimens with dimensions like L 3.5, H 3.0, D 2.5 mm, and even more than 4 mm in length are not rare in Europe. The largest specimen of *P. obtusale* I ever saw originates from northern Norway and measures L 4.9, H 4.3, D 3.8 mm. However, the large (L 5 mm) *P. obtusale* var. *magnificum* Clessin (Westerlund, 1873: 547) from Scandinavia, of which I have examined the type series (NMG[3]), belongs, as already stated by Odhner (1929: 73), to *P.*

[3]NMG = Naturhistoriska Museet, Göteborg, Sweden. Other abbreviations, which follow, are: ANSP = Academy of Natural Sciences, Philadelphia, Pennsylvania, U.S.A.; BML = British Museum (Natural History), London, U.K.; MCZ = Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts, U.S.A.; NHMW = Naturhistorisches Museum, Wien, Austria; UMMZ = Museum of Zoology, The University of Michigan, Ann Arbor, Michigan, U.S.A.; USNM = U.S. National Museum of Natural History, Smithsonian Institution, Washington, D.C., U.S.A.; ZMA = Instituut voor Taxonomische Zoölogie and Zoölogisch Museum, Amsterdam, The Netherlands; ZMB = Institut für Spezielle Zoologie und Zoologisches Museum der Math.-Naturwissenschaftlichen Fakultät der Humboldt-Universität, Berlin, Federal Republic of Germany.

casertanum (syn. *P. cinereum*). Schlesch (1942: 113) published *P. obtusale* var. *major*, from Denmark, also with a length of 5 mm. Specimens which I received at the time from Schlesch prove that they are globose individuals of *P. casertanum* (ZMA K 2277).

One of the characteristics of *Pisidium obtusale* is its important relative convexity, which is calculated for a single valve by the formula 100D:2H. Within the genus, the extreme C.i. (= Convexity index) values are 20 (for the recently described species *P. maasseni* from Mace donia) and 70 (*P. ventricosum*)[4]. The C.i. varies individually and from one population to another. It increases also somewhat during individual growth. The C.i. limits of *P. obtusale* are 33 and 45. The above-mentioned large specimen with a length of 4.9 mm has a C.i. of 44. In certain ecologic conditions, the shell remains small and becomes very convex, whereas the beaks grow broad and globose. This is the case with the climatic form or subspecies *P. o. lapponicum* Clessin (Figs. 6-12), which is common in Pleistocene interglacial deposits of western Europe and still lives north of the Polar Circle in Scandinavia. Its length generally does not exceed 2.2 mm. Its proportional formula is L = H = D, its C.i. being 50. A very tumid specimen of *P. o. lapponicum* (L 1.5, H 1.5, D 1.6 mm) has a C.i. of 53. The conchological borderline between *P. o. lapponicum* and the different forms of *P. obtusale* of the moderate climate belt is not sharp. Intermediates occur, even in the same population (Kuiper, 1972: 201).

The outline (without the beaks) of the Palearctic *Pisidium obtusale* varies from circular (Figs. 6-9) to oval (Figs. 13-16). The shape of the beaks is rather variable and defines the general aspect of the shell (compare Figs. 12 and 17). The upper margin and the hinge (measured from the cusp of a2 to that of p2) are short and less than half the shell length. When not incrustated with micro-algae, the shell is glossy. There may be a more or less developed concentric striation. The position of the beaks of *P. obtusale* is sub- to postmedian (Figs. 6-19), and is never so far behind as in *P. ventricosum* (Figs. 1-4).

In interglacial deposits of western Europe, *Pisidium obtusale lapponicum* is not rarely associated with several species of *Pisidium*, among them the originally Asiatic *P. stewarti* = *P. vincentianum* (Kuiper, 1968:

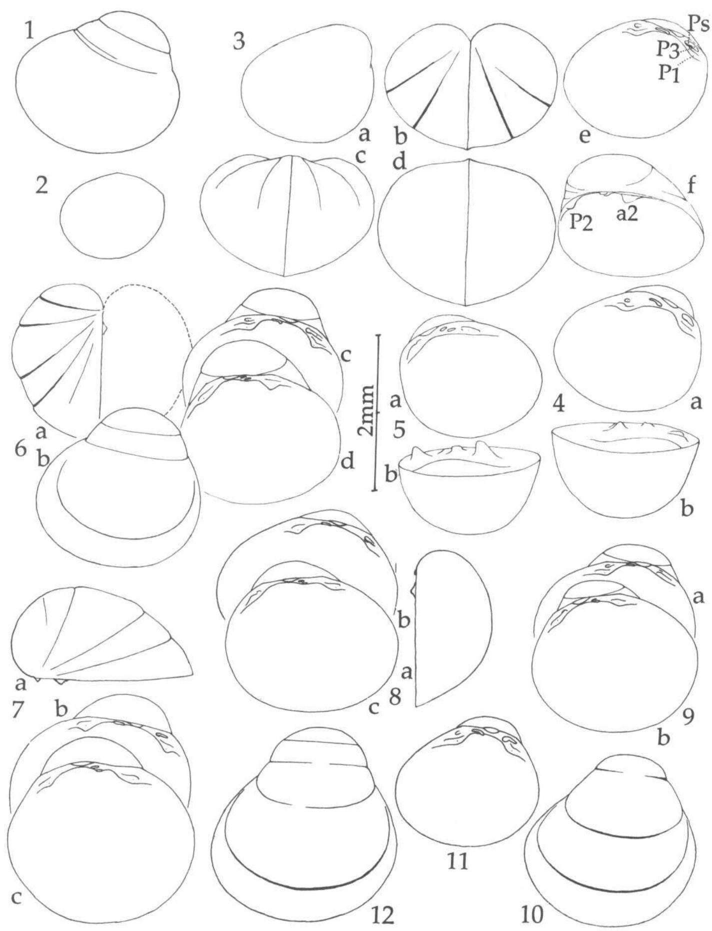
[4]Descriptive terms of convexity of Sphaeriidae (Kuiper, 1983: 18): C.i. inferior to 30 = shell flat or compressed; C.i. between 30 and 40 = moderately convex, tumid, swollen; C.i. between 40 and 50 = inflated, ventricose, globose; C.i. more than 50 = very or extremely tumid, inflated, ventricose.

34; 1972: 204). Some authors have identified *P. o. lapponicum* with *P. ventricosum*. In my opinion, this is not correct. The latter is distinguished by its strikingly oblique shape (Figs. 3, 4), even in juvenile individuals (compare Figs. 2 and 14d), by its comparatively more solid shell, by its relatively heavy hinge, and by its extraordinary convexity, its C.i. varying from 40 to 70 (Figs. 3b,c,d). *Pisidium ventricosum* is by far the most swollen species of *Pisidium* I know. The following table shows that its C.i. is not correlated with the size of the shell.

	C.i.	*Length*	*Height*	*Diameter*
1	70	1.90	1.65	2.3 mm
2	65	2.00	1.7	2.2 mm
3	64	1.7	1.4	1.8 mm
4	61	1.6	1.3	1.6 mm
5	58	2.2	1.9	2.2 mm
6	56	1.8	1.7	1.9 mm
7	54	1.6	1.3	1.4 mm
8	52	2.5	2.2	2.3 mm
9	50	1.6	1.35	1.35 mm

The first specimen above originates from Crooked Lake, Ontario, legit Herrington 1942 (ZMA/K 3417); specimens 2, 5 and 8 are cotypes (MCZ 19814); specimens 3, 4, 6, 7 and 9 are from Caribou, Maine, legit Nylander (NHMW).

Both *Pisidium ventricosum* and *P. obtusale* (including *P. rotundatum*) have a characteristic element in the hinge, viz., the pseudocallus (Phillips & Stelfox, 1918: 37). Ellis (1978: 63) described this detail in *P. obtusale* as follows: "p3 curving across p1 anteriorly and ending in a lump or "pseudocallus" which is a diagnostic character, differing from the callus in *P. personatum* in being joined to or a part of p3 and present only in the right valve". As a matter of fact, in the left valve it is often visible as a slight thickening at the end of the inner slope of p2 (Fig. 14c). The callus in *P. personatum* was first described by Woodward (1913: 54). The difference between the callus and the pseudocallus is clearly figured by Phillips & Stellfox (1918, figs. 3b and 4b). In North America, no species of *Pisidium* possesses a callus.



FIGS. 1-5. *Pisidium ventricosum* Prime. FIG. 1. Outline of adult specimen (L 2.2, H 2.0, D 2.1 mm, C.i. 53) from Barren Brook, Caribou, Maine. FIG. 2. Outline of juvenile specimen (L 1.2 mm) from Crooked Lake, Ontario. FIG. 3a-f. Extremely swollen specimen (L 1.9, H 1.65, D 2.3 mm, C.i. 70) from Crooked Lake. a, Lateral outline; b, front view; c, diagonal view; d, ventral profile; e, hinge right valve (pl, inner posterior lateral; p3, outer posterior lateral; ps, pseudocallus); f, umbonal view of left valve (a2, anterior lateral; p2, posterior lateral). FIG. 4a,b. Right valve (L 1.9, H 1.7, D 2.2 mm, C.i. 65) from Crooked Lake. FIG. 5a,b. Left valve (L 1.8, H 1.6, D 2.2 mm, C.i. 68) from Crooked Lake.

FIGS. 6-12. *Pisidium obtusale* (Lamarck), climatic form *lapponica* Clessin. FIG. 6a-d. Swollen specimen with high, broad beaks (L 2.2, H 2.2, D 2.2 mm, C.i. 50) from Tönset, Norway. FIG. 7a-c. Large, nearly round specimen (L 2.5, H 2.5, D 2.5 mm) from Dalsland, Sweden. FIG. 8a-c. Specimen (L 2.4, H 2.1, D 2.0 mm, C.i. 48) from Troldvand, northern Norway. FIG. 9a,b. Specimen (L 2.15, H 2.10, D 2.0, C.i. 48) from Disko Fjord, Greenland. FIG. 10. Lecto-

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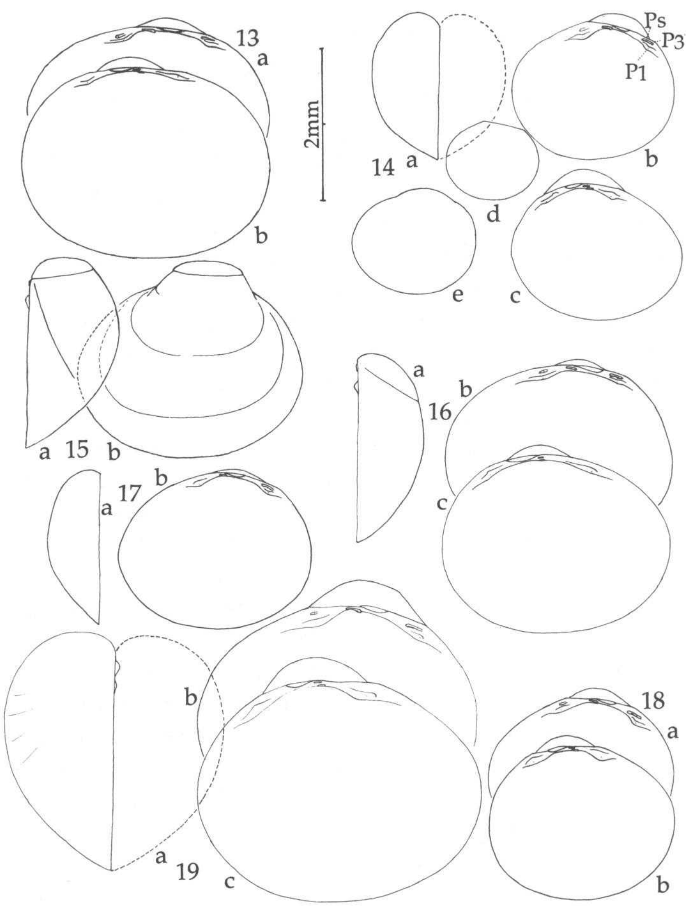

FIGS. 13-19. *Pisidium obtusale* (Lamarck). FIG. 13a,b. Forma *acidicola* Stelfox, Roundstone, Ireland. FIG. 14a-e. *P. rotundatum* Prime (L 2.25, H 2.0, D 1.8 mm, C.i. 45), meadow west of Ward, Montana. a, Frontal profile; b, right valve (p1 and p3, posterior laterals; ps, pseudocallus); c, same individual, left valve; d, juvenile specimen (L 1.3 mm); e, half-grown specimen (L 1.6 mm). FIG. 15a,b. Common form (L 3.0, H 2.7, D 2.45, C.i. 46), Vlachtwedde, Netherlands. FIG. 16a-c. Forma *acidicola* Stelfox, Glengariff Co., Ireland. FIG. 17a,b. *P. turanicum* Clessin, syntype (L 1.95, H 1.6, D 1.1 mm, C.i. 34), Dumansköl, Turkestan. FIG. 18a,b. *P. yarkandense* Prashad, syntype, Yarkand, China. FIG. 19a-c. Large form (L 3.9, H 3.4, D 2.8 mm, C.i. 41), Svendborg, Denmark.

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type, herewith designated, of *P. scholtzii* Clessin var. *lapponicum* Clessin (1873), ZMB 17691 (L 2.3, H 2.3, D 2.35 mm, C.i. 51). FIG. 11. Fossil right valve (L 2.0, H 1.75, D 1.8 mm, C.i. 51) with strong hinge-plate, Weichselian Glaciation near Lebenstedt, western Germany. FIG. 12. Large specimen (L 2.6, H 2.6, D 2.6 mm, C.i. 50) with extremely high and broad beaks, from northern Norway.

As to ecology, *Pisidium obtusale* in Europe lives in ponds, drainages, forest ditches with rotting leaves, temporary pools, marshy prairies, peats, bogs and swamps, as well as in shallow tarns in dense border vegetation. The species does not belong to the fauna of rivers and streams. It is only accidentally collected in such habitats. Stefano (1969: 43) reports that *P. obtusale* is a typical species of the successive vegetation zones of many Pyrenean mountain tarns (1800-2200 m elevation). Out of the seven species of *Pisidium* living in these small lakes, *P. obtusale* has proven to be quantitatively dominant in the *Carex* zone and less common in that of *Menyanthes*, but it forms dense populations in the *Eriophorum* zone, where it is not accompanied by any other species of the genus (Combes et al., 1971: 129). Ökland (1971: 137) regularly collected *P. obtusale* in northern Norway in small water bodies where it was relatively numerous in *Carex* vegetation. *Pisidium obtusale* is absent in habitats with significant daily temperature fluctuations like in the small "pozzines" in mountain bogs (up to 20°C difference), where *P. casertanum* is often abundant. On the other hand, *P. obtusale* tolerates seasonal temperature fluctuations, which is why Meier-Brook (1975: 87) considered this species eurythermic. Ökland (1971) found *P. obtusale* in "temporary ice waterpools" above 900 m in northern Norway. In peaty regions in the low parts (several meters below sea level) of the Netherlands, I collected *P. obtusale* also in humid *Sphagnum*, together with hygrophile land snails like *Vertigo antivertigo* Draparnaud, *Cochlicopa lubrica* (Müller) and *Carychium minimum* (Müller). It has also been found in *Sphagnum* in Austria at 1500 m altitude (Kuiper, 1974: 21). Karen Ökland (Ökland & Kuiper, 1982), who did the fine sphaeriid mapping of Norway based on her own investigations in many hundreds of lakes, found that *P. obtusale*, which turned out to be one of the most frequent Sphaeriidae of Norway, tolerates water extremely poor in calcium, whereas it has an acidification tolerance limit of pH 5.0.

Pisidium obtusale is absent in the littoral zone of the deep pre-alpine lakes of central Europe. Walter (Walter & Kuiper, 1978) collected, in his methodical way of sampling, successively about 20,000 specimens of *Pisidium* belonging to 12 species (without *P. obtusale*) in Lake Zürich. Girod (Girod & Kuiper, 1977) did not find any specimens of *P. obtusale* among the numerous materials dredged in Lake Lugano, Italy. Neither did Favre (1927: 302) record it in Lake Geneva: "Ce *Pisidium* manque complètement à nos lacs et à nos eaux courantes et limpides. C'est l'espèce des eaux stagnantes, fangeuses, et par conséquent de nos mares sans effluents et de nos marais encombrés de végétaux en décomposition". Favre (1940: 341), in his thorough malacological study of the Lake du Bourget, France, did not find *P. obtusale* inside the lake, but he found many in the surrounding marshes. These examples could be multiplied by many other literature citations. I myself identified extensive materials, not yet published, from 40 pre-alpine lakes in Switzerland and Austria. In all, 12 species of *Pisidium* were recorded, but not a single specimen of *P. obtusale.*

As far as I know, detailed ecological information for Sphaeriidae is unavailable for North America, but the general indications in the literature agree, in my opinion, rather well with the above-mentioned facts. Herrington & Taylor (1958: 16) summarized the ecology of *Pisidium obtusale* as follows: "the form *rotundatum* prefers shallow water and it is principally in ponds, bog ponds, lagoons and flood plains". *Pisidium ventricosum*, on the contrary, as concluded from brief indications on museum collection labels, is a species of well-oxygenated moving water of streams and open lakes. It seems to be preferentially a river dweller. Henson & Herrington (1965: 92) recorded only three samples of *P. ventricosum* in lakes Huron and Michigan. Enigmatic is Clarke's (1973: 303) conclusion that there is "no discernable difference between the ecology of *P. ventricosum* s.s. and form *rotundatum* in the Canadian Interior Basin". He gives interesting statistical facts on the presence of *P. ventricosum* and *P. rotundatum* in the various water bodies of the mentioned Basin, but, as a matter of fact, nearly nothing is said on the kind of habitat nor on the synecology in the respective categories.

In Palearctis, the range of *Pisidium obtusale* extends from western Europe to the Far East. It occurs mainly north of the Alpine mountain chains and the Himalayas. It is sporadic in the Mediterranean area and in the Near East and is not known from North Africa. It has been recorded in Iceland and Greenland. In Nearctis, this species extends from the eastern states to the Aleutians and goes southward as far as New Jersey, Ohio, Kansas, Colorado, Utah and northern California.

Pisidium japonicum Pilsbry & Hirase (1908: 35), from Japan, of which I have examined several type lots (USNM 342654, ANSP 94744, UMMZ 109872, MCZ 44761), is identical to *P. obtusale.*

Galileja lapponica cor Starobogatov & Streletzkaja (1967: 251), from Kamchatka, of which I have had the opportunity to study the type series belonging to the Academy of Sciences of the USSR, Zoological Institute, Leningrad, is, in my opinion, *Pisidium obtusale lapponicum* with a maximum C.i. of 50, the largest specimen being 1.8 mm in length.

Pisidium stoliczkanum (Prashad, 1933: 5) (type series BML 8812.4.-690.3; BML 3224.03.VII.1; BML 1098.06.1.1; UMMZ 194590; ZMB 30175) and *P. yarkandense* Prashad (1933: 3) (type series UMMZ 194619; ZMB 27543; ZMB 27648), both from western China, are *P. obtusale* as well (Fig. 18a,b).

Pisidium turanicum Clessin (1874: 38) (type ZMB), Fig. 17a,b, from Turkestan, is *P. obtusale*. Clessin (1879: 46) himself suggested its specific identity with *P. scholtzii* (= *P. obtusale*). Woodward (1913: 84) put *P. turanicum*, for reasons unknown to me, in the synonymy of *P. subtruncatum*.

Shadin (1933: 518) reported *Pisidium obtusale* from Baikal. M. Kozhov, Irkutsk, in 1963 sent me some samples of *P. obtusale* from localities near Lake Baikal.

Pisidium obtusale is known from Kazakstan (Kuiper, 1969: 53).

As to the geographical range of *Pisidium ventricosum*, I refer to Herrington (1962: 47) and Clarke (1973: 202).

LITERATURE CITED

BAUDON, A. 1857. Essai monographique sur les pisidies françaises. *Mem. Soc. Acad. Oise*, 3: 315-367, 5 pl.

BOETTGER, C.R. 1961. Zur Systematik der in die Gattung *Pisidium* C. Pfeiffer gerechneten Muscheln. *Arch. Molluskenkd.*, 90: 227-248.

BOWDEN, J. & HEPPELL, D. 1968. Revised list of British Mollusca. 2. Unionacea - Cardiacea. *J. Conchol.*, 26: 237-272.

BURCH, J.B. 1975. *Freshwater sphaeriacean clams (Mollusca: Pelecypoda) of North America.* Malacol. Publ., Hamburg, Michigan. 96 pp.

CLARKE, A.H. 1973. The freshwater Mollusca of the Canadian Interior Basin. *Malacologia,* 13: 1-509.

CLARKE, A.H. 1981. *Les mollusques d'eau douce du Canada.* Natl. Mus. Canada, Ottawa. 447 pp.

CLESSIN, S. 1873. Zur Kenntnis unserer Pisidien. *Malakol. Blatt.*, 20: 21-30.

CLESSIN, S. 1874. *In:* Fedchenko, A.P., *Puteshestvie v Turkestan*, etc. Tom. II, chast. 1, Sliznyaki (Mollusca). 66 pp, 3 pls. Izvyest. imp. Obshchest. Lyubit. Estestvoz. Antrop. i Etnogr. Moskva, XI, vuip. 1.

CLESSIN, S. 1879. Die Familie der Cycladeen. In Abbildungen nach der Natur., Vol. 9(3), *Systematisches Conchylien-Cabinet von Martini und Chemnitz.* Bauer und Raspe, Nürnberg. 282 pp., 46 pls.

COMBES, C., KUIPER, J.G.J. & STEFANO, Y. de. 1971. Ecologie des espèces du genre *Pisidium* Pf. dans les étangs du Carlit (Pyrénées). *La Terre et la Vie*, 25: 96-131, pl. 1-4.

DALL, W.H. 1903. Review of the classification of the Cyrenacea. *Proc. biol. Soc. Wash.*, 16: 5-8.

DYDUCH-FALNIOWSKA, A. 1983. Shell microstructure and systematics of Sphaeriidae. *Acta Zool. Cracov,* 26(9): 251-296.

ELLIS, E.A. 1940. The identification of the British species of *Pisidium. Proc. malacol. Soc. London,* 24: 44-88, pl. 3-6.

ELLIS, A.E. 1962. *British freshwater bivalve molluscs. With keys and notes for the identification of the species.* Synopses of the British fauna, no. 13. Linnaean Society of London, London. 92 pp., 16 pls.

ELLIS, A.E. 1978. *British freshwater bivalve Mollusca. Keys and notes for the identification of the species.* London. 109 pp.

FAVRE, J. 1927. Les mollusques post-glaciaires et actuels du Bassin de Genève. *Mem. Soc. Phys. Hist. nat. Genève,* 40: 171-434, pl. 1-17.

FAVRE, J. 1940. La faune malacologique post-glaciaire et actuelle du Lac du Bourget. *Ann. Ec. nat. Eaux Forêts,* 7: 295-475, pl. 1-13.

GIROD, A. & KUIPER, J.G.J. 1971. Notes sur les Sphaeriidae du Lac de Lugano. *Atti Soc. Ital. Sci. nat. Mus. civ. Stor. nat. Milano,* 118: 293-298.

HEARD, W.H. 1962a. Distribution of Sphaeriidae in Michigan, U.S.A. *Malacologia,* 1: 139-161.

HEARD, W.H. 1962b. The Sphaeriidae of the North American Great Lakes. *Am. midl. Nat.,* 67: 194-198.

HEARD, W.H. 1966. Subgeneric classification of *Pisidium* in North America. *Nautilus,* 79: 86-89.

HENSON, E.B. & HERRINGTON, H.B. 1965. Sphaeriidae of lakes Huron and Michigan in the vicinity of the Straits of Mackinac. *Publ. 13, Great Lake res. Div., Univ. Mich.,* pp. 77-95.

HERRINGTON, H.B. 1954. *Pisidium* species and synonyms of North America, north of Mexico. *Nautilus,* 67: 131-138.

HERRINGTON, H.B. 1962. A revision of the Sphaeriidae of North America (Mollusca: Pelecypoda). *Misc. Publ. Mus. Zool., Univ. Mich.,* (118): 1-74, pl. 1-7.

HERRINGTON, H.B. 1965. Corrections of sphaeriid nomenclature. *Nautilus,* 79: 42-45.

HERRINGTON, H.B. & TAYLOR, D.W. 1958. Pliocene and Pleistocene Sphaeriidae from the central United States. *Occas. Pap. Mus. Zool., Univ. Mich.,* (596): 1-28.

JAECKEL, S.G.A. 1962. Ergänzungen und Berichtigungen zum rezenten und quartären Vorkommen der mitteleuropäischen Mollusken. *Die Tierwelt Mitteleuropas,* 2. Ergänzung, Leipzig, 260 pp., 9 pls.

JOHNSON, R.I. 1959. The types of Corbiculidae and Sphaeriidae in the Museum of Comparative Zoology, and a bio-bibliographic sketch of Temple Prime, an early specialist of the group. *Bull. Mus. comp. Zool., Harv. Coll.,* 120: 431-479, pl. 1-8.

KUIPER, J.G.J. 1962. Systematische Stellung und geographische Verbreitung von *Pisidium tenuilineatum. Arch. Molluskenkd.,* 96: 173-181.

KUIPER, J.G.J. 1966. The status of *Pisidium hibernicum* Westerlund. *J. Conchol.,* 26: 42-46.

KUIPER, J.G.J. 1968. Die spätpleistozänen Pisidien des ehemaligen Aschersslebener Sees. [Summary in English.] *Arch. Molluskenkd.,* 98: 23-38.

KUIPER, J.G.J. 1969. Pisidien aus Kasakstan, Sibirien. *Arch. Molluskenkd.,* 99: 49-53.

KUIPER, J.G.J. 1972. Pisidia. *In:* Stelfox, A.W., Kuiper, J.G.J., McMillan, Nora F. & Mitchell, G.F., The Late-Glacial and Post-Glacial Mollusca of the White Bog, Co. Down. *Proc. r. Ir. Acad.,* 72(B, 11): 185-207.

KUIPER, J.G.J. 1974. Die Pisidien der Hochalpengewässer. *Arch. Molluskenkd.,* 104: 1-27.

KUIPER, J.G.J. 1983. The Sphaeriidae of Australia. *Basteria,* 47: 3-52.

KUIPER, J.G.J. 1987. *Pisidium maasseni* n. sp., a new species from Lake Prespa, Jugoslavia (Bivalvia, Sphaeriidae). *Basteria,* 51: 163-165.

MACKIE, G.L. 1981. Nearctic freshwater Sphaeriacea. *Bull. Am. malacol. Union, 1981,* 48: 49-52.

MEIER-BROOK, C. 1975. Der ökologische Indikatorwert mitteleuropäischer *Pisidium* Arten. *Eiszeitalter u. Gegenwart,* 26: 190-195.

ODHNER, N.Hj. 1929. *Die Molluskenfauna des Tåkern.* Stockholm. 129 pp., pl. I-VII, map.

ODHNER, N.Hj. 1939. Sphaeriids from the Aleutian Islands. *Nautilus,* 52: 79-84, fig. 6.

ÖKLAND, K.A. 1971. On the ecology of Sphaeriidae in a high mountain area in North Norway. *Norw. J. Zool.,* 19: 133-143.

ÖKLAND, K.A. & KUIPER, J.G.J. 1982. Distribution of small mussels in Norway, with notes on their ecology. *Malacologia,* 22: 469-477.

PHILLIPS, R.A. & STELFOX, A.W. 1918. Recent extensions of the range of *Pisidium hibernicum. Ir. Nat.,* 27: 33-50, pl. 1, 2.

PILSBRY, H.A. & HIRASE, Y. 1908. New land and freshwater Mollusca of the Japanese empire. *Proc. Acad. nat. Sci. Philad.,* 60: 31-36, fig. 1.

PRASHAD, B. 1933. Notes on lamellibranchs in the Indian Museum. No. 8. Species of the genus *Pisidium* from Western Tibet, Yarkand, Persia and Syria. *Rev. Indian Mus.,* 35(1): 1-8.

PRIME, T. 1865. Monograph of the American Corbiculadae. (Recent and Fossil). *Smithson. misc. Collect.,* (145): i-xi, 1-80.

SCHLESCH, H. 1942. 3. Nachtrag zu "Revidiertes Verzeichnis der dänischen Land- und Süsswassermollusken und ihre Verbreitung. *Arch. Molluskenkd.,* 74: 104-113.

SHADIN, W.I. 1933-35. Ueber die ökologische und geographische Verbreitung der Süsswassermollusken in der UdSSR. *Zoogeographica,* 1933/35: 495-554.

STAROBOGATOV, Y.I. & STRELETZKAJA, E.A. 1967. Composition and zoogeographical characteristics of freshwater malacofauna of the East Siberia and northern part of the Far East. *Publ. Acad. Sci. USSR,* 42: 221-268.

STEFANO, Y. de. 1969. *Recherches sur l'écologie des espèces du genre* Pisidium *dans les étangs du Carlit (Pyr. Or.).* Dipl. d'Etat sup., Montpellier. 54 pp., 37 pls.

STELFOX, A.W., KUIPER, J.G.J., McMILLAN, Nora F. & MITCHELL, G.F. 1972. The Late-Glacial and Post-Glacial Mollusca of the White Bog, Co. Down. *Proc. r. Ir. Acad.,* 72(B, 11): 185-207.

STERKI, V. 1903. New North American pisidia. *Nautilus,* 17: 42-43.

STERKI, V. 1916. A preliminary catalog of the North American Sphaeriidae. *Ann. Carnegie Mus.,* 10: 429-477.

STERKI, V. 1926. Sphaeriidae, Palearctic and Nearctic. *Nautilus,* 40: 26-30.

STERKI, V. 1928. Sphaeriidae, Palearctic and Nearctic II. *Nautilus,* 42: 23-27.

WALTER, J.E. & KUIPER, J.G.J. 1978. Über Verbreitung und Ökologie von Sphaeriiden im Zürichsee. *Schweiz. Z. Hydrol.,* 40: 61-86.

WESTERLUND, C.A. 1873. Fauna Molluscorum terrestrium et fluviatilium Sveciae, Norvegiae et Daniae. - II. Sötvattenmollusker. Stockholm. pp. 298-651.

WOODWARD, B.B. 1913. *Catalogue of the British species of* Pisidium *(Recent and fossil) in the collections of the British Museum (Natural History) with notes on those of Western Europe.* Br. Mus. (nat. Hist.), London. Pp. i-ix, 1-144, pl. 1-30.

ZEISSLER, H. 1971. Die Muschel *Pisidium.* Bestimmungstabelle für die Mitteleuropäischen Sphaeriaceae. *Limnologica,* 8: 453-503.

WALKERANA, P. O. Box 2701, Ann Arbor, Michigan 48106, U.S.A.

Walkerana, Trans. POETS Soc., 1987, 2(8): 159-163

SEASONAL STUDIES OF TWO POPULATIONS OF *TAREBIA GRANIFERA*

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ABSTRACT. – Seasonal variations in the densities of *Tarebia granifera* were compared in two different habitats: a dam and a creek. Densities were higher in the dam, which holds abundant food, but the fluctuations and reproductive peaks were similar in both populations. The only morphological shell differences that could be found were in the sizes of the animals, which were smaller in the creek than in the dam.

INTRODUCTION

Several species of mollusks have been proposed as biological control agents for snail intermediate hosts mediating tropical diseases. Laboratory experiments have been carried out in order to determine the effectiveness of such mollusks in controlling other mollusks, but little has been published about the ecology and biology of these species under natural conditions. Among snail biological competitors, *Tarebia granifera* (Lamarck) likely may be the best suited for a molluscan control role. This Asian snail was found in the United States in the 1950s (Abbott, 1952), but it was not discovered in Cuba until 1968 (Jaume, 1972). It was found originally in the easternmost province, but it has now spread to nearly all the water bodies of the island. Its ability to displace pulmonate populations was observed in Puerto Rico by Chaniotis et al. (1980) and by Prentice (1983) in St. Lucia. In Cuba, Yong & Perera (1983) made similar observations, as *T. granifera* displaced a pulmonate snail population that was established in a dam*.

*"Dam" as used here means an artificially empounded body of water, rather than the water-retaining barricade itself.

MATERIALS AND METHODS

The studies were done in two habitats with different characteristics: El Rubio Dam and El Berro Creek, both located to the northeastern part of Havana, and selected because of their accessibility. El Rubio (Fig. 1) is a wide dam about 16 m deep and 1400 m^2 in area. The shores

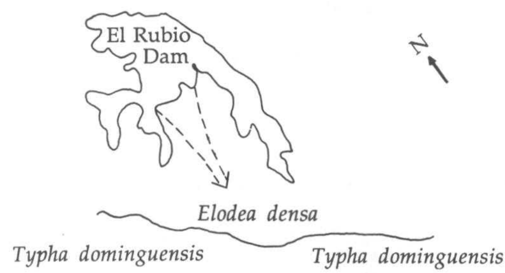


FIG. 1. Distribution of aquatic vegetation in the sampled area in El Rubio Dam.

are covered by *Typha dominguensis* Persoon and *Egeria densa* Planchon as aquatic vegetation. Muddy bottom and dark waters are characteristic of this habitat. El Berro (Fig. 2), on the other hand, has very clear flowing waters, is much colder and has a rocky bottom.

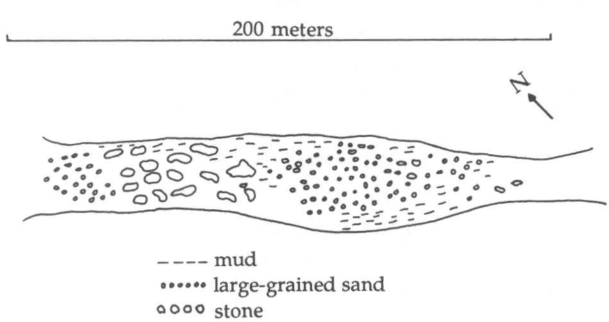


FIG. 2. Distribution of substrate types in El Berro Creek.

Five samples were taken at random every fortnight at depths between 20 and 75 cm, using a square sampler of 42 cm^2 in which a scoop of 1 mm mesh fits so that it covers the whole area. Previous observations had shown that *Tarebia granifera* is concentrated at these lower depths.

The snails of the samples were sorted into size classes by passing them through a set of sieves (0.8 mm, 1.6 mm, 2.7 mm, 4.5 mm and 6.5 mm). The snails were counted each time to keep a record of the density at each habitat. A stratified sampling also was done to compare the two populations morphologically. Random samples of 40 snails were taken for size measurements of their shells in each stratum. The shell length and width were measured and their relationships obtained by a linear regression. Two hundred snails were measured for the regression curves.

RESULTS AND DISCUSSION

The regression curves obtained (Fig. 3) showed that there are no morphological differences in length/width ratios between the two populations and that the two populations are highly correlated (r = 0.9 in both cases). The size of the shell (smaller in the creek) is the only difference that could be found between the populations of the two habitats. The size difference may be due to the rapid flow of water in the creek, which enhances a diminution of food in comparison to the quiet waters of the dam. In addition, the lower temperatures found in the creek must have an influence in the carbon dioxide cycle and on the intake of calcium by the mollusks (Wilbur & Yonge, 1964).

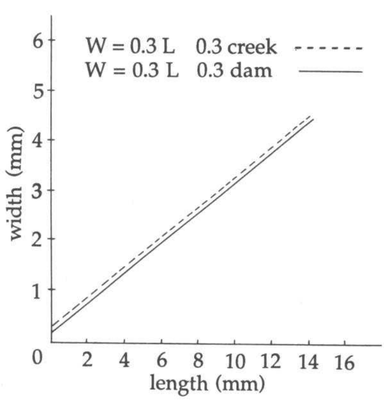
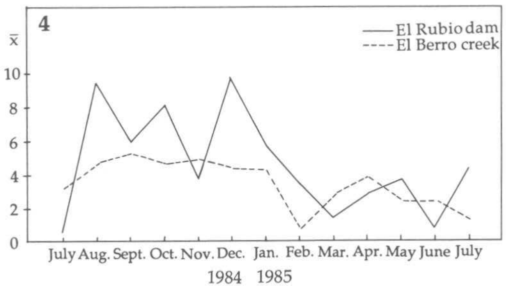
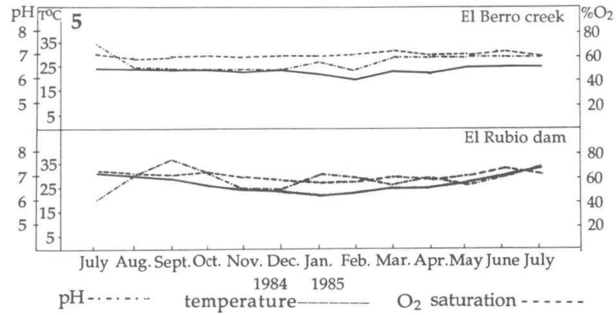


FIG. 3. Linear regression curves of the relation length/width of *Tarebia granifera* in El Rubio Dam and El Berro Creek.

The variations of the total number of animals in a year can be seen in Fig. 4. El Berro had its lowest densities during the month of February,





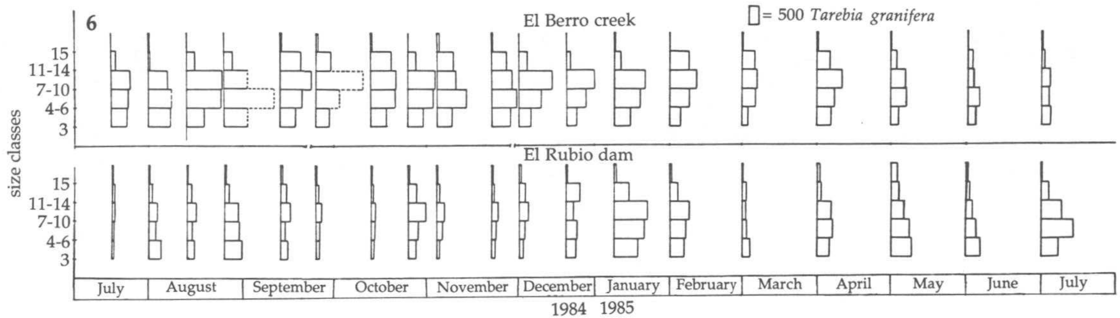


FIG. 4. Mean densities of *Tarebia granifera* in El Berro Creek and El Rubio Dam during rainy and dry seasons (values were divided by 10^3). FIG. 5. Fluctuations of abiotic factors in El Berro Creek and El Rubio Dam. Measurements were taken 10 cm from the surface between 10:00 A.M. and 11:00 A.M. FIG. 6. Variations of density of different size classes of *Tarebia granifera* in El Berro Creek and El Rubio Dam. Samples were taken between 10:00 A.M. and 11:00 A.M. with a sampler which covered an area of 42 cm^2.

which is possibly related to the lowering of pH and the diminution of oxygen; both have their lowest values during this month (Fig. 5). The lowest snail densities in El Rubio Dam occurred in June, but here the pH reached its lowest values in November and December, and the lowest dissolved oxygen values occurred in January.

The growth of the different size classes can be seen in Fig. 6. The reproductive peaks show the evolution of the population.

The intense drought that afflicted the country during the years 1984 to 1985 had its effect on the populations of snails. The densities were higher in 1984 than in 1985, so a severe dry season can exert an effect on the populations of this prosobranch, which are not very successful in estivating.

ACKNOWLEDGEMENTS

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LITERATURE CITED

ABBOTT, R.T. 1952. A study of an intermediate snail host (*Thiara granifera*) of the oriental lung fluke (*Paragonimus*). *Proc. U.S. natl. Mus.*, 102: 71-116.

CHANIOTIS, B.N., BUTLER, J.M., FERGUSON, F.F. & JOBIN, W.R. 1980. Bionomics of *Tarebia granifera* (Gastropoda: Thiaridae) in Puerto Rico. *Caribb. J. Sci.*, 16(1-4): 81-89.

JAUME, M.L. 1972. Nuevo genero y especie de molusco fluvial para la fauna malacologica cubana (Gastropoda: Prosobranchia: Thiaridae). *Circ. Mus. Bibl. Zool.*, Havana, pp. 1523-1525.

PRENTICE, M.A. 1983. Displacement of *Biomphalaria glabrata* by the snail *Thiara granifera* in field habitats in St. Lucia, West Indies. *Ann. trop. Med. Parasitol.*, 77(1): 51-59.

WILBUR, K.M. & YONGE, C.M. 1964. *Physiology of Mollusca.* Academic Press, New York. 588 pp.

YONG, M. & PERERA, G. 1983. Growth of *Tarebia granifera* in its natural habitat. *Proc. 8th int. malacol. Congr.*, Budapest. p. 161.

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FIRST RECORD OF AND ECOLOGICAL STUDIES ON *MELANOIDES TUBERCULATA* IN CUBA

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ABSTRACT. – The finding of a well-established population of *Melanoides tuberculata* in Hanabanilla dam, Cuba, constitutes a new species record for the Cuban freshwater molluscan fauna. Since this locality and others on the island had been carefully monitored since 1981, it is certain that this snail did not occur previous to 1983. The sudden appearance of *M. tuberculata* in Cuba is probably due to the snail being transported by migratory birds.

Growth studies were carried out on *Melanoides tuberculata* in its natural habitat using plastic boxes especially designed for this purpose. The growth parameters were $k = 0.125$ and $L\infty = 22.10$, showing that *M. tuberculata* is a slow-growing and long-living snail. Field observations indicate that *M. tuberculata* is a promising biological control agent of other snails which are intermediate hosts of human parasites.

INTRODUCTION

Until recently, the molluscan family Thiariidae was represented in Cuba only by the introduced *Tarebia granifera* (Lamarck), which was first discovered in 1968 in the country's easternmost provinces (Jaume, 1972). A second species of this prosobranch family, *Melanoides tuberculata* (Müller), has now been discovered on the island. A well-established population was found in Hanabanilla in May 1983. This mollusk, native to India, is now well spread among the Pacific Islands, and was introduced during the 1940s to the Western Hemisphere, to the southern United States. It was later found in Venezuela and on several of the Lesser Antilles (Abbott, 1973).

Melanoides tuberculata is the first intermediate host of some flukes of the families Opistorchidae and Troglotrematidae, but since the infection of these parasites in man occurs only with the consumption of the raw second intermediate host, parasite transmission probably does not occur in many regions of the snail's distribution.

Field observations on the competitive action of *Melanoides tuberculata* against pulmonate mollusks encourage the study of the biology, especially ecology, of this snail in the hope that it can be used as a biological control agent of snail intermediate hosts of tropical diseases. So far there have been few studies on the growth, mortality and reproduction of *M. tuberculata* under natural conditions.

HABITAT AND MATERIALS AND METHODS

Hanabanilla dam (reservoir) (Fig. 1) is located in the Escambray Mountains in the central part of Cuba. Rivers and springs from the mountains make the water clear and cold even during summer months.

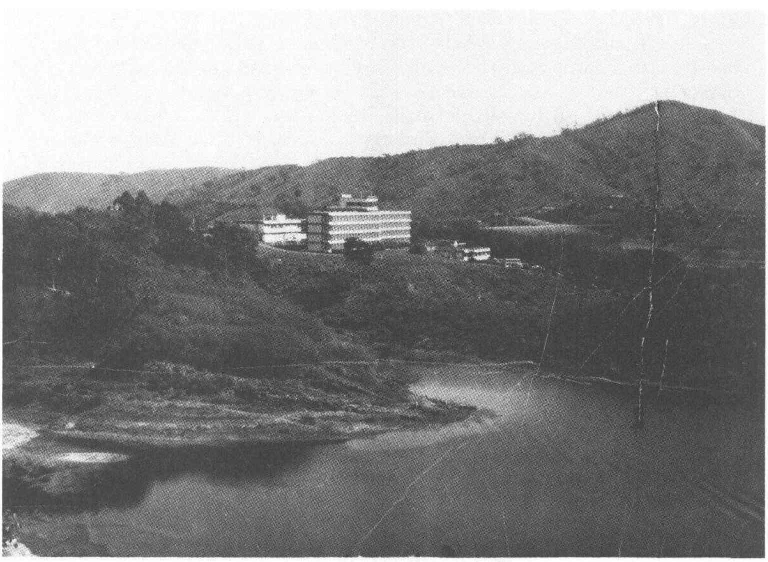

FIG. 1. Hanabanilla dam (reservoir) in central Cuba.

The bottom of the reservoir is mostly sand and rocks. The shores are partly covered with *Eichornia crassipes* (Martius) Solms-Laubach and *Elodea densa* (Planchon) Caspary, which are the predominant aquatic plants. In addition to *Melanoides tuberculata*, other snails present in the dam are *Physella cubensis* (Pfeiffer), *Pomacea paludosa* (Say), *Pyrgophorus parvulus* (Guilding), *Tarebia granifera*, *Gyraulus* sp., *Planorbella duryi* (Wetherby) and *Gundlachia radiata* (Guilding). The publications of Morrison (1954) and Burch (1982) were used for identification and classification of the snails. Voucher specimens have been deposited in the Museum of the Institute of Ecology and Systematics of the Cuban Academy of Sciences.

Snails used for growth studies were collected near the shores of Hanabilla dam, mainly from the rocks. The shell length (from the apex to the posterior end of the siphonal canal) was measured with a calliper. One hundred sixty-nine mollusks were separated into 10 size classes (4-6 mm, 7-8 mm, 9-10 mm, 11-12 mm, 13-14 mm, 15-16 mm, 17-18 mm, 19-20 mm, 21-22 mm, 23-24 mm), and placed in plastic boxes for growth studies (Yong & Perera, 1983). The boxes were placed at the collecting sites and provided with food. The snails were measured at regular monthly intervals. Growth curves were calculated by Bertalanffy's (1938) equation: $Lt = L_\infty (1-e^{-kt})$, in which Lt is the shell length at a time t after birth, L_∞ is the shell length for a zero growth rate, k is a characteristic growth constant and t the age of the animal. The growth parameters k and L_∞ were calculated by Walford's (1946) method.

Mortality rates were observed under natural conditions at the same time the growth studies were done. By extrapolations in Bertalanffy's calculated growth curves, the sizes were converted into age, and mortality percentages at different ages of the animals were plotted.

Temperature, pH and oxygen saturation were measured regularly.

RESULTS AND DISCUSSION

The comparison of morphological characteristics of our specimens with those deposited in the Muséum National d'Histoire Naturelle, Paris, France, and in the Smithsonian Institution, Washington, D.C., U.S.A., as well as descriptions of the species in Morrison (1954) and Burch (1982), led us to the conclusion that the newly found mollusk in Hanabanilla dam was *Melanoides tuberculata.*

Tarebia granifera and *Melanoides tuberculata* are two prosobranch mollusks which can be confused taxonomically, and the latter was reported in St. Lucia as *T. granifera* (Pointier, 1983). Both are elongate and turriculate. The shell of *M. tuberculata* (Fig. 2) has rounded whorls,

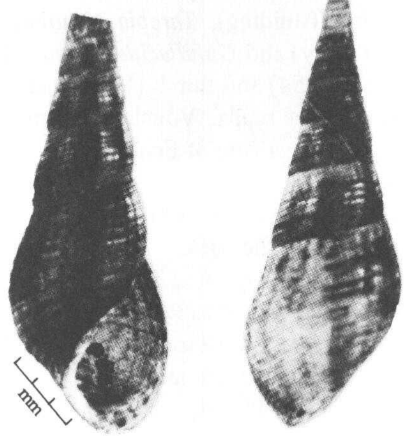

FIG. 2. Shells of *Melanoides tuberculata* from Hanabanilla dam.

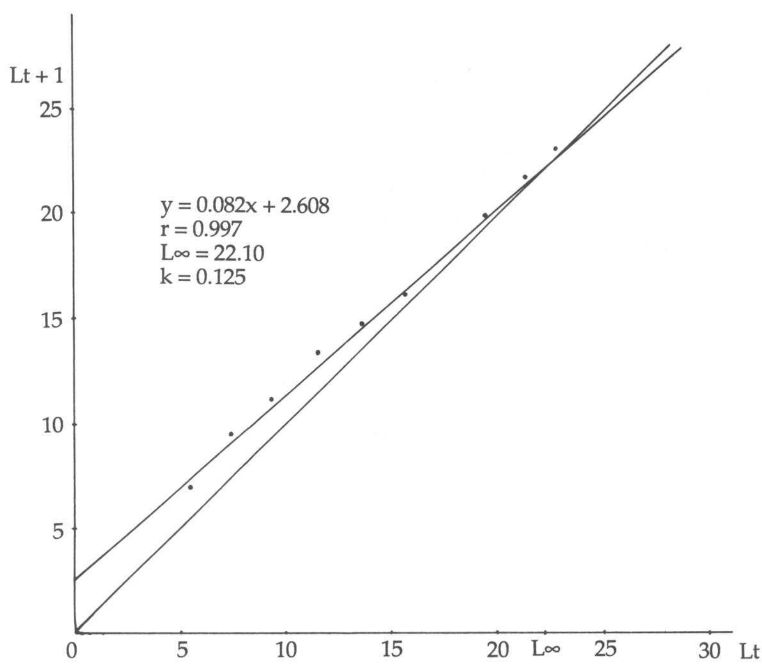

FIG. 3. Calculations of k and L∞ by Walford's method. Values of Lt and Lt + 1 (interval between two measurements) are highly correlated (r = 0.997).

the aperture is ovate and the paucispiral operculum has smooth growth lines. *Tarebia granifera* has flattened whorls with nodular sculpture, an oblique aperture, and the paucispiral operculum has coarse and irregular growth lines.

The growth parameters for *Melanoides tuberculata* calculated by Walford's (1946) method were k = 0.125 and L_∞ = 22.10 (Fig. 3). Table 1 shows the growth parameters of several species of snails compared with *M. tuberculata*. As can be seen, these prosobranch snails grow more slowly than do the pulmonates and attain a greater size.

TABLE 1. Values of the parameters k (characteristic growth constant), L_∞ (shell length at a zero-growth rate) and validity range of different species of mollusks compared with *Melanoides tuberculata*. The time interval between two successive measurements was a fortnight for pulmonate snails and a month for prosobranchs.

Species	Locality	k	L_∞	Validity
Planorbella duryi (Wetherby)	Treasure Lake	0.12	11.16	3.5 -10.3
Biomphalaria havanensis (Pfeiffer)	Camagüira	0.17	11.12	3.1 -10.3
Biomphalaria helophila (d'Orbigny)	Camagüira	0.12	8.61	0.99- 2.11
Fossaria cubensis (Linné)	Batabanó	0.07	12.42	4.6 - 9.5
Pseudosuccinea columella (Say)	Batabanó	0.27	12.29	2.7 - 8.4
Marisa cornuarietis (Linné)	Caonao	0.05	51.2	16.7 -44.6
Tarebia granifera (Lamarck)	El Rubio	0.11	37.53	3.9 -23.9
Melanoides tuberculata (Müller)	Hanabanilla	0.13	22.10	4.0 -23.5

The growth curves for *Melanoides tuberculata* (Fig. 4) show that it is a relatively slow-growing snail with a long life span, which ensures stable populations. Laboratory-reared snails from Martinique show a similar growth curve.

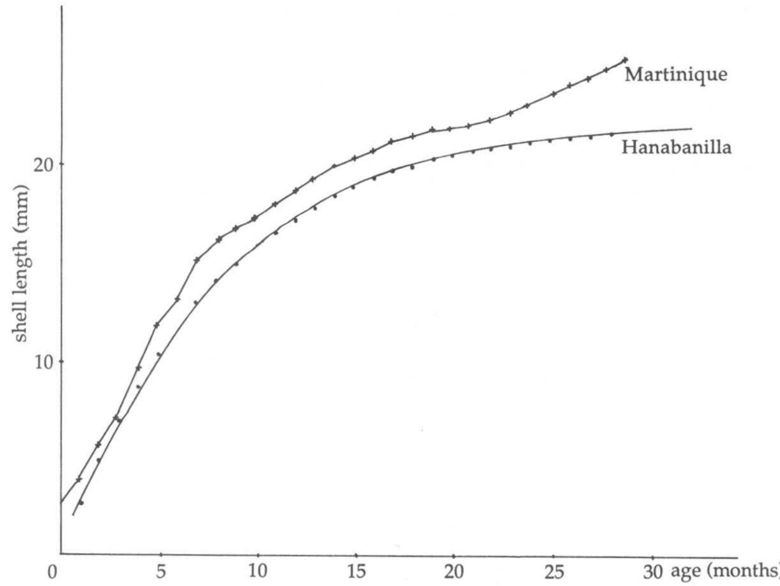

FIG. 4. Growth curves for *Melanoides tuberculata* from Hanabanilla calculated by Bertalanffy's equation and for *M. tuberculata* from Martinique (French Antilles), grown in the laboratory by J.P. Pointier. Both strains show a similar growth pattern.

Reproduction was observed to begin at 6 months and mortality percentages were relatively low (Fig. 5).

Temperature at Hanabanilla dam ranged from 25-27°C, which is lower than usual values for aquatic habitats during the summer months in Cuba, but is characteristic of this reservoir. Hydrogen ion concentration and oxygen saturation were constant (7% and 84% respectively). These factors can influence the size of the snails, but at present this is the only locality in Cuba in which *Melanoides tuberculata* is present, so, as yet, comparisons cannot be made with this species from other localities.

Field observations in Guadeloupe (French Antilles) show that *Melanoides tuberculata* is able to displace colonies of *Biomphalaria glabrata* (Say) in permanent water bodies (Pointier, personal communication). The growth characteristics of this *M. tuberculata*, together with its low

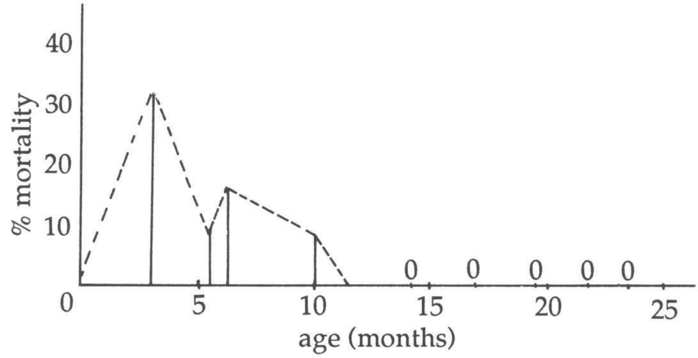

FIG. 5. Mortality percentages of *Melanoides tuberculata* observed under natural conditions in Hanabanilla dam. Highest percentages were at 3 months (34%) and 6.5 months (16%).

mortality rates and the fact that it is ovoviviparous and parthenogenetic, are features which may make it useful as a biological control agent.

LITERATURE CITED

ABBOTT, R.T. 1973. Spread of *Melanoides tuberculata. Nautilus,* 87(1): 29.

BERTALANFFY, L. von. 1938. Quantitative theory of organic growth. *Human Biol.,* 10: 181-213.

BURCH, J.B. 1982. *Freshwater snails (Mollusca: Gastropoda) of North America.* Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, EPA-600/3-82-026. 294 pp.

JAUME, M.L. 1972. Nuevo género y especie de molusco fluvial para la fauna malacológica cubana (Gastropoda-Prosobranchiata-Thiariidae). *Circ. Mus. Bibl. Zool., Habana,* (Julio): 1523-1525.

MORRISON, J.P.E. 1954. The relationship of Old and New World melanians. *Proc. U.S. natl. Mus.,* 103(3325): 380-386.

POINTIER, J.P. 1983. La lutte biologique contre les mollusques hôtes intermédiaires des bilharzioses a l'aide de mollusques compétiteurs. *Symbioses,* 15(2): 85-91.

WALFORD, L.A. 1946. A new graphic method of describing the growth of animals. *Biol. Bull.,* 90: 141-146.

YONG, M. & PERERA, G. 1983. Growth of *Tarebia granifera* in its natural habitat. *Proc. 8th int. malacol. Congr.,* Budapest. pp. 301-304.

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GUIDE FOR THE IDENTIFICATION OF FRESHWATER SNAILS OF THE FAMILY PILIDAE IN THAILAND

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INTRODUCTION

The gastropod family Pilidae (Ampullariidae) is commonly found in tropical fresh-waters throughout the world. Its species are generally known as "apple snails" because of their large size and globose shape. In Thailand, the family is represented by the genus *Pila*, which is common in rice fields, and in shallow bodies of water with succulent vegetation, which provides food and places for shelter. *Pila*, because of its size and abundance, is frequently used as human food, especially by farmers.

Pilid snails are intermediate hosts of two important species of parasites infecting humans, *Angiostrongylus cantonensis* and *Echinostoma ilocanum*. *Angiostrongylus cantonensis* is a nematode parasite of rodents. The parasitic larvae must develop in an invertebrate, and can infect species of *Pila*, which, when eaten by a mammal, transfer the infective larval parasites to the predator, where they continue their development. In humans, *A. cantonensis* causes angiostrongyliasis (eosinophilic meningoencephalitis), often resulting in death. The second parasite, *Echinostoma ilocanum*, is a trematode, an intestinal fluke which lives attached to the wall of the small intestine of its human host. This parasite causes inflamation, ulceration, diarrhea and anemia in its human hosts.

The pilid snail is dextrally coiled. The head has a contractile snout, terminating into two labial palps or "anterior tentacles." The true tentacles are long and tapered, and have prominently stalked eyes situated at their bases. Projecting anteriorly over the foot and on the two sides of the head are epipodial lobes forming left (inhalent) and right (exhalent) channels (Keawjam, 1987).

The foot is roughly triangular in outline, with the apex of the triangle directed backwards. The outline of the foot is constantly changing and is very extensile. The operculum is attached to the dorsal surface of the foot, and is concentric with an excentric submedian nucleus, which is closer to the operculum's columellar margin.

The family Pilidae, basically aquatic, seems to have an evolutionary trend towards the terrestrial biotope. Morphological adaptation for the transition from the aquatic to the terrestrial habitat is provided by the animals having a lung in addition to gills. Since the calcareous eggs of taxa such as *Pila* are deposited out of water, the dependence of the snails on an aquatic habitat is reduced.

The various species of *Pila* are amphibious, and their respiration may be wholly branchial or entirely by the pulmonary surface of the mantle cavity, depending on whether the snails are in or out of the water. In the dry season, the snails can bury themselves in the ground, where they remain in a comatose condition, with the operculum tightly sealing the aperture of the shell.

Pila selects the proper time to be active and breed (Keawjam, 1986b); sympatric species avoid competing for space and food by having non-overlapping peaks of exploitation of the habitat. *Pila ampullacea* emerges from the ground at the first rain, copulates and enlarges its population, and then starts declining in number at the time *P. pesmei* appears. *Pila polita* is the third species, consecutively, occupying the habitat during summer. When it appears, its competitors, *P. ampullacea* and *P. pesmei,* begin aestivating.

Pila snails breed immediately after they come to the surface of the ground after their prolonged aestivation. Rain is the factor which arouses the snails to activity (except for *P. polita,* which moves away when rain starts and disappears into the water). Copulation lasts for a few hours. For oviposition, the female needs the bank above water level to lay its cluster of one to three hundred eggs. After hatching, the young snails can probably reach maturity within one season, if the habitat is rich in nutrients. If the snail is still immature at the end of the season, it will become adult in the next season, after its first aestivation.

The various species of *Pila* are very difficult to distinguish morphologically; their shell characters differ very slightly, leading not only to misidentifications, but to confusion as to just what are the valid species in the genus and as to what characters can be used to define the species.

Because of their role as mediators of human parasitic diseases, it is of some importance to be able to identify the various species of pilid snails, especially in studies directed toward gaining a better biological understanding of these snails. Species in the family have traditionally been classified according to characteristics of their shells and opercula.

DESCRIPTIONS OF SHELLS, WITH DISTRIBUTIONS AND HABITATS

Shells of the genus *Pila* are medium to large in size, oval, ovate-conical, or globosely conic in shape, dextrally coiled, and have a thin or thick, brown or greenish-brown periostracum. Their sizes range from medium to very large (i.e., from 30 mm to 86 mm), they are moderately thick to thin, and are usually perforate, sometimes narrowly umbilicate (rarely the umbilicus is closed). The shell surface is usually smooth, with transverse growth lines or striae. Color markings, if present, are of dark brown streaks or bands. The shell lip is widely or elongately oval, and has a straight columellar margin. The operculum completely closes the aperture; it is thick, rigid, and concentric, with its nucleus nearer the parietal margin. The inner surface of the operculum is nacreous.

Pila ampullacea **(Linnaeus 1758)** (Fig. 1). Shell large, moderately thick, globosely or widely conic, with low, conical or obliquely flat spire whose ca. 4 1/2 whorls are often corroded; number of whorls 5 1/2, with the body whorl well rounded or evenly convex, its upper surface appearing obliquely flattened. The aperture is oval, obliquely rounded near the basal lip; the width of the mouth is about 3/5 of the aperture height (which is approximately 3/4 of the shell length). The parietal callus is moderately thick and wide, but not as thick and wide as that of *Pila pesmei.* The lip is sharp, thick and strong, and is whitish or somewhat purplish-white in color. The operculum is heavy and thick, with the inner surface or nacre silvery pinkish-white. The umbilicus is relatively wide, and deep, but it is sometimes covered over by the retroverted inner lip of the mouth. The color of the shell is brown or olive-green, unbanded or rarely banded. Size of fullgrown shells: Width (W) 45-80 mm; height (H) 55-86 mm (Keawjam, 1986a).

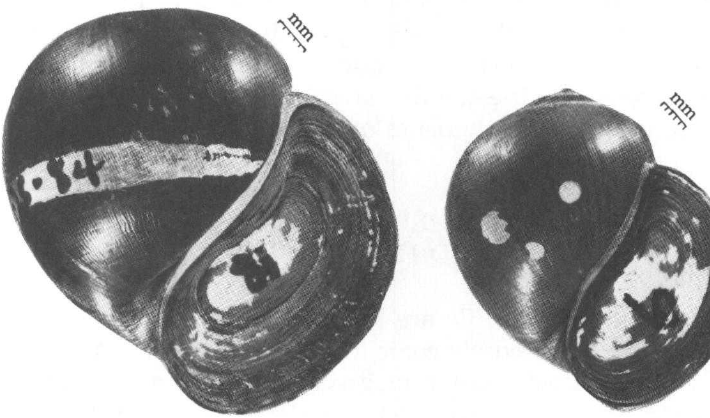

FIG. 1. Shells of *Pila ampullacea.*

Pila ampullacea is common in the central part of Thailand, and rare in the northern and northeastern provinces. It has not been found in Prachuap-khiri-khan Province or in the south. *Pila ampullacea* inhabits canals in which the water current is not fast, e.g., ditches, swamps and even irrigation canals. The snails attach mostly to aquatic plants such as water hyacinthes, water lilies, morning glories and grasses. They are very common in July through October and are rarely seen from November through March, during which time they are probably aestivating underground. *Pila ampullacea* is found in the same water bodies as *P. polita* and *P. pesmei,* but the proportion of these three species varies with the season.

Pila pesmei **(Morelet 1889)** (Fig. 2). Shell sizes and characteristics are very variable. The shell is medium to large, thick, globosely or widely conic, with a low spire, whose one or two nuclear whorls were often eroded. The number of whorls is 4 1/4, or rarely 5 1/4. The body whorl is well rounded, its upper margin slightly cushioned. The aperture is elongately oval, its upper margin a little angled. The width of the aperture is about half its height. The height of the aperture is about 3/4 the shell length. The parietal callus is thick and wide. The lip is thick and slightly retroverted, strong, and yellowish orange. The operculum is thick, with silvery pinkish-white nacre. The umbilicus is narrow and moderately deep, often covered over by the raised peristome. The shell color is brown, chestnut brown or greenish brown, with both narrow and wide darker brown spiral lines. Unicolored unbanded shells are not rare. Size of fullgrown shells: very variable; W 27-57 mm; H 30-62 mm.

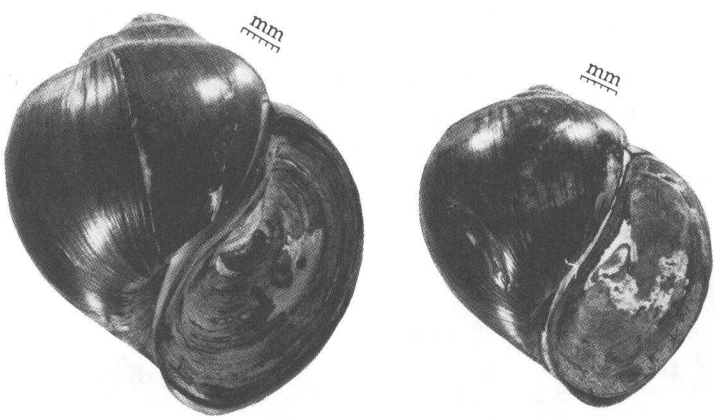

FIG. 2. Shells of *Pila pesmei*.

This widely distributed species is common in a wide variety of waters in the central and northeastern parts of the country. It is rare in the north, and has never been found in the south. *Pila pesmei* inhabits slow-moving waters (rivers and streams) and standing waters (pools, ponds, roadside ditches, and even rice fields). It lives in clean or dirty water in which the surface is always partly covered by aquatic plants. *Pila pesmei* lives sympatrically with *P. ampullacea* and *P. polita,* but is found in different proportions in relation to these two species, depending on the season. Populations of *P. pesmei* increase in size from

July to September, and the snails are very common in October through December. They are rarely seen during April-June, aestivating 1-3 feet underground.

***Pila angelica* (Annandale 1920)** (Fig. 3). Shell large, widely globose, having a low, flat spire with one or two eroded nuclear whorls. The shell is usually thin, thicker when the animal is extremely large, but never as thick as that of *Pila ampullacea* or *P. pesmei*. The body whorl has a narrow, smooth shoulder, which is then rounded and tapered downward at the basal lip. The number of whorls is 4 1/4. The aperture is elongately oval, often with a beak at the basal lip. The aperture width is about half the aperture height (which is higher than 3/4 of the shell length). The upper end of the aperture is shorter in distance below the upper margin of the body whorl than in *P. ampullacea* and *P. pesmei*. The lip is sharp, thin, moderately strong, yellowish orange or grayish orange, with a thin and narrow parietal callus . The operculum is somewhat thin, with steel-blue nacre. The umbilicus is somewhat narrow. The color of the shell is chestnut brown or greenish brown with thin darker-brown spiral bands. Size of fullgrown shells: W 50-70 mm; H 60-75 mm.

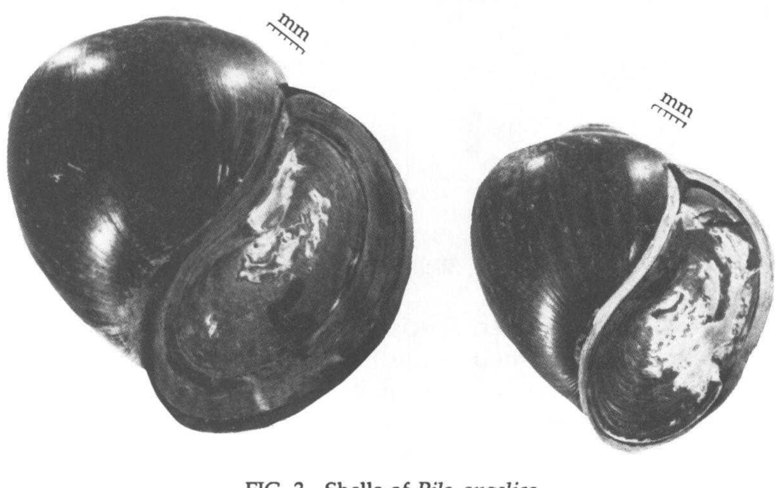

FIG. 3. Shells of *Pila angelica*.

Pila angelica has been found only in the southern provinces, from Chumphon southward to the southernmost part of the country. It is very common in Suratthani, Phang-nga, Songkhla and Pattani. It is found in both moving and standing waters. It attaches to rocks, logs and aquatic plants, in clear and somewhat rapid mountain streams or creeks. It is also common in brackish lakes. These snails are most common from April through August. They occupy the same habitats as *P. gracilis*, but they need higher water levels.

***Pila polita* (Deshayes 1830)** (Fig. 4). Shell large, glossy, moderately thick, oval to subglobosely conic, with a moderately high, conical spire. The shell has 6 1/2 whorls, the body whorl being evenly convex. The aperture is oval, retroverting very little laterally. The width of the aperture is about half the aperture height, which is less than 3/4 of the shell length. The parietal callus is thin and wide. The lip is sharp, thin but strong, orange or purplish orange colored. The operculum is relatively thin, with steel-blue nacre on the inner surface. The umbilicus is very narrow, usually covered over by the inner lip of the mouth. The shell is unbanded, and brown, chestnut brown or greenish brown in color. Size of fullgrown shells: W 40-60 mm; H 50-85 mm.

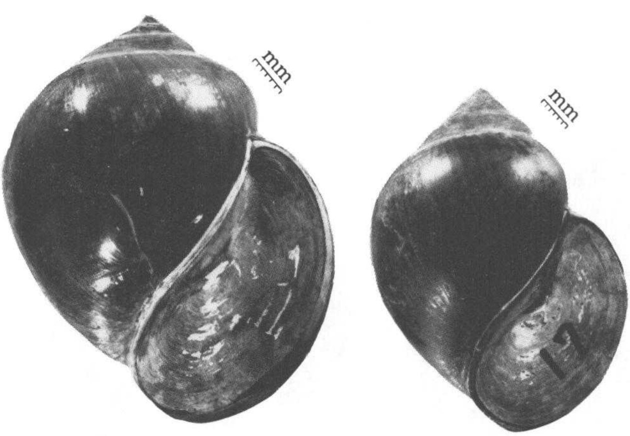

FIG. 4. Shells of *Pila polita*.

Pila polita is common in the central, northeastern and northern provinces, and is absent in the south. It prefers standing water bodies to streams or irrigation canals. It lives in pools, ponds, ditches and water reservoirs which are partly covered by aquatic plants. It is very common in the dry season, i.e., from March through June, when most of the snails are adults. They decrease in number during the rainy season, probably having difficulty competing with *P. ampullacea* and *P. pesmei.* Young snails are found during the rainy season, whereas the adults come out in the dry and winter seasons.

***Pila gracilis* (Lea 1856)** (Fig. 5). Shell medium, rarely large, texture thin, ovate-conical or subglobosely conic, with spire little exerted. The one or two nuclear whorls are eroded. The number of whorls is 4 1/4, with the body whorl smoothly sloped at the upper surface, increasingly rounded at the middle, and then evenly tapered downward near the basal lip. The aperture is oval, with the mouth angled downward. The width of the mouth is about half the aperture height, which is not greater than 3/4 of the shell length. The lip is sharp and thin, somewhat strong, yellow colored, with the parietal callus being thin and narrow. The operculum is thin, with the inner surface nacre steel-blue. The umbilicus very narrow, often covered over by the retroverted inner lip of the aperture. The color of the shell varies with the environments, ranging from chestnut brown to dark brown or greenish brown, with conspicuous darker-brown spiral bands. Unbanded specimens are occasionally found. Size of fullgrown shells: W 24-38 mm; H 30-46 mm.

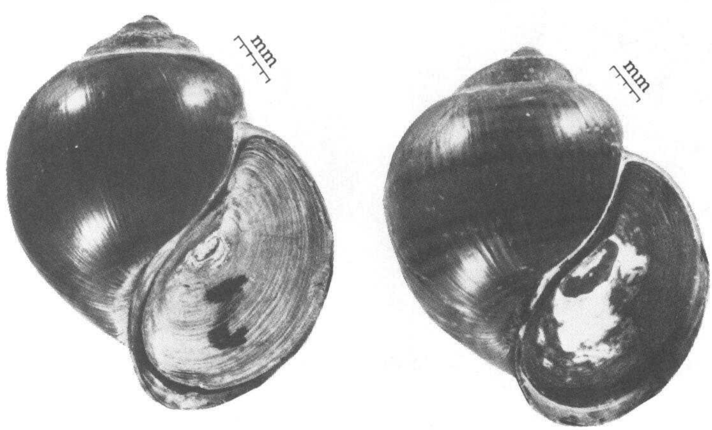

FIG. 5. Shells of *Pila gracilis.*

Pila gracilis has been found only in the southern part of

Thailand. It is common in Phang-nga, Phuket, Krabi, Phatthalung, Songkhla, Pattani and Yala, but is rare in the provinces above Phang-nga. It has never been found in the central, northern and northeastern parts of the country. *Pila gracilis* is very common in standing waters, rare in canals and mountain streams. It attaches to rice stalks in rice fields or to aquatic plants, i.e., algae, morning glories, grasses and water hyacinthes, which grow in swamps, pools, ditches and ponds. This species often inhabits polluted water in effluent pipes. It is found during the same time periods as *P. angelica,* but needs lower levels of water than *P. angelica.*

COMPARISONS OF SPECIES

Pila ampullacea is not difficult to distinguish from the other Thai pilid species; it has a uniquely white or purplish-white lip. The shell is generally large to very large, and usually lacks bands. *Pila ampullacea* is common only in the central provinces, and does not occur in the south. Brandt (1974) probably identified young *P. angelica* in the south as *P. ampullacea,* because immature *P. angelica* do not develop the yellowish-orange color of the lip.

Pila ampullacea is usually found sympatrically with *P. polita.* In some areas, such as in Chon Buri, *P. ampullacea* is found in unequal numbers compared with *P. pesmei* and *P. polita. Pila ampullacea* is very common from the beginning through the middle of the rainy season, during which time the water level of the habitat is high (*P. ampullacea* needs high water levels). *Pila ampullacea* decreases in number during the end of the rainy season (October-November), a time at which *P. pesmei* is increasing in number. During the winter and summer seasons, before the rain starts, *P. ampullacea* burrows into the ground and aestivates to avoid the drought. Only rarely is *P. ampullacea* found in a water body during the dry season.

Pila pesmei shows much variability in regard to shell characteristics. Populations occur with typically well-rounded globose shells, and other populations have the slightly reversedly conical form resembling the shape characteristic of *P. angelica.* The unique character of the shell of *P. pesmei* is the thick, retroverted lip with a wide parietal callus. *Pila pesmei* specimens with large shells may be confused with *P. angelica.* However, electrophoretically the two species are quite distinct (Keawjam, 1988). Also, on close inspection, *Pila angelica* is different from *P. pesmei* in shell characters, including thickness of shell and texture. As a species, *P. angelica* is often misidentified. Brandt (1974) called the small form of *P. pesmei* "*P. gracilis*" because of its size, yellowish-orange lip and banding pattern similar to that of *P. gracilis.* However, *P. pesmei* has certain characteristics which distinguish it from *P. gracilis.* The shell of *P. pesmei* is more rounded and thicker than *P. gracilis.* The nacre of the operculum of *P. pesmei* is silvery pinkish-white, whereas in *P. gracilis* it is steel-blue. *Pila pesmei* is widely distributed, but does not occur in the south, whereas *P. gracilis* is found only in the southern provinces.

Pila pesmei lives alone in some habitats, but it is often found sympatrically with *P. ampullacea* and *P. polita.* *Pila pesmei* is present in the highest proportion, compared to *P. ampullacea* and *P. polita,* during the middle of the rainy season through the middle of winter. It does not need a very high level of habitat water. Therefore, it easily inhabits rice fields and other water bodies which dry up during summer. *Pila pesmei* is probably able to withstand drought for a long time because of its thick shell and operculum.

Pila pesmei and *P. ampullacea* are very closely related, their genetic similarities being quite high (Keawjam, 1988). The two species share the same color of nacre of the operculum, which is silvery pinkish-white, and they have a similar shell shape, which is well-rounded globose. *Pila ampullacea* has a slightly thinner shell than *P. pesmei.*

Pila angelica, as mentioned above, is very similar to *P. pesmei.* However, *P. angelica* is more reversely conical than *P. pesmei,* and large specimens of *P. angelica* are generally larger than the adult *P. pesmei.* The shell and apertural lip of *P. angelica* are thin, whereas those of *P. pesmei* are thick. (The lip of *P. pesmei* is very strong and retroverted to maintain its operculum securely.) The inner side of the operculum of *P. angelica* is colored differently from that of *P. pesmei;* in *P. angelica* it is steel-blue, while in *P. pesmei* it is silvery pinkish-white.

Brandt (1974) included *Pila angelica* as a large form of *P. pesmei*. It is very difficult to separate *P. angelica* from *P. pesmei* if one studies only the shell characteristics. These two species are very closely related, and obviously share a common ancestor. However, they live allopatrically; *P. pesmei* is widely distributed, but does not occur in the south, while *P. angelica* occurs only in the southern provinces.

Due to its large size, *Pila angelica* must live in habitats with high water levels. However, it has the advantage in being able to exploit both standing and running waters, which makes this species very common in the south.

Pila polita has a unique, easily recognizable shell shape (oval with moderately high spire and very polished surface), which makes it easily distinguishable from the other species. It also has a very glossy shell texture. *Pila polita* diverged from the same common ancestor as *P. gracilis*, and so the two are closely related. *Pila polita* and *P. gracilis* both have an oval or ovate-conical shell-shape and a relatively thin operculum with steel-blue nacre.

In pools and ponds in which the water does not dry up during the dry season, *Pila polita* is found in great numbers from March through June, during which time *P. ampullacea* and *P. pesmei* are scarce. If there are *P. ampullacea, P. pesmei* and *P. polita* living sympatrically in a habitat, *P. polita* increases in number last. That is, *P. ampullacea* is most abundant first, then *P. pesmei* increases in number while *P. ampullacea* decreases, and finally *P. polita* becomes the major group during summer. It is an advantage for *P. polita* to exploit a water body without any competitors. Probably *P. polita* is not able to compete with *P. ampullacea* and *P. pesmei*. It, therefore, has unusual behavior, by which it goes underground and stays quietly, closing its operculum tightly during the short rainy season. *Pila angelica* and *P. gracilis* do not aestivate very long, probably because the ground in the south is generally or often moist. *Pila polita* may have the ability to remain in the wet ground for a period of three to four months, as does *P. angelica* and *P. gracilis*. Its very shiny shell may help repel water, and its thin operculum does not seem to aid in keeping water within the shell.

Pila gracilis is separated into a single lineage from the other Thai pilid snails; it has a medium-sized, ovate-conical shell, characters which may be ancestral in *Pila*. The same common ancestor probably gave rise to *P. polita*, which is closer to *P. gracilis* than to other species. Nevertheless, *Pila gracilis* and *P. polita* share a few common features, such as shell shape, thickness and color of the nacre of the operculum, and lip color.

Pila gracilis and *P. angelica* live sympatrically, but they can be distinguished by the differences in their adult sizes and shell shapes. However, there are some transitional forms, i.e., some *P. gracilis* have a nearly globose shell shape, which make them look similar to young *P. angelica.*

Pila gracilis, due to its medium size and to the nutrient-rich habitats in the southern areas of the country, reproduces very fast; large populations are commonly found in the provinces near Phang-nga and southward. Nature seems to favor *P. gracilis* in exploiting any kind of standing water body, including polluted water, since it cannot compete with *P. angelica,* which must live in clean (standing or moving) water.

IDENTIFICATION KEY FOR THE SPECIES OF *PILA* IN THAILAND

1 Shell globosely or widely conic, with a moderately low or flat spire 2

Shell ovate-conical, oval or subglobosely conic, its spire a little exerted or moderately high 4

2(1) Shell medium or large, *moderately thick to quite thick, globosely* or widely conic; body whorl well rounded. *Lip thick,* with parietal callus wide, moderately thick to very thick 3

Shell *large, thin,* widely conic, with low, flat spire. The *body whorl* has a smooth, narrow shoulder. The body whorl is rounded at the middle, then *tapers down-*

ward. Aperture elongately oval, *beaked at the basal lip.* Color of shell chestnut brown or greenish brown, banded. Lip thin, yellowish orange or grayish orange, with parietal callus thin and narrow. Operculum thin, with *steel-blue nacre.* Distributed only in the south. Fig. 3... ***P. angelica***

3(2) Shell *large,* moderately thick, globosely or widely conic, with low, obliquely flat spire; brown or olive-green colored, *unbanded.* Body whorl well rounded. *Lip* widely oval, *thick, whitish or purplish-white,* with parietal callus thick and wide. Operculum heavy, thick, with *silvery pinkish-white nacre.* Common in central Thailand, rare in the north and northeast, absent in the south. Fig. 1 .... ***P. ampullacea***

Shell *medium or large,* thick, globosely or widely conic, with low spire; brown, chestnut brown or greenish brown in color; *banded or unbanded.* Body whorl well rounded, with *upper margin slightly cushioned. Lip thick, slightly retroverted,* with parietal callus thick and wide, *yellowish-orange colored.* Operculum thick, with *silvery pinkish-white nacre.* Widely distributed, except in the south. Fig. 2................................ ***P. pesmei***

4(1) *Shell moderately thick, large, glossy, oval* or sub-globosely conic, with moderately high spire; chestnut brown or greenish brown, *unbanded.* Lip retroverting very little laterally, thin, orange or purplish-orange colored, with parietal callus thin and wide. Operculum thin, with *steel-blue nacre.* Widely distributed, except in the south. Fig. 4 .... ***P. polita***

Shell *thin, medium,* rarely large, *ovate-conical* or sub-globosely conic, with spire little exerted; chestnut brown, dark brown or greenish brown, conspicuously *banded,* rarely unbanded. *Body whorl somewhat smoothly sloped at the upper surface,* middle surface rounded, then *evenly tapered downward* near the basal lip; *lip thin,* with parietal callus thin and narrow, yellow colored. Operculum thin, with *steel-blue nacre.* Distributed only in the south. Fig. 5................ ***P. gracilis***

REFERENCES

BRANDT, R.A.A. 1974. The non-marine Mollusca of Thailand. *Archiv für Molluskenkunde,* 105(1-4): 1-423.

KEAWJAM, Rojana S. 1986a. The apple snails of Thailand: Distribution, habitats and shell morphology. *Malacological Review,* 19: 61-81.

KEAWJAM, Rojana S. 1986b. Laboratory maintenance, narcotization and induction of aestivation of apple snails (Mesogastropoda: Pilidae). *Malacological Review,* 19: 111-112.

KEAWJAM, Rojana S. 1987. The apple snails of Thailand: Aspects of comparative anatomy. *Malacological Review,* 20: 69-90.

KEAWJAM, Rojana S. 1988. The apple snails of Thailand: Molecular genetics. *Journal of Medical and Applied Malacology,* 1: in press.

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A NEW FRESHWATER PROSOBRANCH SNAIL (MESOGASTROPODA: PLEUROCERIDAE) FOR KOREA

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The study of Korean pleurocerid ("melaniid") snails has a long history, and a number of species have been named specifically from the country (Martens, 1886, 1894, 1905). Other publications, not naming new taxa, list all or some of the species of pleurocerids (as "*Semisulcospira,*" "*Oxytrema,*" "*Koreanomelania*" or "Thiaridae") known to occur in Korea (e.g., Kuroda, 1929; Shiba, 1934; Omori, 1935; Miyanaga, 1938, 1942; Abbott, 1948; Morrison, 1954; Kang *et al.*, 1975; Yoo, 1976; Kwon & Habe, 1979). Additionally, there are numerous papers listing the faunas of localized areas in Korea that include pleurocerid snails (e.g., Yoo, 1969; Kil, 1976, 1977; Ha *et al.*, 1981; Kwon, 1982; Kwon & Choi, 1982; Cho, 1984; Kwon & Cho, 1984; Kim, 1985). Nearly all of the pleurocerids in these publications have elongate, high-spired shells, typical in general for this family of snails. Now, a subglobose pleurocerid snail is added to the known Korean freshwater snail fauna.

Koreoleptoxis globus ovalis, n. gen., n. ssp.

(Figs. 1-4)

Diagnosis: A dioecious species of Korean Pleuroceridae with an egg-laying groove on the external right side of the foot in females, and a smooth, short-spired, subglobose shell.

Holotype: UMMZ 250519, collected June 3, 1984, by Choon-Koo Lee; legacy of Pyung-Rim Chung.

Type locality: Stream in Hajin-ri, Juksung-myun, Danyang-gun, Choongchungbuk do, Korea.

Description: Adult shell (Fig. 1) with about four whorls, solid, imperforate, subglobose, with a short spire and large body whorl, and attaining a shell length of about 17 mm. The aperture is broadly ovate, about 78% of the shell height, and rounded anteriorly. The palatal lip is moderately sharp, and, in side view, nearly straight (with a slight sinuosity in the basal half). The columellar lip is curved, heavy and thick, and rounded in cross-section. The parietal callus is moderately thick. The shell surface is marked by well defined axial striae (growth lines) and irregularly spaced varices. Although the shell surface is basically smooth, the irregularities of the growth lines give it a rough appearance. The periostracum is olive green in color, with brownish areas. Most specimens have two (some have three) rather broad, spiral, dark green color bands. These are especially noticable in the shell aperture. Some specimens have additional thinner, less prominent, spiral bands. The periostracum is more darkly colored along the varices. The apical surface in most specimens is eroded. Shell of holotype: 17.2 mm high, 15.3 mm wide, aperture height 13.5 mm, aperture width (including the columellar lip) 11.2 mm. In addition to the holotype, there are 54 paratypes (UMMZ 250520) of varying ages. A juvenile paratype is shown in Fig. 2a. Some juveniles have a relatively somewhat higher spire than do adults.

The operculum (Fig. 2b) is paucispiral, corneous, thin and dark chestnut brown in color.

The central radular teeth have one very large median cusp, with one broad, slightly bifurcate point, or occasionally in-

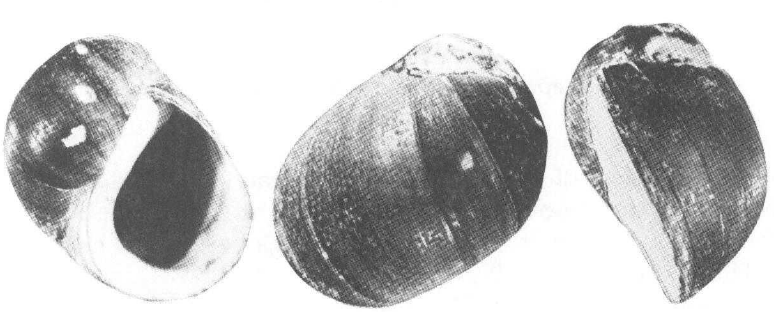


FIG. 1. Shell of *Koreoleptoxis globus ovalis*, n. g., n. ssp., Hajin-ri, Juksung-myun, Choongchungbuk do, Korea; holotype, UMMZ 250519.

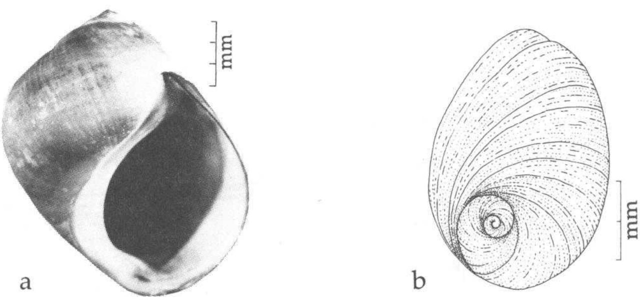


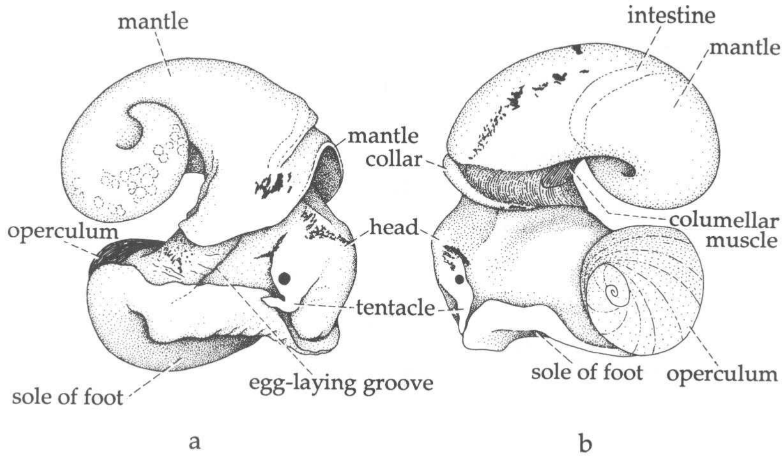
FIG. 2. *Koreoleptoxis globus ovalis*, n. g., n. ssp. **a**, Shell of juvenile paratype, UMMZ 250520; **b**, operculum of an adult paratype.

stead two asymmetrical points, one larger than the other. The lateral teeth are quite strong, with a large, broad blade. The marginal teeth are of two kinds, one with 10 smaller cusps, the other with six larger cusps.

Anatomical observations were made from preserved material. The specimens were generally unexpanded, although in a few the headfoot protruded a little from the shell aperture. The specimens were not ideal for dissections, so future observations on living animals will add details to those provided here.

The sexes can be distinguished by the presence or absence of an egg-laying groove on the right side of the headfoot. Females (Fig. 3a) have this groove, males (Fig. 4a) do not. Both males and females have a small projecting papilla where the genital tract opens to the outside (Fig. 4b). This papilla is located near the mantle collar. The egg-laying groove in females begins near this papilla and extends to the margin of the sole of the foot.

The lobes and ducts of the ovary are located in the first several whorls, and are embedded in the digestive gland. Especially noticable at the anterior (or terminal) end of the digestive gland is a concentration of ovarian lobes. The pallial oviduct begins near the anterior terminus of the liver lobes, and terminates near the mantle collar, beside the anus. The pallial oviduct consists of two glandular, more or less parallel ducts. In some specimens, one duct is considerably larger and more convoluted (and more active sexually?). The two parallel ducts join near the terminal end of the oviduct, just prior to the genital papilla. In none of the female specimens dissected was



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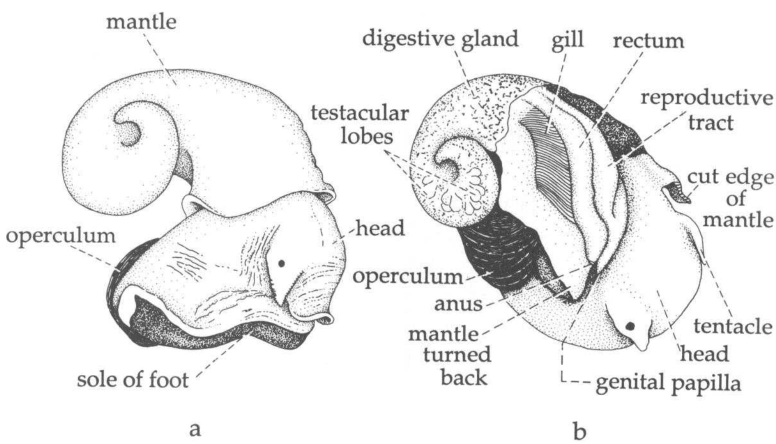

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FIGS. 3, 4. External characteristics and some mantle cavity features of *Koreoleptoxis globus ovalis*, n. g., n. ssp., as seen in preserved paratypes. FIG. 3. Females. **a**, Right side; **b**, left side. FIG. 4. Males. **a**, Right side; **b**, dorsal view, with anterior mantle cut and turned back.

there an internal brood pouch.

In males, the testacular lobes are embedded in the digestive gland (Fig. 4b). Tubes from the individual lobes join a median anterio-posterior sperm duct, which runs close to the shell columella. A glandular organ (prostate gland?; "spermatophore organ"?) appears near the anterior end of the digestive gland, where the sperm duct branches. One of the branches leads to the glandular tube, the other runs parallel to the mantle edge. The two ducts rejoin near the genital papilla (Fig. 4b). Males lack any trace of an external groove on the right side of the foot (Fig. 4a).

Melanin pigment on the headfoot of our preserved specimens varied from being nearly totally absent, to having only a few patches around the posterior bases of the tentacles, to the headfoot being nearly uniformly covered with dense melanin pigment. In all specimens, the mantle had very little melanin pigment, with only a few scattered small patches on the anterior dorsal surface.

Comparisons: Only one other Korean pleurocerid snail, *"Melania" globus* Martens, approaches *Koreoleptoxis ovalis* in shape. We have not seen specimens of *"M." globus*, but Martens (1905) provided a good picture of it, which shows a relatively long penultimate whorl. With such a penultimate whorl, together with the earlier whorls (eroded away in Martens' figure), *"M." globus* is obviously a relatively high-spired species, in spite of its name and its somewhat globular appearance (due mainly to its eroded upper spire). There is no information on whether *globus* is oviparous (i.e., probably related to *Hua*) or ovoviviparous (i.e., probably related to *Semisulcospira*), but we are assuming that it is oviparous.

Morrison (1954) used the generic name *Oxytrema* Rafinesque 1819 for oriental oviparous snails, including *nodifila* Martens 1886 of Korea. Kwon & Habe (1979) used the nude name *Koreanomelania* for *nodifilae* Martens 1894 [*sic nodifila* Martens 1886], presumably based on Morrison's observations but not using his choice of genus name, and included a second species under the name *Koreanomelania:* Martens' *globus. "Melania" nodifila* has a relatively high-spired, lirate or nodulate shell. A diagnosis for *Koreanomelania* is that it is a taxon which includes Korean oviparous pleurocerid snails with subovately conic shells (spire angles of $50^{\circ} \pm 5^{\circ}$) which are sculptured with lirae or nodules, but not ribs. Its type species, here selected, is *Melania nodifila* Martens. Other oviparous snails in Korea have shells that are either elongately conic (spire angles of about $30^{\circ} \pm 5^{\circ}$) and variously sculptured, including ribbed (but are not smooth) [*Hua s.s.*] or are globosely conic (spire angles of about $80^{\circ} \pm 5^{\circ}$) and smooth [*Koreoleptoxis*].

Anatomically, at least in regard to the egg-laying groove in females, *Koreoleptoxis globus ovalis* is similar to *Hua telonaria* (Heude) and its relatives (see Abbott, 1948). Because of these similarities, we believe that *K. g. ovalis* is allied to the genus *Hua*. But, because of the great difference in the shell of *K. g. ovalis* from the various species of *Hua* (and from *Koreanomelania nodifila*), we are placing *ovalis* in a different genus, *Koreoleptoxis*.

Comparing *Koreoleptoxis globus ovalis* to extralimital taxa, the most obvious similarity (in shell shape) to us is with the North American *Leptoxis* Rafinesque. It is because of that that we are giving it the name *Koreoleptoxis*.

LITERATURE CITED

ABBOTT, R. Tucker. 1948. Handbook of medically important mollusks of the orient and the western Pacific. *Bulletin of the Museum of Comparative Zoology at Harvard College*, 100(3): 245-328, pls. 1-5.

CHO, Kyu-Song. 1984. General environmental research on the Han River area. (I). [In Korean]. Han River Ecology Institute at Kangwon National University. Pp. 148-152.

HA, Young-Chil, Hong, Soon-Woo, KIM, Hoon-Soo, CHUNG, Yong-Ho, WON, Pyong-Oh, HA, Young-Ku, LEE, Kyung, CHOI, Hong-Kun & AHN, Tae-Seok. 1981. Review of the ecology of the Han River. Institute of Science, Seoul National University. Pp. 224-225.

KANG, Young-Sun, KIM, Chang-Whan, KIM, Hoon-Soo, PAIK, Gap-Yong, WON, Byong-Hwee, LEE, Duk-Sang, CHO, Bok-Sung, CHOI, Ki-Chull & WOON, Il-Byong. 1975. *Nomina animalium koreanorum, (3),* Invertebrata. Zoological Society of Korea, pp. 1-180. [Mollusca on pp. 51-81].

KIL, Bong-Seop. 1976. Ecological studies on the fresh-water mollusks (shell fish) from Korea. Distribution and standing crops of the fresh-water Mollusca in the Jeonbuk Do, Korea. *Korean Journal of Limnology*, 9(1-2): 15-20.

KIL, Bong-Seop. 1977. Ecological studies on the freshwater gastropods in Korea. - Distribution of *Semisulcospira forticosta* in the Taebaek Range. [In Korean]. *Korean Journal of Limnology*, 10(3/4): 29-35.

KIM, Duk-Man. 1985. A review on the study of molluscan fauna in the Han River. [In Korean, with English abstract]. *Korean Journal of Malacology*, 1(1): 51-63.

KURODA, Tokubei. 1929. On Japanese melanians. [In Japanese]. *Venus*, 1(5): 179-193, pl. 4.

KWON, Oh-Kil. 1982. A study on the freshwater molluscan fauna in Soyang Lake. *Research Bulletin, Kangwon National University*, Korea, 17: 89-92.

KWON, Oh-Kil & CHO, Dong-Hyun, 1984. A list of mollusks in Han River. [In Korean]. Pp. 148-152. In: Cho, Kyu-Song, General environmental research on the Han River area. Han River Ecology Institute at Kangwon National University.

KWON, Oh-Kil & CHOI, Joon-Kil. 1982. The studies on the mollusks in the Lake Uiam (2). The studies of the fresh-water mollusks in the Lake Uiam and the swimming-out of pre-larva fish from mussels. *Korean Journal of Limnology*, 5(1/2): 39-50.

KWON, Oh-Kil & HABE, T. 1979. A list of non marine molluscan fauna of Korea. *Korean Journal of freshwater Ecology*, 12(1/2): 25-33.

MARTENS, Eduard von. 1886. Japan und Korea gesammelten Land und Süsswasser-Mollusken. *Sitzungs-Bericht der Gesellschaft naturforschender Freude zu Berlin*, (5): 76-80.

MARTENS, Eduard von. 1894. Neue Süsswasser-Conchylien aus Korea. *Sitzungs-Bericht der Gesellschaft naturforschender Freunde zu Berlin*, (8): 207-217.

MARTENS, Eduard von. 1905. Koreanische Süsswasser-Mollusken. *Zoologischen Jahrbüchern*, 1905, suppl. 8, pp. 23-70, pls. 1-3.

MIYANAGA, Muneo. 1938. On the *Semisulcospira* spp. in Korea. [In Japanese]. *Chosen Medical Journal*, 28: 1752.

MIYANAGA, Muneo. 1942. Kawanina snails of the genus *Semisulcospira* from Korea. [In Japanese]. *Chosen Hakubutsu Zasshi* [Korean Journal of biological Science], 9(36): 114-130.

MORRISON, J.P.E. 1954. The relationships of Old and New World melanians. *Proceedings of the United States National Museum*, 103(3325): 357-394.

OMORI, Noburu. 1935. On the *Semisulcospira* spp. in Korea. [In Japanese]. *Chosen Medical Journal*, 25: 1624.

SHIBA, Noboru. 1934. Catalogue of the Mollusca of Chosen (Corea). [In Japanese]. *Chosen Journal of Natural History*, 18: 6-31.

YOO, Jong-Saeng. 1969. The distribution and standing crops of freshwater mollusks in the Han River system. *Bulletin of the High School Attached to Seoul National University Normal College*, 12: 79-97.

YOO, Jong-Saeng. 1976. *Korean shells in color*. Il Ji Sa Publishing Co., Seoul, Korea. Pp. 1-196, pls. 1-36.

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Walkerana, 1987, 2(8): 195-232

A GUIDE TO THE FRESHWATER SNAILS OF KOREA

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INTRODUCTION

The freshwater molluscan fauna of Korea is of considerable importance to human welfare. As one of the dominant groups of benthic organisms, freshwater mollusks play significant roles as links in food chains, as detritus feeders improving bottom sediments, and as human food. Some species can serve as indicators of ecological conditions, others are useful in studying geographic patterns and relationships, and others are important in tracing past stream histories. On the negative side, some of the species of Korean freshwater snails are of critical concern because of their role in transmission of human trematode parasites.

In spite of their significance, the freshwater mollusks of Korea have not been thoroughly studied, and this is due in part to the lack of readily available means for biologists to identify the taxa inhabiting the country. Therefore, one purpose of this guide is to provide a means for the identification of the higher taxa and genera of Korean freshwater snails. A second purpose is to give a framework of classification for Korean freshwater snails. Thirdly, we are presenting an extensive bibliography relating to Korean freshwater snails, and providing annotations for most of the bibliographic references, especially the more important ones.

OUTLINE OF CLASSIFICATION

Class Gastropoda Cuvier 1797 (Duméril 1806)
  Subclass **Prosobranchia** Milne Edwards 1848 (Streptoneura Spengel 1881)
    Order Neritopsina Cox & Knight 1960 (Order Neritacea auct.)
      Superfamily Neritoidea Rafinesque 1815
        Family NERITIDAE Rafinesque 1815
          Genus *Clithon* Montfort 1810 (*Nerita corona* Linnaeus)*

    Order Mesogastropoda Thiele 1927 [Taenioglossa Troschel 1848; Monotocardia Mörch 1865]
      Superfamily Viviparoidea Gray 1847
        Family VIVIPARIDAE Gray 1847
          Genus *Cipangopaludina* Hannibal 1912 (*Paludina mallea* Reeve)

        Family BITHYNIIDAE Gray 1857
          Genus *Gabbia* Tryon 1865 (*Gabbia australis* Tryon)
          Genus *Parafossarulus* Annandale (in Annandale & Prashad 1924) (*Bithinia striatula* Benson)

      Superfamily Truncatelloidea Gray 1840 [Rissooidea H. & A. Adams 1854]
        Family HYDROBIIDAE Troschel 1857
          Genus *Bythinella* Moquin-Tandon 1855 (*Bulimus viridus* Poiret)

        Family ASSIMINEIDAE H. & A. Adams 1858
          Genus *Assiminea* Fleming 1828 (*Assiminea grayana* Fleming)
          Genus *Pseudomphala* Heude 1882 (*Assiminea latericea miyazakii* Habe)
          Genus *Angustassiminea* Habe 1943 (*Assiminea castanea* Westerlund)

        Family STENOTHYRIDAE Fischer 1887
          Genus *Stenothyra* Benson 1856 (*Nematura deltae* Benson

*Type species are placed in parentheses after each generic group name.

Superfamily Vermetoidea Rafinesque 1815 [Cerithioidea Fleming 1822]
Family PLEUROCERIDAE Fischer 1885
Genus *Semisulcospira* O. Boettger 1886 (*Melania libertina* Gould)
Genus *Hua* Chen 1943 (*Melania telonaria* Heude)
Subgenus *Hua s.s.*
Subgenus *Koreanomelania* Kwon & Habe 1979 (in Burch & Jung, 1988) (*Melania nodifila* Martens)
Genus *Koreoleptoxis* Burch & Jung 1988 (*Koreoleptoxis globus ovalis* Burch & Jung)

Subclass **Pulmonata** Cuvier 1817 (Fleming 1822) [Euthyneura Spengel 1881, in part]
Order Lymnophila Férussac 1812 [Basommatophora Keferstein 1864, in part]
Superfamily Lymnaeoidea Rafinesque 1815
Family LYMNAEIDAE Rafinesque 1815
Genus *Radix* Montfort 1810 (*Radix auriculatus* Montfort = *Helix auricularia* Linnaeus)
Genus *Fossaria* Westerlund 1885 (*Buccinum truncatulum* Müller)
Genus *Austropeplea* Cotton 1942 (*Limnea papyracea* Tate)

Superfamily Ancyloidea Rafinesque 1815
Family PHYSIDAE Fitzinger 1833
Genus *Physella* Haldeman 1843 (*Physa globosa* Haldeman)

Family PLANORBIDAE Rafinesque 1815
Genus *Gyraulus* Charpentier 1837 (*Planorbis hispidus* Draparnaud = *Planorbis albus* Müller)
Genus *Hippeutis* Charpentier 1837 (*Planorbis complanatus* Draparnaud = *Helix complanatus* Linnaeus)
Subgenus *Helicorbis* Benson 1855 (*Planorbis* (*Helicorbis*) *umbilicalis* Benson)
Genus *Segmentina* Fleming 1817 (*Nautilus lacustris* Lightfoot = *Planorbis nitidus* Müller)
Subgenus *Polypylis* Pilsbry (in Pilsbry & Ferriss) 1906 (*Planorbis hemisphaerula* Benson)

Family ANCYLIDAE Rafinesque 1815
Genus *Pettancylus* Iredale 1943 (*Ancylus tasmanicus* Tenison-Woods)

IDENTIFICATION

Characteristics of both the animals and their shells are important in taxon recognition among freshwater snails. In both the higher and lower taxonomic categories, characteristics of the shells are especially useful, so it is essential that the nomenclature for the basic parts of a gastropod shell are understood. This is shown in Fig. 1. Shell characters of taxonomic importance include adult size (Fig. 2) and general form of the shell, direction of coiling, presence or absence of operculum, shape of the whorls and shell aperture, presence and size, or absence, of a basal columellar opening (umbilicus), type of operculum when present, details of the columellar margin and outer lip, surface coloration, banding, sculpture, etc. Shell surface markings are shown in Fig. 3.

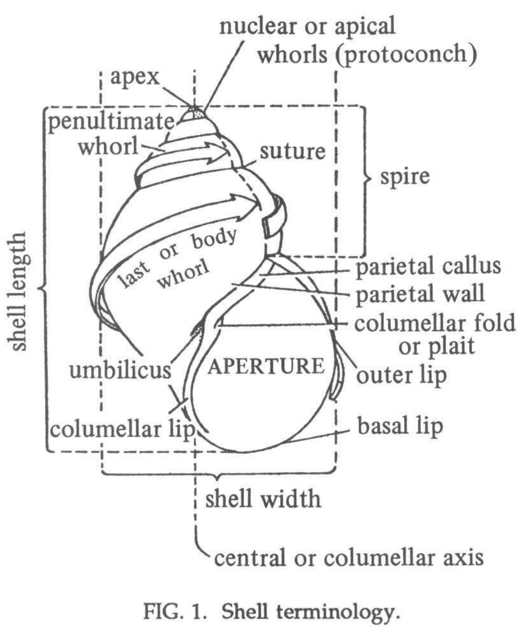


FIG. 1. Shell terminology.

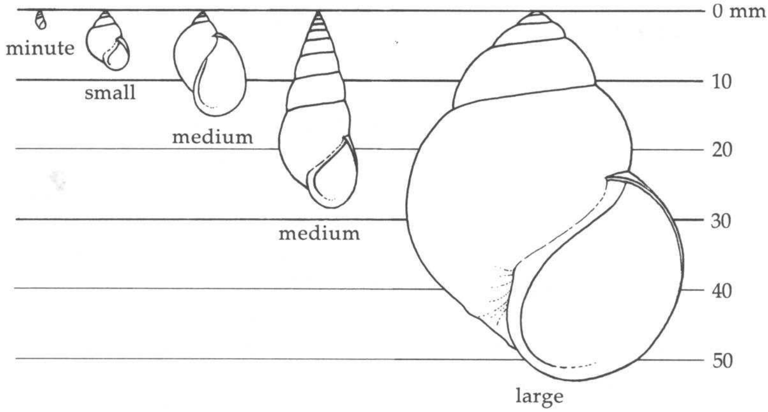


FIG. 2. Shell sizes: up to 3 mm = minute; 3+ to 10 mm = small; 10+ to 30 mm = medium; over 30 mm = large.

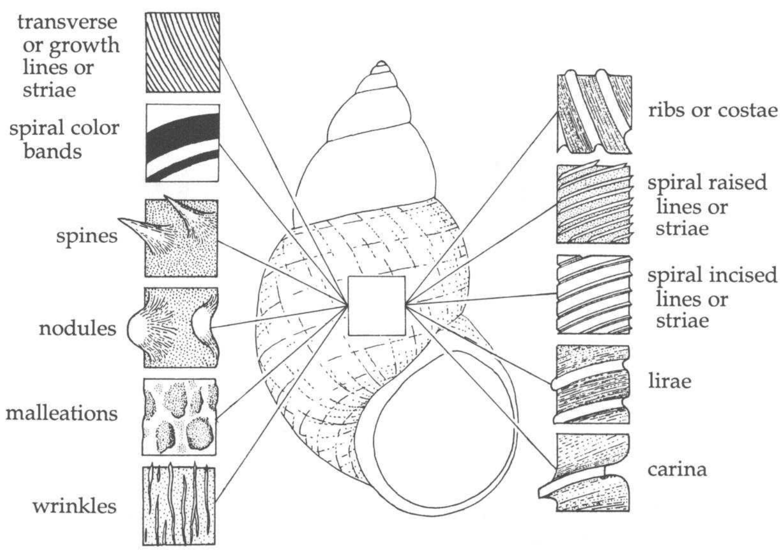
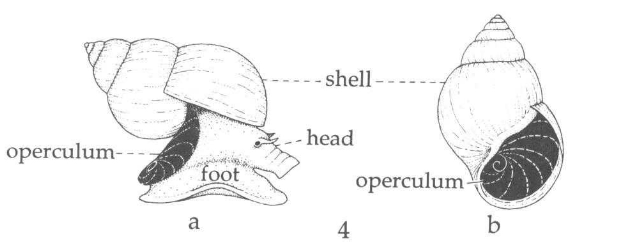


FIG. 3. Shell surface markings.

IDENTIFICATION KEY TO THE FRESHWATER SNAILS OF KOREA

1 Aperture of shell, in life, closed by an operculum (Fig. 4a); respiration by gills; mantle opening facing anteriorly. Subclass **Prosobranchia**............................2

Aperture of shell not closed by an operculum in life; respiration by the vascularized lining of a pulmonary cavity (true gills are lacking) or by a pseudobranch (false gill) outside the pulmonary cavity; opening to the respiratory cavity directed to the side (to the right or left, depending on whether the animal is dextral [right coiled] or sinistral [left coiled] (Fig. 5). Subclass **Pulmonata,** Order **Lymnophila** [= Basommatophora, in part]..13



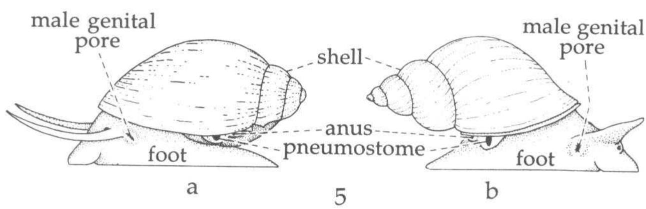


FIG. 4. An operculated snail, i.e., one that carries an operculum attached to its dorsal posterior foot. **a,** Position of the operculum when the snail is active; **b,** position of the operculum when the snail has withdrawn into its shell. FIG. 5. Right-coiled and left-coiled snails. **a,** A snail with sinistral organization of its body, i.e., respiratory, excretory and reproductive openings on the left side; **b,** a snail with dextral organization of its body, i.e., respiratory, excretory and reproductive openings on the right side.

2(1) Shell neritiform, i.e., with relatively large body whorl, a very small coiled spire and toothed columellar margin (Fig. 6a); operculum with an elongate attachment process (apophysis) on its inner surface (Fig. 6b); gill bipectinate or feather-like, i.e., with gill laminae on both sides of the gill axis; radula rhipidoglossate (Fig. 7a), with many marginal teeth. Order **Neritopsina**[1*], Superfamily Neritoidea, Family NERITIDAE. Figs. 8, 36. .... Genus *Clithon*[2]

Shell not neritiform, spire generally pronounced (but if short, then other characters not as above); inner surface of operculum without an apophysis on its inner surface; gill monopectinate, i.e., with gill laminae only on one side of the gill axis (which is adnate to the pallial wall along its entire length); radula taenioglossate (Fig. 7b), with few (two) marginal teeth on each side. Order **Mesogastropoda**[3] 3

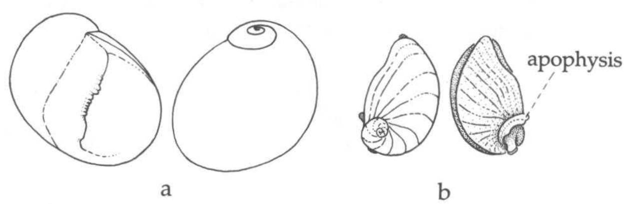


FIG. 6. **a**, Neritiform shell; **b**, neritid operculum, external view (left figure) and inner surface (right figure), which in life is attached to the dorsal foot.

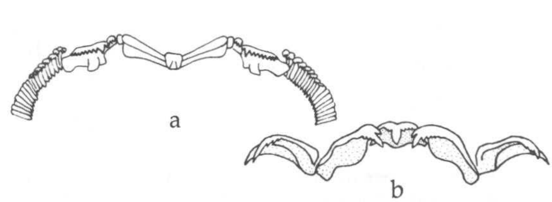


FIG. 7. **a**, One longitudinal row of teeth of (**a**) a rhipidoglossate radula, and (**b**) a taenioglossate radula.

*Superscript numbers throughout the text refer to corresponding comments under Supplemental Notes at the end of the text (pp. 213-216).

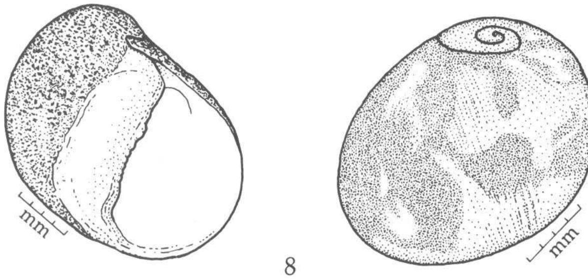


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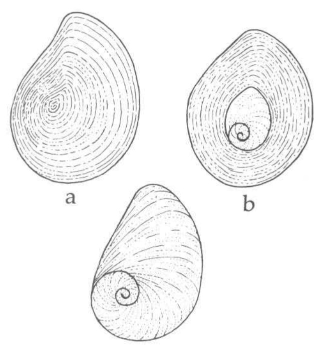
FIG. 8. Genus *Clithon*.

3(2) Adult shell large, ovate-globose, 40 mm or longer in length; operculum concentric (Fig. 9a); the right tentacle in males modified as a penis sheath. Superamily Viviparoidea, Family VIVIPARIDAE. Figs. 10, 37 ....Genus ***Cipangopaludina***[4]

Adult shells large to small, but if more than 30 mm in length then they are narrowly or elongately conic, not ovate-globose or ovately conic 4



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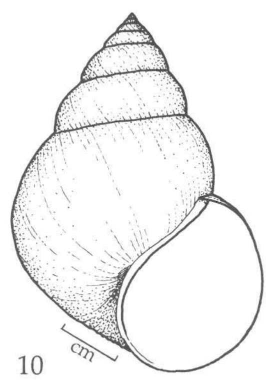

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FIG. 9. Types of opercula. **a**, Concentric; **b**, concentric with spiral nucleus; **c**, spiral. FIG. 10. Genus *Cipangopaludina*.

4(3) Adult shell less than 15 mm in length; operculum calcareous, concentric with spiral nucleus (Fig. 9b); head with a skin flap behind the right tentacle; verge bifid, with two ducts (Fig. 11). Family BITHYNIIDAE........5

Adult shell small to large; operculum corneous, spiral (Fig. 9c); head without a skin flap behind the right tentacle; verge, if present in males, with a single prong and one duct, not bifid..6

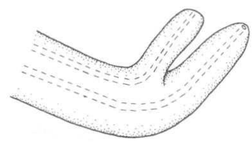
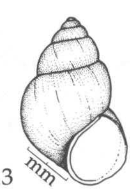


FIG. 11. Bifid verge of a bithyniid snail.

5(4) Adult shells more than 8 mm in length; with spiral ridges. Figs. 12, 38......................Genus ***Parafossarulus***[5]

Adult shells (with about 5 1/2 whorls) less than 8 mm in length; smooth. Figs. 13, 39................Genus ***Gabbia***[6]

12

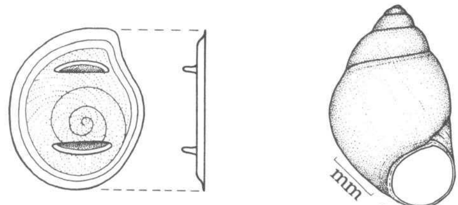


13

FIG. 12. Genus *Parafossarulus*. FIG. 13. Genus *Gabbia*.

6(4) Adult shell small, less than 5 mm in length; last part of last (body) whorl deflected and reduced in size; operculum with distinct, raised ridges on the inner surface where the foot is attached (Fig. 14a); verge with a tiny calcareous stylette at the tip. Family STENOTHYRIDAE. Figs. 14b, 40..........................Genus ***Stenothyra***[7]

Adult shell small to large, more than 5 mm in length; entire body whorl and aperture follow the shell's initial spiral symmetry and gradual increase in size; operculum generally without thicker supporting ridges on the inner surface; verge, if present in male, without a calcareous stylette at the tip....................................7

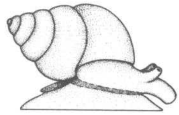


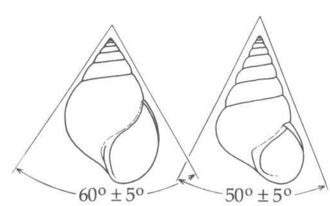
a b

FIG. 14. **a**, Stenothyrid operculum; **b**, Genus *Stenothyra*.

7(6) Adult shell medium to large, more than 10 mm in length; shells may be relatively smooth or sculptured with prominent spiral and transverse ridges, cords or nodules; foot not divided by a groove into upper and lower portions; tentacles well developed, elongate, with eyes at their bases; males without a prominent external copulatory organ; animals live submerged in fresh water. Family PLEUROCERIDAE[8] 10

Adult shell small, less than 10 mm in length; shells smooth or without prominent sculpture; foot divided by a groove on each side into an upper and lower portion (Fig. 15); tentacles greatly reduced, forming low ocular peduncles (Fig. 15); prominent verge present in males; characteristically amphibious, in or near brackish water. Family ASSIMINEIDAE 8



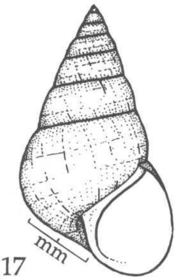


15 a 16 b

FIG. 15. Animal of an assimineid snail. FIG. 16. Spire angles. **a**, Ovately conic; **b**, subovately conic.

8(7) Shell ovately conic (Fig. 16a) 9

Shell narrowly subovately conic. Figs. 16b, 17 .... Genus ***Angustassiminea***[9]



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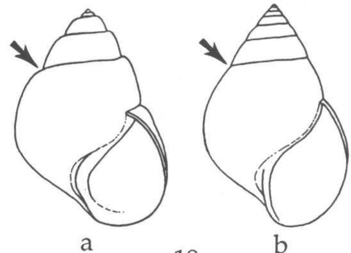
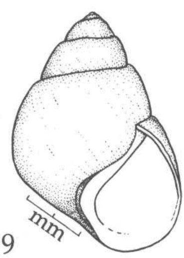


a 18 b

FIG. 17. Genus *Angustassiminea*. FIG. 18. **a**, Shell with shouldered whorls and impressed sutures; **b**, shell without shouldered whorls or impressed sutures.

9(8) Whorls shouldered; sutures impressed. Figs. 18a, 19, 41 ....Genus ***Assiminea***[10]

Whorls not shouldered; sutures not impressed. Figs. 18b, 20, 42.................................Genus ***Pseudomphala***[11]



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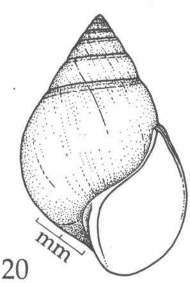

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FIG. 19. Genus *Assiminea*. FIG. 20. Genus *Pseudomphala*.

10(7) Shell narrowly to elongately conic; animal ovoviviparous, females retaining developing embryos in a uterine brood pouch; females without a groove on the right side of body to assist in egg-laying (Fig. 21a). Figs. 22, 43 ....Genus ***Semisulcospira***[12]

Shell elongately conic to globosely conic; animal oviparous, females laying eggs on objects in surrounding water; females with a groove on the right side of body to assist in egg-laying (Fig. 21b)..............................11

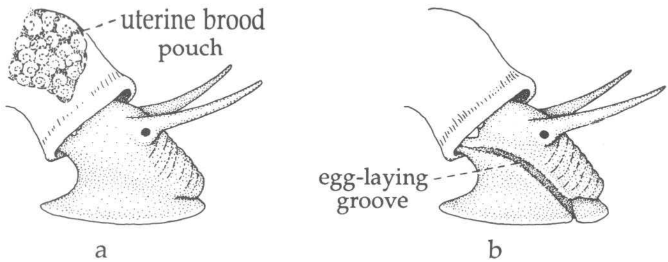


FIG. 21. **a**, Animal with a uterine brood pouch and without an egg-laying groove (*Semisulcospira*); **b**, animal with egg-laying groove and without a brood pouch (*Hua* and *Koreoleptoxis*).

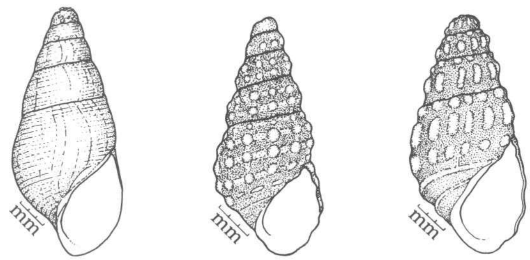


FIG. 22. Genus *Semisulcospira*.

11(10) Shell elongately conic to subovately conic, sculptured with lirae, nodules or ribs. Genus ***Hua***. Figs. 24, 45 12

Shell globosely conic, without lirae, nodules and ribs. Fig. 23, 44....................................Genus ***Koreoleptoxis***

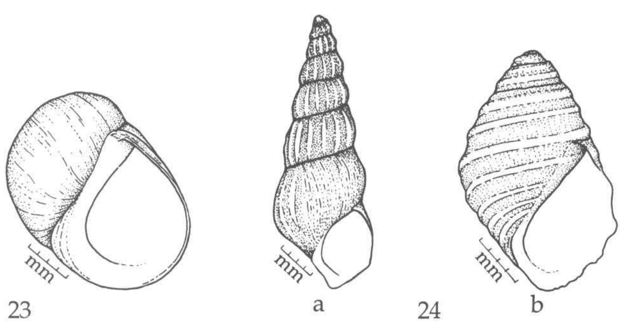


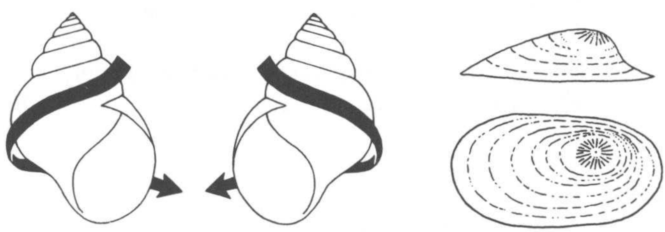
Fig. 23. Genus *Koreoleptoxis*. Fig. 24. Genus *Hua*. **a**, Subgenus *Hua s.s.*; **b**, subgenus *Koreanomelania*.

12(11) Shell elongately conic. Figs. 24a, 45a. Subgenus ***Hua s.s.***

Shell subovately conic. Figs. 24b, 45b............................ .... Subgenus ***Koreanomelania***

13(1) Shell and animal coiled to the right (dextral; Fig. 25a). Superfamily Lymnaeoidea, Family LYMNAEIDAE[13].. 14

Shell coiled to the left (sinistral; Fig. 25b) or cap-shaped (Fig. 26); animal sinistral. Superfamily Ancyloidea.. 16



a b

25 26

FIG. 25. Direction of coiling. **a**, Shell coiled to the right, i.e., *dextral*; **b**, shell coiled to the left, i.e., *sinistral*. FIG. 26. Cap-shaped (ancyliform; patelliform) shell, left side and top views.

14(13) Medium in size, adult shells with 4+ whorls more than 14 mm in length; columella generally twisted, making a fold or plait at the apertural margin. Figs. 27, 46.......... .... Genus ***Radix***[14]

Small, adult shells with 4+ whorls less than 12 mm in length; columella generally straight, without a fold or plait at the apertural margin.................................. 15

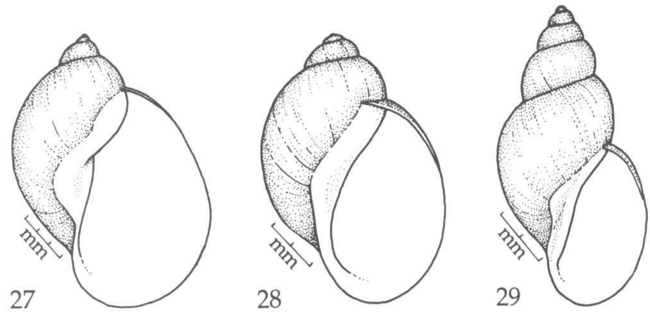


FIG. 27. Genus *Radix*. FIG. 28. Genus *Austropeplea*. FIG. 29. Genus *Fossaria*.

15(14) Shell ovate; body whorl relatively very large. Figs. 28, 47 .... Genus ***Austropeplea***[15]

Shell more elongate; body whorl relatively smaller. Figs. 29, 48 .... Genus ***Fossaria***[16]

16(13) Shell cap-like (limpet-shaped; ancyliform), not coiled. Family ANCYLIDAE. Figs. 30, 53 .... Genus ***Pettancylus***[17]

Shell coiled, not cap-like 17

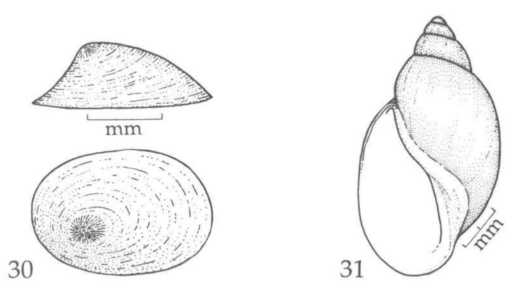


FIG. 30. Genus *Pettancylus*. FIG. 31. Genus *Physella*.

17(16) Shell elongate, coils not restricted to one plane. Family PHYSIDAE. Figs. 31, 49 .... Genus ***Physella***[18]

Shell planorboid (planispiral; discoidal), coiled in one plane (Fig. 32). Family PLANORBIDAE.................. 18

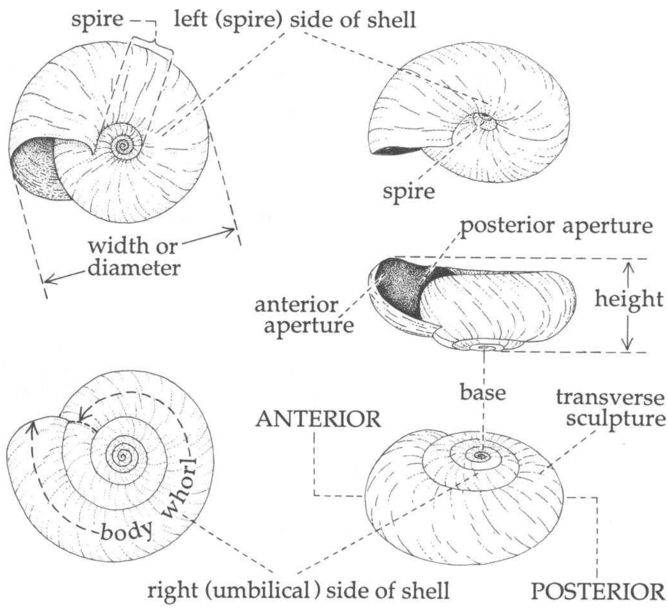


FIG. 32. Terminology of a planorbid shell.

18(17) Basal side of shell flattened; inverted spire wide and shallow; shell dull to moderately glossy. Figs. 33, 50 ....Genus *Gyraulus*[19]

Basal side of shell roundly convex; inverted spire more or less narrow and deep; shell moderately to very glossy 19

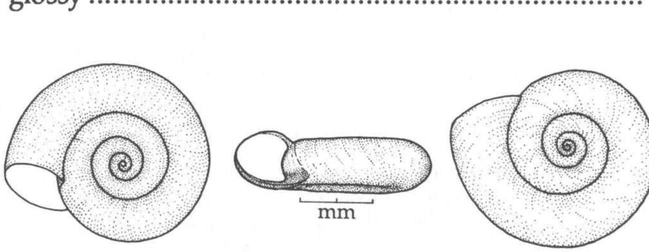


FIG. 33. Genus *Gyraulus*.

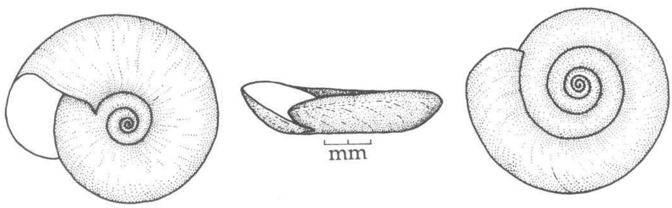


FIG. 34. Genus *Hippeutis*.

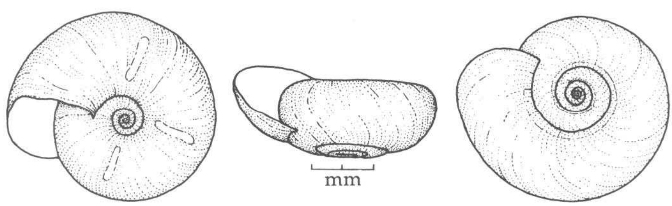


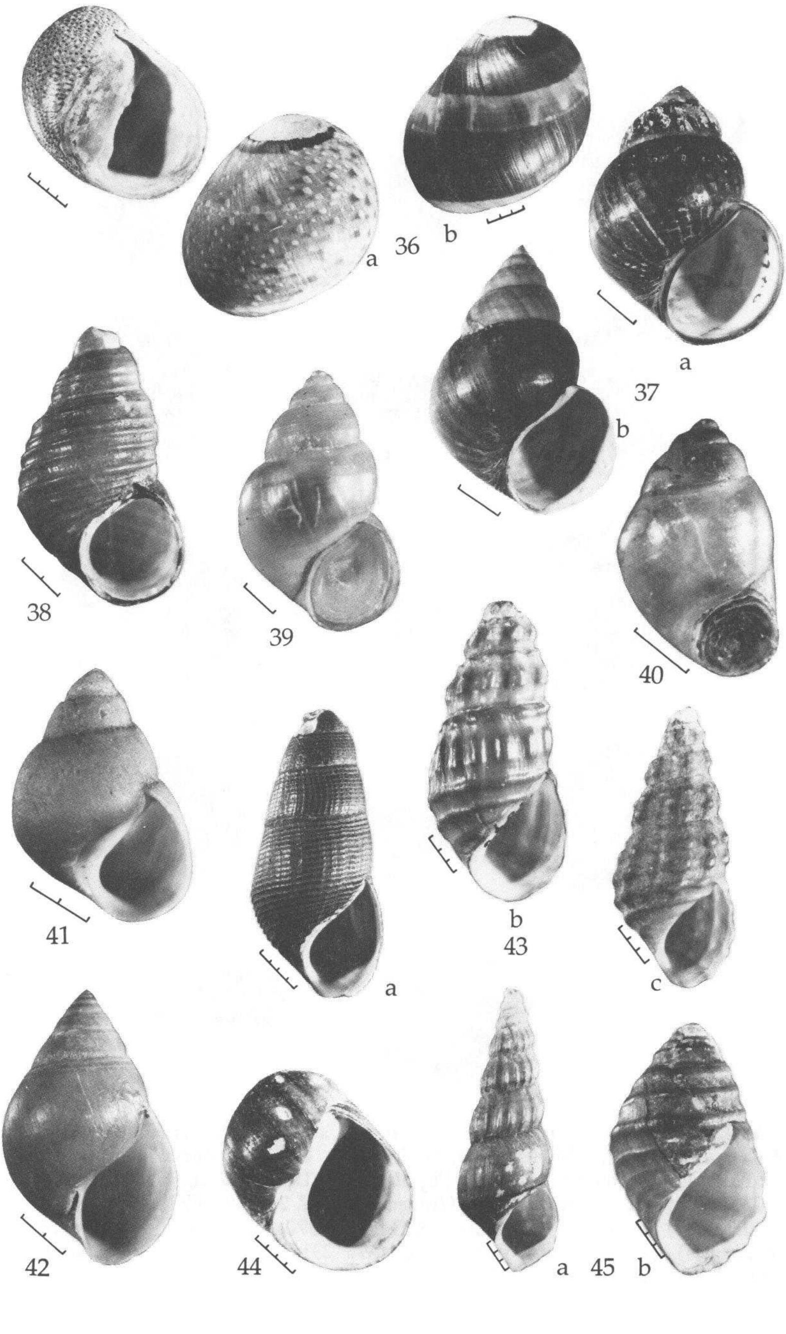
FIG. 35. Genus *Segmentina*.

19(17) Body whorl without internal lamellae. Figs. 34, 51 ....Genus ***Hippeutis*** (subgenus ***Helicorbis***)[20]

Body whorl with internal lamellae. Figs. 35, 52........... ....Genus ***Segmentina*** (subgenus ***Polypylis***)[21]

(Figure legends, facing page)

FIG. 36. *Clithon*. **a**, *C. retropictus* (Martens), UMMZ 220260; **b**, *C. sowerbianus* Récluz, UMMZ 20577. FIG. 37. *Cipangopaludina*. **a**, *C. chinensis malleata* (Reeve), UMMZ 94622; **b**, *C. japonica* (Martens), UMMZ 166975. FIG. 38. *Parafossarulus manchouricus* (Bourguignat), UMMZ 231307. FIG. 39. *Gabbia misella* (Gredler), UMMZ 231297. FIG. 40. *Stenothyra glabrata* A. Adams, UMMZ 230765. FIG. 41. *Assiminea japonica* Martens, UMMZ 74239. FIG. 42. *Pseudomphala latericea* (H. & A. Adams), UMMZ 74241. FIG. 43. *Semisulcospira*. **a**, *S. libertina* (Gould), UMMZ 208115; **b**, *S. gottschei* (Martens), UMMZ 15846; **c**, *S. nodiperda* (Martens), UMMZ 68256. Fig. 44. *Koreoleptoxis globus ovalis* (Burch & Jung), UMMZ 250519. FIG. 45. *Hua*. **a**, *H. amurensis* (Gerstfeldt), UMMZ 71381; **b**, *H.* (*Koreanomelania*) *nodifila* (Martens), UMMZ 250519. Measurement lines = mm, except for *Cipangopaludina* (Fig. 37), which is in cm.


a 36 b
a
37
b
38
39
40
41
b
43
a
c
42
44
a 45 b

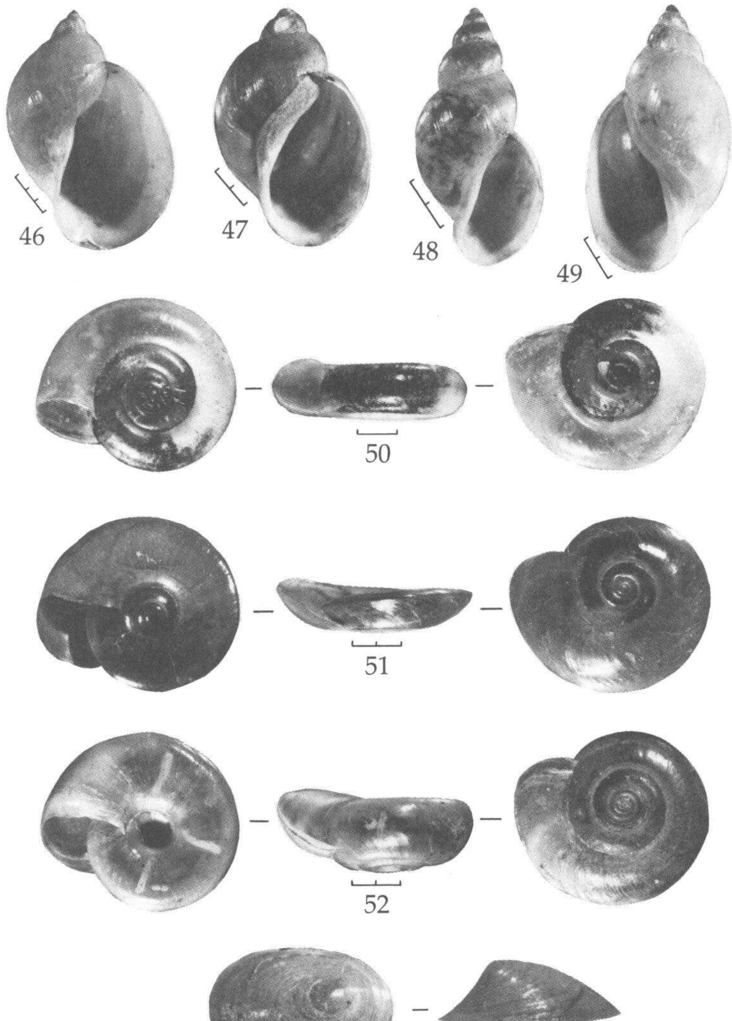


FIG. 46. *Radix auricularia* (Linnaeus), *s.l.*, UMMZ 3015. FIG. 47. *Austropeplea pervia* (Martens), UMMZ 78774. FIG. 48. *Fossaria truncatula* (Müller), UMMZ 80362. FIG. 49. *Physella acuta* (Draparnaud), UMMZ 116306. FIG. 50. *Gyraulus convexiusculus* (Hutton), UMMZ 230749. FIG. 51. *Hippeutis* (*Helicorbis*) *umbilicalis* (Benson), UMMZ 237870. FIG. 52. *Segmentina* (*Polypylis*) *hemisphaerula* (Benson), UMMZ 231431. FIG. 53. *Pettancylus nipponicus* (Kuroda), UMMZ 250326.

SUPPLEMENTAL NOTES

[1] Using the Order Neritopsina for the neritid snails separates them as a group of equivalent rank from the Order Archeogastropoda. For a discussion of anatomical distinctions between neritids and the marine archeogastropods, see Yonge (1960).

[2]Two species of freshwater Neritidae were listed for Korea by Kwon & Habe (1979), *Clithon retropictus* (Martens) and *C. sowerbianus* Récluz, the latter doubtfully. Yoo (1976) listed *C. sowerbianus.* In addition, Choi (1975) listed *C. (Pictoneritina) oualaniensis* (Lesson). Adam & Leloup (1938) placed Recluz's (1842) *Nerita sowerbiana* in the Genus *Neritina* Lamarck 1816. H.B. Baker (1923) included *Clithon* as a subgenus in *Theodoxus* Montfort 1810, using radular and opercular characters for this system. This taxonomic placement was followed by Knight *et al.* (1960). While we do not have reason to doubt Baker's placement of *Clithon,* or Adam & Leloup's, we hesitate to make nomenclatural changes until the Korean freshwater neritid species can be studied more thoroughly. Brandt (1974) placed *"Clithon sowerbyana"* in *Clithon* s.s., and said *C. retropicta* (Martens) "is restricted to Japan (? and the Fiji Islands)."

[3]In addition to the mesogastropod families Assimineidae, Bithyniidae, Pleuroceridae, Stenothyridae and Viviparidae, the family Hydrobiidae (for the genus *Bythinella* Moquin-Tandon) is added to the Korean freshwater snail fauna on the authority of Tadashige Habe (personal communication). We have not seen *Bythinella,* so it is not included in the key. *Bythinella viridis* (Poiret), the type species of the genus, has a minute (length = ca. 2.5 mm), elongately ovate shell with a blunt apex, shouldered whorls, entire and adnate lip, and roundly ovate aperture.

[4]*Cipangopaludina* contains the largest freshwater snails known for Korea. *Cipangopaludina chinensis laeta* (Martens) has been reported for Korea by Kwon & Habe (1979). They considered *C. malleata* (Reeve) to be a synonym of *C. chinensis laeta.*

[5]*Parafossarulus* is sometimes considered to be a subgenus of *Bithynia* Leach (in Abel) 1818 [type species *Helix tentaculata* Linnaeus 1758]. *Parafossarulus manchouricus* (Bourguignat) is a common species in Korea and other parts of the Orient. Its shell morphology can be variable, which has led to a number of synonyms in the Far East.

[6]Gredler's (1884) *Bythinia misella* in Korea has been placed either in

the genus *Bithynia* Leach (in Abel) (Meier-Brook & Kim, 1977) [or its synonym *Bulimus*] or in *Gabbia* [type species *Gabbia australis* Tryon 1865], either as a subgenus of *Bithynia* or as a full genus (Chung, 1984). However, the exact relationship of the Korean snails to the Australian *Gabbia australis* Tryon has not yet been studied.

[7]*Stenothyra glabra* (A. Adams) has been reported for Korea by Kwon & Habe (1979). Kim *et al.* (1985) reported *S. glabra* and *S. japonica.*

[8]*Semisulcospira* is common in Korea and its many populations exhibit a number of different shell forms. Three of these are shown in Fig. 43. The taxonomic status of these populations has not yet been studied well enough to make taxonomic judgements as to which are taxa worthy of recognition and which have names that are merely synonyms.

[9]One species of *Angustassiminea* has been reported from Korea, *A. castanea* (Westerlund) (Kwon & Habe, 1979). Pace (1973) doubted the validity of the taxon *Angustassiminea,* and placed *castanea* Westerlund in the genus *Assiminea.*

[10]One species of *Assiminea* has been reported from Korea, *A. lutea* (A. Adams) (Kwon & Habe, 1979) [*Assiminea japonica* Martens was considered to be a synonym].

[11]One species of *Pseudomphala* has been reported from Korea, *P. latericea* (H. & A. Adams) (Kwon & Habe, 1979).

[12]Abbott (1948) characterized the animals of the genus *Semisulcospira* Boettger 1886 as having a smooth mantle, lacking the long papillae characteristic of *Thiara* and *Stenomelania,* and females having a uterine brood pouch. He characterized the genus *Hua* Chen 1943 as having females lacking brood pouches (all species probably being egg-layers) and possessing an indented groove extending down the right side of the body to the edge of the foot [sole]. Species he observed as having the egg-laying groove and lacking uterine brood pouches were *H. telonaria* (Heude) (type species of Chen's genus *Hua*), *H. dolium* (Heude), *H. jacquetiana* (Heude) and *H.* (*Namrutua*) *ningpoensis* (Lea). In *Hua,* Abbott also provisionally placed "*Melania*" *amurensis* Gerstfeldt, and listed as synonyms the Chinese and Korean snails "*M.*" *heukelomiana* Reeve, "*M.*" *gottschei* Martens, "*M.*" *tegulata* Martens and "*M.*" *nodiperda* Martens (with its varieties *connectens, pertinax* and *quinaria*). However, Abbott stated that "the animal of this species ["*H.*" *amurensis*] has not been examined, and is provisionally included in *Hua,* although a subsequent work may place it in the

genus *Semisulcospira."* Morrison (1954) extended the observations regarding brood pouches vs. egg-laying grooves, giving the latter characteristics for the Korean *"Oxytrema" nodifila* (Martens). For such snails, Morrison used the eastern North American genus name *Oxytrema* Rafinesque 1819 [a synonym of *Pleurocera* Rafinesque 1818; e.g., see Opinion 1195 of the International Commission on Zoological Nomenclature]. Subsequently, Kwon & Habe (1979) provided the name *Koreanomelania* for *nodifila,* and for *globus* Martens as well (see Burch & Jung, 1988, for a generic-group diagnosis for *Koreanomelania* and designation of type species [*Melania nodifila* Martens]).

Morrison (*op. cit.*) examined the animals of *gottschei, nodiperda* and *graniperda* and found them to have the characteristics of *Semisulcospira.*

[13]In many reports, all lymnaeids in East Asia are included in the Holarctic genus *Lymnaea.* However, the eastern and southeastern Asian and Australasian lymnaeids belong to different stocks from the Holarctic *Lymnaea stagnalis,* the type species of the genus *Lymnaea.* Two species groups (genera or subgenera) of Lymnaeidae occur in the East Asian region, *Radix* and *Austropeplea. Austropeplea* may be only a subgroup of the much more widely distributed *Radix.*

[14]*Radix* of Eurasia is the most widely distributed generic-group taxon in the Lymnaeidae, and its lower-level taxonomy is still a problem. The specific limits of *R. auricularia* especially needs study. Martens (1886) gave the common name *coreana* to the Korean form of *R. auricularia.*

[15]*Austropeplea* is the genus-group taxon name applied to the species of lymnaeids with the smallest number of chromosomes ($n = 16$, $2n = 32$) for the family (Inaba, 1969). The smaller species of this group have all been lumped (Hubendick, 1951) under the oldest name, *Lymnaea viridus* Quoy & Gaimard 1833, a species of Guam. However, *"Lymnaea" viridus* of Guam has not yet been studied in detail.

[16]*Fossaria* Westerlund 1885 is used for the group of small lymnaeids with the chromosome number ($n = 18$, $2n = 36$) most common for the family, rather than *Galba* auct. (which is only doubtfully the same as *Galba* Schrank 1803, type species *Galba pusilla* Shrank 1803 by monotypy, but actually unidentifiable (see Pilsbry & Bequaert, 1927, p. 106).

[17]The ancylid genus common to the western Pacific area seems to be *Pettancylus.* Far Eastern *"Gundlachia"* is a synonym. Choi (1975) and Yoo (1976) listed *P. nipponicus* (Kuroda) for Korea.

[18]*Physella acuta* (Draparnaud) has become widely spread by human commerce. It now occurs in many places in the western Pacific region, including Korea (Ha *et al.*, 1981).

[19]Choi (1975) listed *Gyraulus compressus* (Hutton) for Korea. Meier-Brook (1983) regarded this name to refer to "a more flattened and strongly angled form, usually considered *Gyraulus convexiusculus* [Hutton, 1849] 'var. *compressus* Hutton.' *"Gyraulus convexiusculus* Benson" was listed for Korea by Kwon & Habe (1979), with various synonyms, including *"Planorbis compressus* Martens, 1867." Meier-Brook (1983) reported *G. spirillus* (Gould) from Korea, rather than *G. convexiusculus* (Hutton), but he did not rule out the possibility that the two might be races of the same species. *Gyraulus spirillus* has a spiral, median periostracal fringe, whereas *G. convexiusculus* does not.

[20]*Helicorbis* is often raised to generic rank, rather than included as a subgenus of *Hippeutis*. Our classification follows Pace (1973). *Hippeutis peipinensis* (Ping & Yen) was listed by Choi (1975) for Korea. Pace (1973) suggested that this name is a synonym of *Hippeutis (Helicorbis) umbilicalis cantori* (Benson), and Kwon & Habe (1979) listed it as a synonym of "*Hippeutis cantori* (Benson)."

[21]*Polypylis* is sometimes raised to generic rank, rather than included as a subgenus of *Segmentina*. Our classification follows Pace (1973). "*Polypylis hemisphaerula* (Benson)" was listed for Korea by Kwon & Habe (1979).

ANNOTATED BIBLIOGRAPHY

ABBOTT, R. Tucker. 1948. Handbook of medically important mollusks of the Orient and western Pacific. *Bulletin of the Museum Comparative Zoology at Harvard College,* 100(3): 245-328, pls. 1-5.

[Discusses three species (*Semisulcospira libertina* Gould, *S. libertina multicincta* Martens and *Hua (Hua) amurensis* Gerstfeldt) which occur in Korea as intermediate hosts of human parasites. Abbott included the following Korean nominal species in the synonymy of *H. amurensis*: "*M.*" *gottschei* Martens, "*M.*" *tegulata* Martens and "*M.*" *nodiperda* Martens (with its varieties *connectens, pertinax* and *quinaria*). (See also supplemental note 12.)]

ADAM, W. & LELOUP, E. 1938. Prosobranchia et Opisthobranchia. In: Straelen, V. van, Résultats scientifiques du voyage aux Indes Orientales Néerlandaises de LL. AA. RR. le Prince et la Princesse Léopold de Belgique. *Mémoires du Musée royal d'Histoire naturelle de Belgique,* hors série, 2(19): 1-209, pls. 1-8.

[A taxonomic treatise on Indonesian mollusks, including some species which have been reported to occur also in Korea.]

BAKER, H. Burrington. 1923. Notes on the radula of the Neritidae. *Proceedings of the Academy of Natural Sciences of Philadelphia,* 75: 117-178, pls. 9-14.

[A good description of the neritid radula and a revised classification for the family.]

BRANDT, R.A.M. 1974. The non-marine Mollusca of Thailand. *Archiv für Molluskenkunde,* 105: i-iv, 1-423, pls. 1-30.

[Although on a Southeast Asian fauna, this is a good general taxonomic and nomenclatural reference for East Asia.]

BURCH, J.B. & CHUNG, Pyung-Rim. 1985. An outline of classification of the freshwater and land snails of Korea, with an annotated bibliography. *Special Publication of the Mukaishima Marine Biological Station,* pp. 33-44.

[Gives a frame of reference for the classification of Korean freshwater and land snails from subclasses down to and including genera. Included are authors and dates of higher taxa and an annotated bibliography. (A typographical error occurs in the date of *Cipangopaludina* Hannibal, which should be 1912, rather than 1812. The full citation for this generic name is Hannibal, Harold, 1912, A synopsis of the Recent and Tertiary freshwater

Mollusca of the Californian province, based upon an ontogenetic classification, *Proceedings of the Malacological Society of London,* 10(2-3): 112-211, pls. 5-8.)]

BURCH, J.B. & JUNG, Younghun. 1987 [1988]. A new freshwater prosobranch snail (Mesogastropoda: Pleuroceridae) from Korea. *Walkerana,* 2(8): 287-293.

[Describes *Koreoleptoxis* as a new pleurocerid genus, with its type species *Koreoleptoxis globus ovalis* n. ssp., and gives a diagnosis and type species designation (*Melania nodifila* Martens 1894) for *Koreanomelania* Kwon & Habe 1979, here considered a subgenus of *Hua* Chen 1943 (type species *Melania telonaria* Heude 1888). All three type species are oviparous, thereby being differentiated from *Semisulcospira,* which is ovoviviparous.]

CHEN, Sui-Fong. 1943. Two new genera, two new species, and two new names of Chinese Melaniidae. *The Nautilus,* 57(1): 19-21, pl. 6, figs, 1-4.

[Describes *Hemimitra tangi* n. sp., *Sermyla kowloonensis* n. sp., *Wanga,* n. gen. (type species *Melania henriettae* Gray 1834) and *Hua,* n. gen. (type species *Melania telonaria* Heude 1888). New names are *Wanga hsui* Chen, new name for *Melania turrita* Hsü 1935, not Klein 1846, and *Hua heudei* Chen, new name for *Melania oreadarum* Heude 1890, not Heude 1888.]

CHO, Kyu-Song. 1984. General environmental research on the Han River area. (I). [In Korean]. Han River Ecology Institute at Kangwon National University. Pp. 148-152.

[Eight species of freshwater snails were found at the 12 stations surveyed in the South Han River: *Semisulcospira coreana, "S." [Koreoleptoxis] globus, S. gottschei, "S." [Hua (Koreanomelania)] nodifila, S. forticosta, Parafossarulus manchouricus, Bithynia (Gabbia) misella, Radix auricularia coreana* and *Austropeplea ollula.* Seven species were found in the North Han River: *Cipangopaludina chinensis, S. coreana, S. gottschei, "S." [H. (K.)] nodifila, R. auricularia, A. ollula, Pettancylus* sp. and *Hippeutis cantori.*]

CHO, Hae-Chang, CHUNG, Pyung-Rim, CHANG, Jae-Kyung & LEE, Keun-Tae. 1985. Distribution of freshwater snails at Kyung Sang Nam Do, Nam River area, and research on infection of trematode cercariae. [Abstract; in Korean]. *Korean Journal of Malacology,* 1(1): 66-67.

[Habitats and infection with trematode cercariae of nine snail species (three of which appeared to have been introduced) during the period August-November 1983 in six localities around Jin Ju city and Jin Yang Lake. The distributions of three species were recorded: *Parafossarulus manchouricus,* the snail intermediate host of the liver fluke in upper Jin Yang Lake; *Semisulcospira libertina* (host of the lung fluke) was infected with *Metagonimus yokogawai; Radix auricularia coreana.* In *P. manchouricus,*

manchouricus, 6.9% of the specimens examined were infected with trematode larvae; 0.14% were infected with liver fluke larvae. Four different trematodes were found: liver fluke, *Furcocercus cercariae* and *Loxogenes liberum types* I and II. In *Semisulcospira libertina*, 4.8% of the specimens examined were infected with trematodes (six different trematode species), especially *Metagonimus yokogawai* (1.5%). In addition to *M. yokogawai*, the other trematodes found were *Cercaria yoshidae*, *C. cristata*, *C. innominatum*, *C. nipponensis* and *Centrocestus formosanus*. Temperature and pH were measured in the different snail habitats. Not much difference was found between habitats. Also measured was dissolved oxygen and BOD. Eight different metallic ions were measured. Seven were below the normal ranges known for these ions in natural waters; one (Ca) was higher than the normal range.]

CHOI, Ki-Chul. 1975. Mollusca. Pp. 51-81. In: Kang, Young-Sun, Kim, Chang-Whan, Kim, Hoon-Soo, Paik, Gap-Yong, Won, Byong-Hwee, Lee, Duk-Sang, Cho, Bok-Sung, Choi, Ki-Chull & Woon, Il-Byong. 1975. *Nomina animalium koreanorum, (3), Invertebrata*. Zoological Society of Korea, pp. 1-180. [

[Contains lists of species of marine, brackishwater, freshwater and terrestrial animals reported for Korea, listed by class, order and family. The Korean and Japanese common names are given for the species listed. The list contains 28 species and four subspecies of freshwater snails (and several brackish-water assimineids not separated here): *Clithon (Pictoneritina) oualaniensis* (Lesson), *Cipangopaludina chinensis nalleata* (Reeve) [*sic; malleata*], *C. japonica* (Martens), *Bulimus* [*Gabbia*] *misellus kiusiuensis* Hirase, *B.* [*Bithynia*] *manchouricus japonicus* (Pilsbry), *Assiminea japonica* Martens, *A. japonica hiradoensis* Pilsbry, *A. latericea* H. & A. Adams, *Paludinella stricta* (Gould), *P. japonica* (Pilsbry), *Angustassiminea castanea* Westerlund, *Semisulcospira libertina* (Gould), *S. forticosta* (Martens), *S. forticosta tegulata* (Martens), *S. forticosta comerii* (Miyanaga), *S. amurensis gottschei* (Martens), *S.* [*Hua (Koreanomelania)*] *nodifila* (Martens), *S.* [*Koreoleptoxis*] *nodifila globus* (Martens), *S. coreana* (Martens), *S. paucicincta* (Martens), "*Lymnaea*" [*Radix*] *coreana* Martens, "*L. ovutus* (Martens)" [sic, *ovatus* Draparnaud], "*L.*" [*Austropeplea*] "*pervia*" [? *ollula*] (Martens), *Radix auricularia* (Linnaeus), *Radix japonica* (Jay), "*Ferrissia*" [*Pettancylus*] *nipponicus* Kuroda, *Gyraulus compressus* (Hutton) [*convexiusculus* Hutton], *Hippeutis peipinensis* (Ping & Yen) [*umbilicalis cantori* Benson].]

CHU, Jung-Kyun. 1980. A summary of bibliography on Korean medical malacology. [In Korean]. Pp. 151-155. In: *A summary on the reports on Korean parasitology*. Moon-Won-Chung-Pan-Sa Co., Seoul.

CHUNG, Pyung-Rim. 1984. A comparative study of three species of Bithyniidae (Mollusca: Prosobranchia) *Parafossarulus manchouricus*, *Gabbia misella* and *Bithynia tentaculata*. *Malacological Review*, 17: 1-66.

[A detailed study on *Parafossarulus manchouricus* from Korea, Japan and Taiwan, *Gabbia misella* from Korea, and *Bithynia tentaculata* from the U.S.A., Germany and Portugal, which includes culture methods, egg-laying characteristics, some morphology, chromosome cytology, allozyme and SDS-PAGE electrophoresis, external parasites, and susceptibility to infection with *Clonorchis sinensis*.]

CHUNG, Pyung-Rim. 1985. Malacological studies on *Parafossarulus manchouricus* (Gastropoda: Prosobranchia) in Korea. *Korean Journal of Malacology*, 1(1): 24-50.

[Excerpts from Chung (1984), with repeated experiments on egg-laying and new information on natural infections of *Parafossarulus manchouricus* and *Gabbia misella* with trematode cercariae, and on water chemistry of bithyniid habitats in Korea.]

CHUNG, Pyung-Rim & BURCH, J.B. 1983. Glutamate-oxaloacetate transaminase variability in four populations of *Parafossarulus manchouricus* (Gastropoda: Prosobranchia). *Malacological Review*, 16(1/2): 89-90.

[GOT was found to be homozygous in three populations of *Parafossarulus manchouricus* (at Haman, Korea; Japan; Taiwan), but heterozygous in a fourth locality (Chongpyung, Korea). This heterozygosity possibly may relate to variability in this last population to infection with *Clonorchis sinensis*.]

CHUNG, Pyung-Rim & SOH, Chin-Thack. 1985. Korean Bithyniidae and malacological studies on freshwater snails. [Abstract; in Korean]. *Korean Journal of Malacology*, 1(1): 67.

[Abstract of lecture on research reported in Chung, 1984, 1985.]

CHYU, Il. 1969. Heterophyidae infection in Korea. Pp. 201-208. In: Harinasuta, Chamlong, 1969, *Proceedings of the Fourth Southeast Asian Seminar on Parasitology and Tropical Medicine, Schistosomiasis and other Snail-Transmitted Helminthiasis*, Southeast Asian Minister of Education Council, 420/6 Rajvithi Rd., Bangkok, Thailand. Pp. i-xviii, 1-315, 1 pl.

[*Semisulcospira libertina* is the most common molluscan host of *Metagonimus* as well as *Paragonimus* in Korea, and widely distributed across the whole country. The cercariae of *Metagonimus*, *Paragonimus* and *Centrocestus* were detected from *Semisulcospira libertina* collected from several localities, including Cheju, Kyong-Nam and Kyong-Gi provinces. Species of *Thiara* and *Hua*, known to be the first intermediate host of Heterophyidae, have not been reported from Korea. Cercariae of the canine *Heterophyes continus* were found in *Cerithidea cingulata* collected in brackish water.]

GREDLER, Vincenz. 1884. Zur Conchylien-Fauna China. VI. *Archiv für Naturgeschichte*, 50: 257-280.

[Contains the original description of *Bithynia misella* Gredler.]

HA, Young-Chil, HONG, Soon-Woo, KIM, Hoon-Soo, CHUNG, Yong-Ho, WON, Pyong-Oh, HA, Young-Ku, LEE, Kyung, CHOI, Hong-Kun & AHN, Tae-Seok. 1981. Review of the ecology of the Han River. Institute of Science, Seoul National University. Pp. 224-225.

[Includes 10 species of freshwater snails: *Cipangopaludina chinensis* (Gray), *Parafossarulus manchouricus* (Bourguignat), *Semisulcospira amurensis* (Gerstfeldt), *S. coreana* (Martens), *Koreanomelania* [*Hua* (*K.*)] *nodifila* (Martens), *K.* [*Koreoleptoxis*] *globus* (Martens), "*Physa*" [*Physella*] *acuta* Draparnaud, *Radix auricularia* (Linnaeus), *Austropeplea ollula* (Gould) and *Hippeutis cantori* Benson.]

HUBENDICK, Bengt. 1951. Recent Lymnaeidae. Their variation, morphology, taxonomy, nomenclature, and distribution. *Kungliga Svenska Vetenskapsakademiens Handlingar*, fjärde serien, 3(1): 1-223, pls.1-5.

[A general overview and bibliography of the Lymnaeidae.]

HUTTON, T. 1849. Notices of some land and fresh water shells occurring in Afghanistan. *Journal of the Asiatic Society*, Bengal, India, 18: 649-661.

[Contains the original description of *Planorbis* [*Gyraulus*] *convexiusculus* Hutton.]

INABA, Akihiko. 1969. Cytotaxonomic studies of lymnaeid snails. *Malacologia*, 7(2-3): 143-168.

[Recognized the lymnaeid species with n=16, 2n=32 chromosomes (including " '*L.*' *ollula* (= *viridis* ?)") as a special group and used the generic-group name *Austropeplea* to include them.]

KIL, Bong-Seop. 1976. Ecological studies on the fresh-water mollusks (shell fish) from Korea. Distribution and standing crops of the fresh-water Mollusca in the Jeonbuk Do, Korea. *Korean Journal of Limnology*, 9(1-2): 15-20.

[Nine species of mollusks were identified from 20 research stations along the Mankyung and Dongjin rivers. Only *Semisulcospira* (*S. bensoni* [*libertina*] and *S. coreana*) were found in the upper stream. *Semisulcospira, Unio, Cristaria, Corbicula*, etc., were found in the middle stream. *Corbicula* was the dominant species. Especially prevalent downstream were *Unio* and *Cristaria*.]

KIL, Bong-Seop. 1977. Ecological studies on the freshwater gastropods in Korea. - Distribution of *Semisulcospira forticosta* in the Taebaek Range. [In Korean, with English abstract]. *Korean Journal of Limnology*, 10(3/4): 29-35.

[This paper is the fourth report by the author on the Gastropoda of fresh waters in South Korea. This report was made after a survey and observations on more than 20 different areas in order to clarify the distribution of *Semisulcospira forticosta* in the country. Special attention was focused on the Taebaek range.

Semisulcospira forticosta inhabits the Korean peninsula east of the latitude of 128°. The species has a wide distribution in the Yeongseo district, but it has a more confined distribution in the Yeongdong district and is found only in Wangsan stream, Myeongju-Gun, Jusu stream, Bukpyong in Samcheok-Gun, Osip stream, Yeongdeog-Gun, etc.. Shapes of the shells of *S. forticosta* collected in the Han and Nagdong rivers and Yeongdong district vary greatly, but those collected in Yeondong and Yeongseo districts in the same latitude closely resemble each other. *Semisulcospira forticosta* in Myeongju and Jeongseon of Gangweon-Do province in Yeongdong and Yeongseo districts was originally the same as populations in other areas, but the variety presently found in the above areas seems to be due to geological isolation. The largest individual found, with shell measurements of 35.89 mm in length and 15.61 mm in width, is from Imgye, Jeongseon-Gun.]

KIM, Chong-Hwan, KIM, Nam-Man & LEE, Chan-Hyun. 1985. Distribution of *Bithynia misella* and *Stenothyra*. [Abstract; in Korean]. *Korean Journal of Malacology*, 1(1): 66.

[Record of the distribution of *Bithynia* [*Gabbia*] *misella* and *Stenothyra* in the Kum, Nak-Dong, Han and Young-San rivers. *Stenothyra japonica* (identified by Kuroda (1962)) was found in one of the four rivers, *S. glabra* was found in another, and in the other two rivers species similar to both stenothyrid species live together.]

KIM, Duk-Man. 1971. Ecological study of freshwater mollusks, no. 2. On the distribution and density of freshwater bivalves and snails in the Han River, Korea. [In Korean]. *Bulletin of Seoul Junior Normal College*, 4: 313-320.

KIM, Duk-Man. 1980. Studies on *Radix* (*Lymnaea*) *auricularia coreana* Martens. (I). On the shell morphologies. Institute of Science Education, Seoul Junior Normal College, 6: 17-26.

KIM, Duk-Man. 1984. Ecological studies on *Physa acuta* (Draparnaud). (I). Ecological observation on *Physa acuta*. [In Korean]. Institute of Science Education, Seoul Junior Normal College, 10: 43-50.

KIM, Duk-Man. 1985a. A review on the study of molluscan fauna in the Han River. [In Korean, with English abstract]. *Korean Journal of Malacology,* 1(1): 51-63.

[Eleven species of freshwater snails are listed for the Han River: *Cipangopaludina chinensis* (Gray), *Parafossarulus manchouricus* (Bourguignat), *Semisulcospira amurensis* (Gerstfeldt), *S. forticosta* (Martens), *S. coreana* (Martens), *Koreanomelania* [*Hua* (*K.*)] *nodifila* (Martens), "*K.*" [*Koreoleptoxis*] *globus* (Martens), "*Physa*" [*Physella*] *acuta* Draparnaud, *Radix auricularia* (Linnaeus), *Austropeplea ollula* (Gould), *Pettancylus* sp. Water pollution problems of the Han River are discussed.]

KIM, Duk-Man. 1985b. Ecological study of Korean "*Physa*" [*Physella*] *acuta* Draparnaud. [Abstract; in Korean]. *Korean Journal of Malacology,* 1(1): 66.

[Behavior, life history, conditions for laboratory culture, and effects of herbicides and pesticides on *Physella acuta.*]

KIM, Jae-Jin, CHANG, Jae-Kyung, CHUNG, Pyung-Rim & SOH, Chin-Thack. 1985. A study on the intermediate hosts of *Paragonimus westermani* in Bogil Islet, Chonra-Nam-Do, Korea. [In Korean]. *Korean Journal of Malacology,* 1(1): 19-23.

[Forty-four out of 182 snails were infected with trematode cercariae (*Metagonimus* sp., *Cercaria yoshidae, C. incerta* and *C. nipponensis.* Metacercarial incidence of *Paragonimus westermani* in crayfish was 65.4%.]

KNIGHT, J. Brookes, COX, L.R., KEEN, A. Myra, BATTEN, R.L., YOCHELSON, E.L. & ROBERTSON, Robert. 1960. "Systematic descriptions," pp. I169-I310. In: Moore, Raymond C., *Treatise on Invertebrate Paleontology,* Pt. I, Mollusca 1, pp. i-xxiii, I1-I351.

[This gives a good general taxonomic overview of fossil and Recent taxa, from classes down to genera.]

KOBAYASHI, Harujiro. 1911. The first intermediate host of *Clonorchis sinensis.* [In Japanese]. *Journal of Bacteriology,* 188: 389-392.

KOBAYASHI, Harujiro. 1918. The first intermediate host of *Paragonimus westermani.* [In Japanese]. *Chosen Medical Journal,* 21: 1-18.

KOBAYASHI, Harujiro. 1919. The first intermediate host of *Paragonimus westermani,* (the second report). [In Japanese]. *Chosen Medical Journal,* 27: 49-60.

KOBAYASHI, Harujiro. 1926. The first intermediate host of *Paragonimus westermani.* [In Japanese]. *Medical World of Japan,* 16(15): 7-9.

KOBAYASHI, Harujiro. 1927. Supplementary notes on *Paragonimus westermani.* [In Japanese]. *Chosen Journal of Natural History,* 5: 20-26.

KOBAYASHI, Harujiro. 1929. Relationship between parasitology and freshwater biology. [In Japanese]. *Medical World of Manchuria and Korea,* 95: 23-25.

KURODA, Tokubei. 1929. On Japanese melanians. [In Japanese]. *The Venus,* 1(5): 179-193, pls 4, 5.

[The author gives a brief nomenclatural and taxonomic history of the "melanian" snails of concern to malacology of Japan, discusses the nominal genera, and provides figures and a key for identification of the Japanese species. He includes a list of Korean melanian species (all under the genus *Semisulcospira*) [pp. 191-192] with bibliographic citations.]

KWON, Oh-Kil. 1982. A study on the freshwater molluscan fauna in Soyang Lake. *Research Bulletin, Kangweon National University,* Korea, 17: 89-92.

[Seven species of snails were found in the lake: *Semisulcospira coreana,* "*S.*" [*Koreoleptoxis*] *globus, S. gottschei,* "*S.*" [*Hua* (*Koreanomelania*)] *nodifila, Austropeplea ollula, Radix auricularia* and *Hippeutis cantori.*]

KWON, Oh-Kil. 1983. A study on egg deposition and developmental period of *Radix auricularia coreana* (Gastropoda: Lymnaeidae). *Research Bulletin, Kangweon National University,* Korea, 18: 133-135.

[Gives data on egg masses and hatching.]

KWON, Oh-Kil & CHO, Dong-Hyun, 1984. A list of mollusks in Han River. [In Korean]. Pp. 148-152. In: Cho, Kyu-Song, General environmental research on the Han River area. Han River Ecology Institute at Kangweon National University.

[The following gastropods are listed: *Cipangopaludina chinensis, Parafossarulus chinensis, P. manchouricus, Semisulcospira coreana,* "*S.*" [*Koreoleptoxis*] *globus, S. gottschei,* "*S.*" [*Hua* (*Koreanomelania*)] *nodifila, S. forticosta, Radix auricularia coreana, Austropoeplea* (and *Austroppeplea*) [= *Austropeplea*] *ollura* [= *ollula*], *Hippeutis cantori* and *Pettancylus nipponicus.*]

KWON, Oh-Kil, CHO, Dong-Hyun, PARK, Gap-Man & LEE, Jun-Sang. 1985. A study on a distribution of the freshwater snails and mussels in the North-South Han River. [In Korean, with English abstract]. *Korean Journal of Malacology*, 1(1): 1-4.

KWON, Oh-Kil & CHOI, Joon-Kil. 1982. The studies on the mollusks in the Lake Uiam (2). The studies of the fresh-water mollusks in the Lake Uiam and the swimming-out of pre-larva fish from mussels. *Korean Journal of Limnology*, 5(1/2): 39-50.

[Seven species of snails were found in the lake: *Cipangopaludina chinensis*, *"Semisulcospira"* [*Koreoleptoxis*] *globus*, *S. gottschei*, *Austropeplea ollula*, *Radix auricularia coreana*, *Hippeutis cantori* and *Pettancylus* sp.]

KWON, Oh-Kil & HABE, T. 1979. A list of non marine molluscan fauna of Korea. *Korean Journal of Freshwater Ecology*, 12(1/2): 25-33.

[Lists 103 species of land snails, 21 species of fresh- and brackishwater snails, and 17 species of bivalves. The aquatic mollusks have been derived from China.]

MARTENS, Eduard von. 1886. In Japan und Korea gesammelten Land- und Süsswasser-Mollusken. *Sitzungs-Bericht der Gesellschaft naturforschender Freunde zu Berlin*, (5): 76-80.

[Original descriptions of *"Melania"* [*Semisulcospira*] *gottschei*, *"M." forticosta*, *"M." coreana*, *"M."* [*Hua* (*Koreanomelania*)] *nodifila*, *"M."* [*Koreoleptoxis*] *globus* and *"Limnaea"* [*Radix*] *auricularia* var. *coreana*.]

MARTENS, Eduard von. 1894. Neue Süsswasser-Conchylien aus Korea. *Sitzungs-Bericht der Gesellschaft naturforschender Freunde zu Berlin*, (8): 207-217.

[Original descriptions of *"Melania"* [*Semisulcospira*] *nodiperda*, *"M." nodiperda* var. *uniserialis*, *"M." nodiperda* var. *connectens*, *"M." nodiperda* var. *pertinax*, *"M." graniperda*, *"M." quinaria*, *"M." tegulata*, *"M." multicincta*, *"M." succincta*, *"M." extensa*, *"M." paucicincta* and *"M." ovulum*.]

MARTENS, Eduard von. 1905. Koreanische Süsswasser-Mollusken. *Zoologischen Jahrbüchern*, 1905, suppl. 8, pp. 23-70, pls. 1-3.

[This is a major reference on Korean freshwater snails. Snail species dealt with, in order, are *"Limnaea"* [*Radix*] *auricularia* var. *coreana* Martens, *"L."* [*Radix*] cf. *ovata* Draparnaud], *"Vivipara"* [*Cipangopaludina*] *chinensis* (Gray), *"Melania"* [*Semisulcospira*] *gottschei* Martens, "M." [S.] succincta Martens, *"M."* [*S.*] *multisculpta* Martens [n.sp.], *"M."* [*S.*] *forticosta* Martens, *"M."* [*S.*] *tegulata* Martens, *"M."* [*S.*] *nodiperda* Martens, *"M."* [*S.*] *nodiperda* var. *quinaria* Martens, *"M."* [*S.*] *nodiperda* var. *pertinax* Martens, *"M."* [*S.*]

nodiperda var. *connectens* Martens, "*M.*" [*Hua* (*Koreanomelania*)] *nodifila* Martens, "*M.*" [*S.*] *graniperda* Martens, "*M.*" [*S.*] *coreana* Martens, "*M.*" [*S.*] *libertina* Gould, "*M.*" [*S.*] *libertina* var. *ambidextra* Martens, "*M.*" [*S.*] *libertina sulcosa*, "*M.*" [*S.*] *multicincta* Martens, "*M.*" [*S.*] *extensa* Martens, "*M.*" [*S.*] *paucicincta* Martens, "*M.*" [*S.*] *ovulum* Martens and "*M.*" [*Koreoleptoxis*] *globus* Martens. All species and varieties are figured, except for *Radix* cf. *ovata*, *Cipangopaludina chinensis*, *Semisulcospira libertina* var. *ambidextra* and *S. libertina* var. *sulcosa*.]

MEIER-BROOK, Claus. 1983. Taxonomic studies on *Gyraulus* (Gastropoda: Planorbidae). *Malacologia*, 24(1-2): 1-113.

[A study of Eurasian *Gyraulus*, including *G. convexiusculus* (Hutton), *G. chinensis* (Dunker), *G. spirillus* (Gould), etc.]

MEIER-BROOK, Claus & KIM, Chong Hwan. 1977. Notes on ciliary feeding in two Korean *Bithynia* species. *Malacologia*, 16(1): 159-163.

[The mechanism of filter feeding in *Parafossarulus manchouricus* and *Gabbia misella* is described. The snails make "food sausages" out of mucus and flagellates. The food particles are caught in a mucous net which extends over the full length of the mantle cavity. From time to time the net breaks off and is expelled from the mantle cavity in sausage-shaped pieces, which are eaten by the snail. These bithyniid snails can feed exclusively on these "food sausages."]

MIYANAGA, Muneo. 1938. On the *Semisulcospira* spp. in Korea. [In Japanese]. *Chosen Medical Journal*, 28: 1752.

[Snails of the genus *Semisulcospira* are intermediate hosts of trematodes. Martens (1986-1905) reported 15 species and three subspecies. Miyanaga believed that these nominal species are more than actually occur, geographical variation having not been taken into account when many of them were named. He thinks there are only six species and several subspecies. *Semisulcospira* in Korea had two ways of reaching the country: (1) from Chinese *canullata* to Manju and Korea to Japan (*S. niponica*, *S. multigranosa and S. nakasakae*). Most Korean *Semisulcospira* belong to this group. The other way (2) is related to Japanese *S. libertina*. Some of the populations in southern Korea belong to *S. libertina*. *Semisulcospira* species are distributed in all areas, except for Hambuk and Hamnam. *Semisulcospira libertina* and *S. forticosta* are distributed in southern Korea; *S. tegulata coreana* is distributed in the middle area of southern Korea; *S. gottschei* and *S. multicincta* are distributed in the middle and western areas; *S. nodiperda* and "*S.*" [*Hua* (*Koreanomelania*)] *nodifila* occur in the middle area. *Semisulcospira paucicincta*'s distribution is also listed.]

MIYANAGA, Muneo. 1942. Kawanina snails of the genus *Semisulcospira* from Korea. [In Japanese]. *Chosen Hakubutsu Zasshi* [Korean Journal of Biological Science], 9(36): 114-130.

[The author describes the characteristics and gives a systematic list of species of *Semisulcospira*. He decided that the Korean "melaniid" snails belong to only one genus (*Semisulcospira*), with two species and three subspecies. Reviewed are the publications of Pfeiffer (1850a, 1850b; both in the *Proceedings of the Zoological Society*, London) [on land snails] and Bequaert (1928; *American Journal of Tropical Medicine*, 8) [on mollusks of medical and veterinary importance.]]

MORRISON, J.P.E. 1949. World relations of the melanians. *American Malacological Union News Bulletin and Annual Report for 1948*, (15): 13-14.

[Abstract. Includes *"Oxytrema"* [*Hua* (*Koreanomelania*)] and *Semisulcospira* from Korea.]

MORRISON, J.P.E. 1954. The relationships of Old and New World melanians. *Proceedings of the United States National Museum*, 103(3325): 357-394.

[Includes *"Oxytrema"* [*Hua* (*Koreanomelania*)] *nodifila* Martens, *Semisulcospira gottschei* Martens, *S. nodiperda* Martens and *S. graniperda* Martens.]

OMORI, Noburu. 1935a. On the *Semisulcospira* spp. in Korea. [In Japanese]. *Chosen Medical Journal*, 25: 1624.

[*Semisulcospira* species are well known as the molluscan intermediate hosts of diastoma hepaticum. Japanese *Semisulcospira* have been divided into two genera, 17 species, eight subspecies and nine unnamed species. In the past, species of *Semisulcospira* were classified in five groups, *Striatella, Plotia, Terebia, Sermyla* and *Semisulcospira*, but currently it has been confirmed that there are only two genera, *Melanoides* and *Semisulcospira* (although some scientists claim there is only one genus and one subspecies). Korean species belong to one genus, *Semisulcospira*. Martens (1886-1905) reported 18 species. Generally these can be reduced to six species. They are distributed in all areas except Hambuk, Hamnam and the mid-northern part of Korea. *Semisulcospira libertina* and *S. forticosta* in the southern part, *S. gottschei* and *"multicincincta"* [*multicincta*] in the middle and western parts, *S. nodiperda* and *S. graniperda* in all areas, and *S. "paucincta"* [*paucicincta*] in Pyungbuk.]

OMORI, Noburu. 1935b. Medical malacology (1). [In Japanese]. *Medical World of Manchuria and Korea*, 185: 29-52.

[Introduction to trematodes of mollusks, the history of the discovery of the intermediate hosts, structure and taxonomy of human and veterinary parasites, molluscan intermediate hosts, and prevention from infection.]

OMORI, Noburu. 1936a. Medical malacology (2). [In Japanese]. *Medical World of Manchuria and Korea*, 186: 14-20.

[Describes general features and taxonomy of mollusks.]

OMORI, Noburu. 1936b. Medical malacology (3). [In Japanese]. *Medical World of Manchuria and Korea,* 187: 19-26.

[Describes more recent information on and taxonomy of mollusks.]

OMORI, Noburu. 1936c. Medical malacology (4). [In Japanese]. *Medical World of Manchuria and Korea,* 189: 31-40.

[Lists mollusks which are intermediate hosts of human and veterinary parasites.]

OMORI, Noburu. 1936d. Medical malacology (5). [In Japanese]. *Medical World of Manchuria and Korea,* 190: 1-16.

[Describes mollusks important as intermediate hosts of trematodes, and a method of prevention.]

OMORI, Noburu. 1937. Medical malacology (6). [In Japanese]. *Medical World of Manchuria and Korea,* 191: 19-31.

[Bibliography related to medical malacology in Manchuria and Korea, and in foreign countries.]

PACE, Gary L. 1973. The freshwater snails of Taiwan (Formosa). *Malacological Review,* suppl. 1, pp. i, 1-118.

[Although this publication is on the freshwater snails of Taiwan, the author deals with the taxonomy, distribution, parasite mediation, etc., of various species of snails whose distributions include Korea (*Assiminea lutea* Adams, *Austropeplea ollula* (Gould) [? senior synonym of *Austropeplea pervia* (Martens)], *Cipangopaludina chinensis* (Gray), *Clithon retropictus* (Martens), *Clithon sowerbianus* (Récluz), *Gabbia misella* (Gredler), *Hippeutis (Helicorbis) umbilicalis* (Benson) [and *cantori* Benson as a subspecies], *Parafossarulus manchouricus* (Bourguignat), *Segmentina (Polypylis) hemisphaerula* (Benson) and *Semisulcospira libertina* (Gould).]

PILSBRY, Henry A. & BEQUAERT, J. 1927. The aquatic mollusks of the Belgian Congo, with a geographical and ecological account of Congo malacology. *Bulletin of the American Museum of Natural History,* 53(2): 69-602, pls. 10-77.

[Although on an African fauna, this is a major taxonomic and nomenclatural reference for freshwater mollusks. For example, it discusses the advisability of using *Fossaria* Westerlund instead of *Galba* Schrank (see Supplemental Note 16) for the small group of lymnaeid snails.]

RÉCLUZ, C.A. 1842. Descriptions of new species of nerites, collected by Mr. Cuming in the Philippine Islands. *Proceedings of the Zoological Society of London,* (10): 168-176.

[Contains the original description of "*Nerita* (*Neritina*)" *sowerbiana*.]

SEO, Byong-Seol. 1969. Paragonimiasis in Korea. Pp. 281-284. In: Harinasuta, Chamlong, 1969, *Proceedings of the Fourth Southeast Asian Seminar on Parasitology and Tropical Medicine, Schistosomiasis and other Snail-Transmitted Helminthiasis,* Southeast Asian Minister of Education Council, 420/6 Rajvithi Rd., Bangkok, Thailand. Pp. i-xviii, 1-315, 1 pl.

[More than six species of *Semisulcospira* ("*Melania*") were collected by Kobayashi in Korea (*S. libertina, S. extensa, S. paucicincta, S. gotschei* [*sic*] *S. nodiperda, S. multicincta,* etc.). These snails are widely distributed along the tributaries of rivers all over the peninsula. *Semisulcospira libertina* and *S. extensa* are commonly found in the southern part of Korea in particular, including Cheju Island. Some of the above species and their varieties were implicated by Kobayashi as intermediate hosts of *Paragonimus westermani,* especially *S. libertina* (varities *extensa* and *multicincta*). However, the validity of these species is still open to question, and therefore a complete review of classification and a revision of nomenclature of the snail hosts is needed.]

SHIBA, Noboru. 1933. Studies on the first intermediate host of *Clonorchis sinensis* in Korea. [Abstract; In Japanese]. *Chosen Medical Journal,* 23: 1546-1547.

SHIBA, Noboru. 1934a. Catalogue of the Mollusca of Chosen (Corea). [In Japanese]. *Chosen Journal of Natural History,* 18: 6-31.

[The author reviews the history of Korean malacology. There are not many publications on Korean mollusks. In 1850, Pfeiffer [1849-1868] and Reinhardt [1877] reported several species [of land snails]. But previously, Adams had travelled to East Asia with the ship Samarang and in 1850 many of the mollusks collected were described in "The zoology of the voyage of H.M.S. Samarang". The mollusk part was by Dr. Reeve. Then in 1860, as reported in a paper "Travels of a naturalist in Japan and Manchuria," Adams travelled to East Asia (which included Korea) on the ship H.M.S. Acteon, and collected in the area of Port Hamilton and Dagelet Island. But, it is not sure just which species were collected. Dr. Carl Gottsche came to Korea to investigate geology, and collected some mollusks, which he asked Carl Eduard von Martens to identify and classify. This was published by Martens in an article entitled "Über einige von Dr. Gottsche in Japan and Korea gesammelten Land- und Süsswasser-Mollusken." In 1887, Adams collected more mollusks, of which the land snails were classified by Dr. Otto von Moellendorf [1884, 1887, 1900] and the freshwater mollusks by Martens and reported in 1905. Several subsequent papers by Japanese authors are listed, but these do not include freshwater snails.

The following freshwater snails are listed: *"Viviparus (Cipangopaludina)" chinensis malleatus, "Bulimus"* [= *Bithynia*] *(Gabbia) "kiusiuensis"* [= *misella*], *"B. (Hydrobioides, section Parafossarulus) striatulus"* [= *Parafossarulus manchouricus*], *"Paludinella"* [*Assiminea*] *japonicus, "Melanoides" (Semisulcospira) libertina, "M.(S.)" gottschei, "M.(S.)" succincta, "M.(S.)" multisculpta, "M.(S.)" forticosta, "M.(S.)" tegulata, "M.(S.)" nodiperda, "M.(S.)" nodiperda quinaria, "M.(S.)" nodiperda pertinax, "M.(S.)" nodiperda connectens, "M.(S.)"* [*Koreanomelania*] *nodifila, "M.(S.)" graniperda, "M.(S.)" coreana, "M.(S.)" multicincta, "M.(S.)" extensa, "M.(S.)" paucicincta, "M.(S.)" ovulum, "M.(S.)"* [*Koreoleptoxis*] *globus, "Lymnaea (Radix)" coreana, "L. (R.)" ovutus, "L.* (Galba)" [*Austropeplea*] *pervia* and *Gyraulus "compressus"* [*convexiusculus*].]

SHIBA, Noboru. 1934b. A review of articles on mollusks occurring in Korean. [In Japanese]. *Chosen Journal of Natural History,* (18): 51-66.

[Three hundred species of mollusks have been found in Korea. There are many references related to mollusks in the areas of limnology, geology and medicine. This list is up to date to March 1933. There probably will be additional mollusks reported in the future.]

SHIBA, Noboru. 1934c. Geographical distribution and species of the genus *Limnaea* in Korea. [In Japanese]. *Chosen Medical Journal,* 24: 1131.

[Lymnaeid snails are known to be intermediate hosts of liver flukes. Three species and their geographic distributions in Korea are reported. These are *"Lymnaea (Galba)"* [*Austropeplea*] *pervia, "L."* (*Radix*) *coreana* and *"L."* (*Radix*) *ovata*.]

SHIBA, Noboru. 1934d On the genus *Bulimus* from Chosen (Korea) and Manchuria. [In Japanese]. *The Venus,* 4(4): 247-257.

[Review of the Bithyniidae of Korea and Manchuria: *"Bulimus (Parafossarulus) striatulus* Benson and *B. striatulus japonicus* Pilsbry" [*Parafossarulus manchouricus* (Bourguignat)], and *"B. (Gabbia) kiusiuensis* (Hirase)" [*Gabbia misella* (Gredler).]

SHIBA, Noboru. 1935. The distribution of *Viviparus (Cipangopaludina) chinensis malleatus* (Reeve) in Chosen (Korea). [In Japanese]. *The Venus,* 5(1): 17-22.

SOH, Chin-Thack. 1969. Clonorchiasis in Korea. Pp. 219-229. In: Harinasuta, Chamlong, 1969, *Proceedings of the Fourth Southeast Asian Seminar on Parasitology and Tropical Medicine, Schistosomiasis and other Snail-Transmitted Helminthiasis,* Southeast Asian Minister of Education Council, 420/6 Rajvithi Rd., Bangkok, Thailand. Pp. i-xviii, 1-315, 1 pl.

[*Parafossarulus striatulus* var. *japonicus* (Pilsbry) [*P. manchouricus*] is the molluscan host of *Clonorchis sinensis* in Korea, and is widely distributed in the plains areas along the rivers of southern Korea. The related *Bulimus kiusiuensis* [*Gabbia misella*], although not yet proven to be an intermediate host of *Clonorchis sinensis*, was collected from only two restricted localities: Kyomwipo in northern Korea and Kongju in southern Korea.]

YONGE, C.M. 1960. General characteristics of Mollusca. Pp. I3-I36. In: Moore, Raymond C. (ed.), *Treatise on invertebrate paleontology*. Pt. I, Mollusca 1, pp. i-xxiii, I1-I351.

[Discusses general features of mollusks, including evolution and higher classification.]

YOO, Jong-Saeng. 1969. The distribution and standing crops of freshwater mollusks in the Han River system. *Bulletin of the High School Attached to Seoul National University Normal College*, 12: 79-97.

[During the period October 1967 through September 1969, the author selected 23 research stations on the Han River (along midstream and downstream from Seoul) to measure the standing crop of freshwater Mollusca, which comprise the major portion of the benthos. Sixteen species of mollusks were collected. Their ecological distributions showed three areas, a downstream *Corbicula* area (research stations 1-6), a midstream *Unio* area (stations 6-12) and an upstream *Semisulcospira* area (stations 12-13). No other benthos was found in the *Corbicula* area. The *Unio* area produced an abundance of other bivalves (*Lamprotula, Cristaria, Anodonta, Lanceolaria*, etc.), and is the center of the mollusk-producing areas of the Han River. The *Semisulcospira* area had only a scattered distribution of bivalves. Measures of the standing crop and ratio of meat to shell for the various mollusks and for various localities are given. The *Semisulcospira* area had three species of this melanioid group, *S. gottschei* belonging to the *S. libertina* group, and "*S.*" [*Hua* (*Koreanomelania*)] *nodifila* and "*S.*" [*Koreoleptoxis*] *globus*, which are peculiar to the middle part of Korea.]

YOO, Jong-Saeng. 1976. *Korean shells in color.* Il Ji Sa Publishing Co., Seoul, Korea. Pp. 1-196, pls. 1-36.

[Includes descriptions and figures of 14 species and two subspecies of Korean freshwater snails: *Clithon sowerbianus, Semisulcospira bensoni* [*libertina*], *S. coreana*, "*S.*" [*Koreoleptoxis*] *nodifila globus, S. gottschei*, "*S.*" [*Hua* (*Koreanomelania*)] *nodifila, S. forticosta, S. forticosta tegulata, Cipangopaludina chinensis malleata, C. japonica, Parafossarulus manchouricus, Assiminea japonica*, "*Lymnaea*" [*Radix*] *auricularia coreana*, "*Bakerilymnaea*" [*Austropeplea*] "*viridis*" [? = *pervia* or *ollula*], "*Ferrissia*" [*Pettancylus*] *nipponica*, and *Gyraulus hiemantium*.]

YOO, Jongsong [Jong-Saeng] & HABE, Tadashige. 1962. Notes on two species of freshwater molluscs from Korea. [In Japanese, with English summary]. *The Venus*, 22(1): 79-81.

[Notes on *Semisulcospira amurensis gottschei* (Martens) and the bivalve *Solenaia triangularis* (Heude).]

Walkerana, 1987, 2(8): 233-291

A REVIEW OF THE CLASSIFICATION, DISTRIBUTION AND HABITATS OF THE FRESHWATER GASTROPODS OF THE NORTH AMERICAN GREAT LAKES†

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INTRODUCTION

Freshwater gastropods have been recorded from the North American Great Lakes since early in the 19th century. Thomas Say (1817), in the first article on American mollusks by an American author, described (from shells brought to him by the French naturalist C.A. Lesueur) *Planorbis* [*Planorbella*] *trivolvis* from "French Creek, near Lake Erie" and "*Lymnaea virginica*" [*Elimia virginica* (Menke)] "from the Lakes [Great Lakes] and their vicinity."[1§] (The *Elimia* species in the Great Lakes received its own special name from Menke in 1830, "*Melania*" [*Elimia*] *livescens*, with the specific locality given as Lake Erie.) In 1821, Say listed two additional species from the Great Lakes, "*Lymneus reflexus*" [a form of *Stagnicola elodes* (Say)] ("inhabits Lakes Erie and Superior") and *L.* [*Lymnaea stagnalis* ssp.] *appressus* ("inhabits Lake Superior"). Say listed a third species for the Great Lakes ("Lake Huron") in 1834, *Planorbis bicarinatus* [*Helisoma anceps* Menke].

Other authors describing or listing snail species from one or more of the Great Lakes during this early period were Valenciennes (1827), Rafinesque (1831), Cooper (1834), Rossmässler (1835), J. de C. Sowerby (1836), Beck (1837, 1838a,b), Haldeman (1840, 1841, 1842), De Kay (1843), Jackson (1844) and Gould (1847, 1848, 1850a,b).

†Contribution from The University of Michigan Biological Station.
§Superscript numbers throughout the text refer to corresponding comments under Supplemental Notes at the end of the text (pp. 276-281).

During the second half of the 19th century, snails occurring in the Great Lakes were recorded in the publications of Reeve (1860), Miles (1861), Küster (1862), Tryon (1865b, 1870-1871, 1873), Currier (1868), Smith & Verrill (1871), G.B. Sowerby (1873), Smith (1874a,b), Clessin (1878-1886), Pilsbry (1890, 1898) and Walker (1894, 1895, 1896).

During the first half of the 20th century, the number of publications dealing with snails found in the Great Lakes increased, and the fauna was becoming better known. These included the works of Crandall (1901), Walker (1901, 1906, 1908, 1909a,b, 1915, 1918a,b), F.C. Baker (1901, 1902, 1905, 1906, 1911, 1926, 1928a,b, 1930, 1932, 1936, 1945), Crandall (1901), Dall (1905), Walker & Ruthven (1906), Letson (1909), H.B. Baker (1911), Goodrich (1911, 1920, 1932), Allen (1911), Latchford, 1914, A.D. Robertson (1915), Vanatta (1915), Winslow (1917), Adamstone (1924), Krecker (1924), Wiebe (1926), Ahlstrom (1930), Brooks (1931), Kindle (1934), A. Mozley (1938), Berry (1943), Herrington (1947), Morrison (1947) and C.L. Robertson & Blakeslee (1948). Some of these publications were faunistic surveys, and some were mainly taxonomic in nature.

The Great Lakes have received much attention during the second half of the 20th century, especially in studies relating to Great Lakes limnology, ecology and distribution of benthic organisms, and pollution. However, many of these later papers have made little contribution to Great Lakes malacology. These more recent references are not enumerated here, but those that include gastropods can be found in the Literature Cited section (pp. 282-291).

The account which follows is an up-to-date taxonomic list of gastropods occurring in the waters of the Great Lakes (pp. 235-275), with those literature citations which we consider generally reliable on these snails' distributions among the Lakes, information on the snails' habitats, and notes supplementing the text (pp. 276-281). Some taxonomic problems still need to be resolved, and much more information is needed on the snails' ecology, ecological physiology, and responses to human-modified environments. But more detail on these aspects must await further studies.

LIST OF SPECIES, WITH DISTRIBUTIONS AND HABITATS

Class Gastropoda[2]

Subclass Prosobranchia

Family VALVATIDAE[3]

Valvata bicarinata **Lea**
(Fig. 1)

Great Lakes Distribution:
Lake Michigan (Walker, 1896; F.C. Baker, 1902; Walker, 1906: var. *connectans* n.v.; La Rocque, 1953: *bicarinata* and *connectans*)
Lake Ontario (Walker, 1906: var. *connectans* n.v.; La Rocque, 1953: *connectans*)
General Distribution: Of discontinuous distribution: New Jersey and Pennsylvania; and Iowa, Illinois, Tennessee, Alabama, Georgia and North Carolina (Heard, 1982).

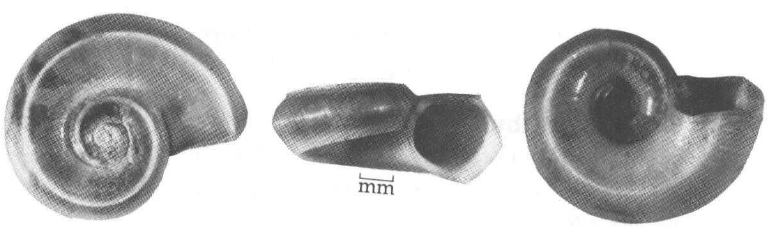


FIG. 1. *Valvata bicarinata.*

Habitat: *Valvata bicarinata* in Wisconsin "appears to be a river form and not found in lakes" (F.C. Baker, 1928b).

Valvata lewisi **Currier**
(Fig. 2)

Great Lakes Distribution:
Lake Superior (Dall, 1905; Walker & Ruthven, 1906; Thomas, 1966)

Lake Michigan (Walker, 1895: *striata* Lewis; F.C. Baker, 1928b: *helicoidea* Dall)
Lake Erie (Krieger, 1984)

General Distribution: Southern Canada from Quebec west to British Columbia, and northern U.S.A. from New York west to Minnesota (Heard, 1982).

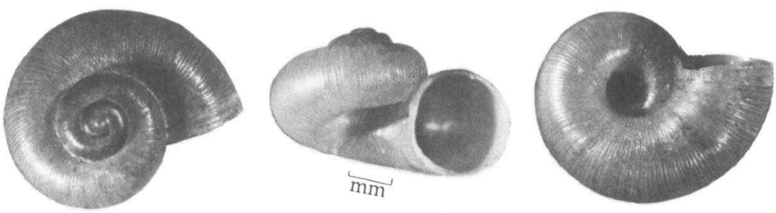


FIG. 2. *Valvata lewisi.*

Habitat: On vegetation in shallow water (F.C. Baker, 1928b). Clarke (1973, for "*Valvata sincera helicoidea*") recorded a variety of habitats (large and small lakes, permanent ponds and rivers of various sizes and at depths of 1.5 - 15 meters), but always associated with aquatic vegetation.

Valvata perdepressa Walker[4]
(Fig. 3)

Great Lakes Distribution:
Lake Michigan (Walker, 1906; F.C. Baker, 1930[5]: *walkeri* F.C. Baker; La Rocque, 1953: *perdepressa* and *walkeri*; Heard, 1982)
Lake Huron (Heard, 1982)

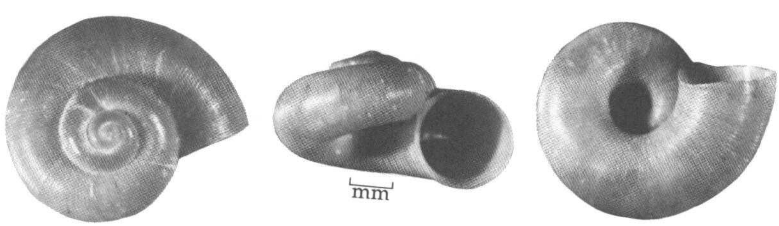


FIG. 3. *Valvata perdepressa.*

Lake Erie (Walker, 1906; La Rocque, 1953: *perdepressa* and *walkeri*; Clarke, 1981; Heard, 1982)

Lake Ontario (Walker, 1906; La Rocque, 1953; Heard, 1982)

General Distribution: Lakes Michigan, Huron, Erie and Ontario (Heard, 1982).

Habitat: "A lake form" (Baker, 1928b). "Has been found only in beach drift on the shores of large and medium-sized lakes. Its detailed ecology and life history are unknown" (Clarke, 1981).

**Valvata piscinalis* (Müller)[6]

(Fig. 4)

Great Lakes Distribution:

Lake Erie (Latchford, 1914; La Rocque, 1953; Robertson & Blakeslee, 1948; Krieger, 1984)

Lake Ontario (Robertson & Blakeslee, 1948; La Rocque, 1953; Clarke, 1981)

General Distribution: Eurasian. Introduced by man into the lower Great Lakes and several of their tributaries.

Habitat: Lakes and slow-moving rivers (Clarke, 1981).

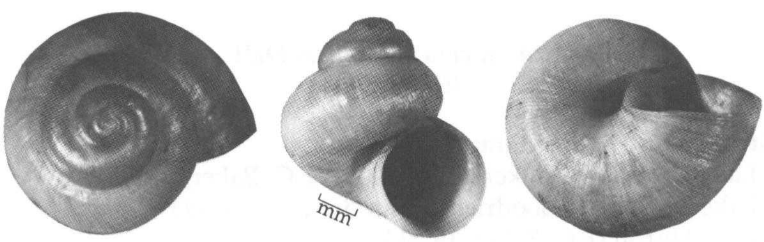


FIG. 4. *Valvata piscinalis.*

Valvata sincera sincera Say

(Fig. 5)

Great Lakes Distribution:

Lake Superior (Smith & Verrill, 1871; Smith, 1874a, 1874b; F.C. Baker, 1902, 1928b; Thomas, 1966)

Lake Michigan (Walker, 1895, 1896, 1906; F.C. Baker, 1928b; Lauritsen & White, 1981)
Lake Huron (Robertson, 1915)
Lake Ontario (Adamstone, 1924)

General Distribution: Maine west to Alberta, and south to South Dakota and Indiana (Heard, 1982).

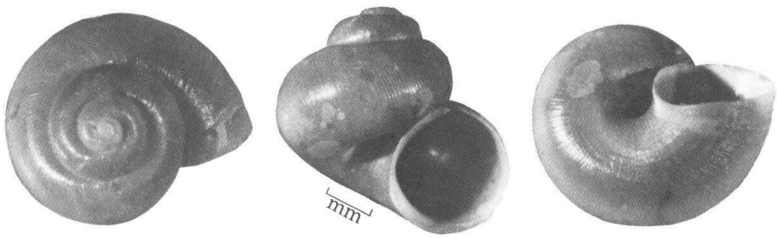


FIG. 5. *Valvata sincera sincera.*

Habitat: Found in lakes, and in Lake Superior and Lake Michigan in rather deep water (F.C. Baker, 1928b). Clarke (1973) found *Valvata sincera sincera* in large and small lakes, in a permanent pond, and in large and small rivers, always associated with aquatic vegetation, and nearly always associated with mud substrates.

Valvata sincera nylanderi Dall
(Fig. 6)

Great Lakes Distribution:
Lake Superior (Walker, 1906, 1909a; F.C. Baker, 1928b)
Lake Michigan (Goodrich & van der Schalie, 1939)
Lake Huron (F.C. Baker, 1928b)

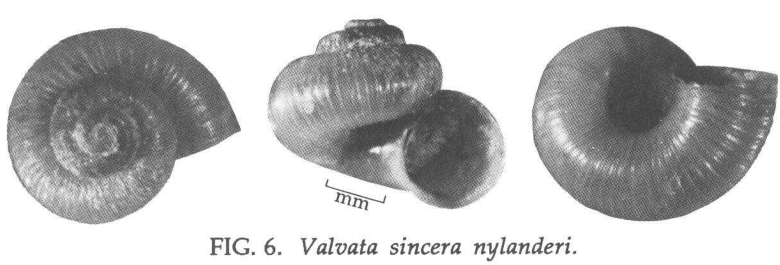


FIG. 6. *Valvata sincera nylanderi.*

General Distribution: Quebec and Maine west to Ontario and Minnesota (Heard, 1982).

Habitat: Bulrush zone (Walker, 1909a); on drift log on a sand bottom in shallow water (F.C. Baker, 1928b).

Valvata tricarinata (Say)[7]
(Fig. 7)

Great Lakes Distribution:

Lake Superior (J. de C. Sowerby, 1836; Smith, 1874a,b; Walker, 1909a; F.C. Baker, 1928b: *simplex* Gould; La Rocque, 1953: *simplex*; Thomas, 1966)

Lake Michigan (Walker, 1895, 1896; F.C. Baker, 1902, 1930)

Lake Huron (Vanatta, 1915: *infracarinata* Vanatta; Robertson, 1915)

Lake Erie (Ahlstrom, 1930; Shelford & Boesel, 1942; Krieger, 1984)

Lake Ontario (Adamstone, 1924; Robertson & Blakeslee, 1948: *perconfusa* Walker)

General Distribution: Quebec and New Brunswick west to Alberta, and south to Wyoming, Arkansas and Virginia (Heard, 1982).

FIG. 7. *Valvata tricarinata.*

Habitat: Clarke (1973) found *Valvata tricarinata* in large and small lakes, in permanent ponds, and in large and small rivers, nearly always associated with aquatic vegetation, and associated with bottom sediments of all types. "Occurs among vegetation and only in perennial-water habitats, namely lakes, rivers, streams and muskeg pools" (Clarke, 1981).

Family VIVIPARIDAE

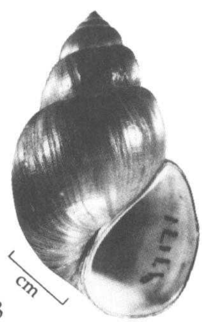
Campeloma crassula **Rafinesque**[8]

(Fig. 8)

Great Lakes Distribution:
Lake Superior[9] (Thomas, 1966: *rufum* Haldeman)
Lake Michigan (F.C. Baker, 1930: *rufum*)
Lake Huron (Walker, 1915: beach drift: *rufum*)

General Distribution: Midwestern United States in the Great Lakes-St. Lawrence and Mississippi drainages as far west as Iowa and south to Tennessee (Burch & Tottenham, 1980).

Habitat: Buried in sand or mud in rivers and lakes.



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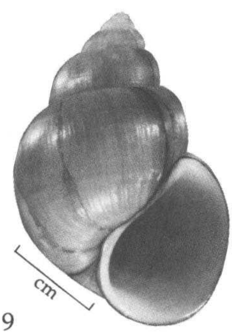

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FIG. 8. *Campeloma crassula.* FIG. 9. *Campeloma decisum.*

Campeloma decisum **(Say)**

(Fig. 9)

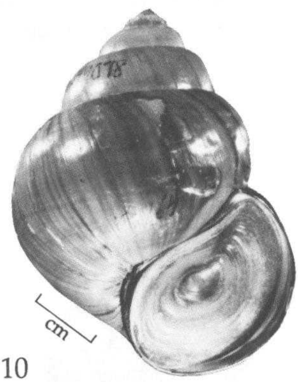
Great Lakes Distribution:
Lake Superior (Dall, 1905)
Lake Michigan (Haldeman, 1840; Walker, 1895, 1896)
Lake Huron (Robertson, 1915)
Lake Erie (Letson, 1909; Ahlstrom, 1930; Robertson & Blakeslee, 1948; Wolfert & Hiltunen, 1968)
Lake Ontario (Robertson & Blakeslee, 1948)

General Distribution: Eastern North America, from Nova Scotia, southern Ontario and southern Manitoba south to Texas, Louisiana, Mississippi, Alabama, northern Georgia and Virginia (Burch & Tottenham, 1980).

Habitat: Buried in sand, mud or clay in lakes and slow or moderately flowing streams.

***Cipangopaludina chinensis malleata (Reeve)[10]**
(Fig. 10)

Great Lakes Distribution:
Lake Erie (Clarke, 1981)
General Distribution: Asian. Widely introduced in the United States (some reports may be confused with *Cipangopaludina chinensis malleata*). Clench & Fuller (1965) list localities in Massachusetts, Michigan and Oklahoma.
Habitat: "Muddy ponds and lakes, backwaters, sloughs, canals, and slow-moving rivers" (Clarke, 1981).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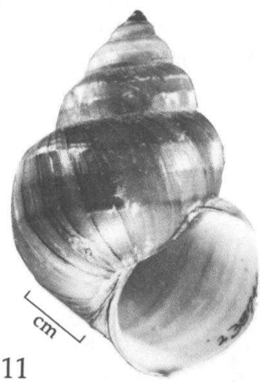
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FIG. 10. *Cipangopaludina chinensis malleata.* FIG. 11. *C. japonica.*

***Cipangopaludina japonica (Martens)**
(Fig. 11)

Great Lakes Distribution:
Lake Erie (Wolfert & Hiltunen, 1968)
General Distribution: Asian. Widely introduced in the United States. Clench & Fuller (1965) list localities in Arizona, California, Colorado, Delaware, Florida, Indiana, Maine, Massachusetts, Michigan, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, Utah, Vermont and Washington.

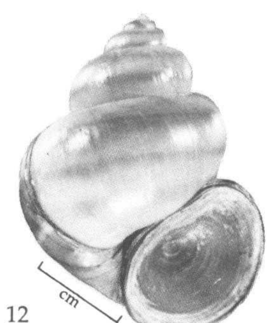
Habitat: Similar to *Cipangopaludina chinensis malleata.*

Lioplax sulculosa (Menke)
(Fig. 12)

Great Lakes Distribution:
Lake Michigan (Clench & Turner, 1955)

General Distribution: Mississippi drainage. Northwestern Wisconsin and eastern Minnesota south to northwestern Arkansas and east to southwestern Ohio and northern Kentucky (Clench & Turner, 1955; Vail, 1979); Paint Rock River of the Tennessee River system, near Paint Rock, Jackson County, Alabama (Clench, 1962).

Habitat: "The best habitat is on a mud bottom in about a meter of water" in rivers and lakes; also found on mud, sand or gravel bottoms (Baker, 1928b, *Lioplax subcarinata wisconsinensis* F.C. Baker).



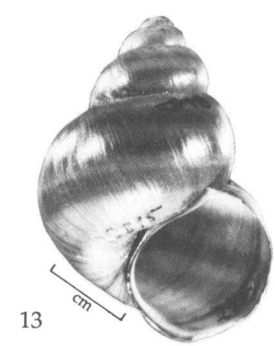


FIG. 12. *Lioplax sulcosa.* FIG. 13. *Viviparus georgianus.*

**Viviparus georgianus* (Lea)[11]
(Fig. 13)

Great Lakes Distribution:
Lake Erie (Robertson & Blakeslee, 1948: *contectoides* W.G. Binney; Clench, 1962)[12]

General Distribution: Southcentral Florida, Georgia, Alabama and north, mainly in the Mississippi River system, to Illinois and northwestern Indiana; it has invaded Ohio, Michigan, Wisconsin, Virginia, Pennsylvania, New York, New Jersey, New England and Quebec since 1967 (Clench, 1962; Clench & Fuller, 1965).

Habitat: Found in shallow waters on mud bottoms in both lakes and rivers (F.C. Baker, 1928b).

Family BYTHINIIDAE

(*)*Bythinia tentaculata* (Linnaeus)[13]

(Fig. 14)

Great Lakes Distribution:

Lake Michigan (F.C. Baker, 1902, 1928b; Walker, 1918a,b; Berry, 1943)

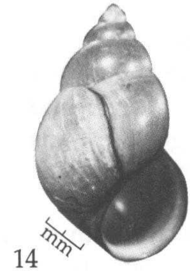
Lake Huron (Walker, 1918a; Berry, 1943)

Lake Erie (Goodrich, 1911[14]; Walker, 1918a; Ahlstrom, 1930; Berry, 1943; Robertson & Blakeslee, 1948; Wolfert & Hiltunen, 1968; Krieger, 1984)

Lake Ontario (Walker, 1918a; Robertson & Blakeslee, 1948)

General Distribution: Great Lakes region from Albany, New York, west to Winnebago Lake, Calumet and Winnebago counties, Wisconsin; recorded from New York, Pennsylvania, Ohio, Indiana, Illinois, Michigan and Wisconsin (F.C. Baker, 1928a,b).

Habitat: Generally inhabitants of large lakes, living on vegetation (F.C. Baker, 1928b). "In shallow water in large lakes, large rivers and canals, where it feeds on filamentous algae" (Clarke, 1981).



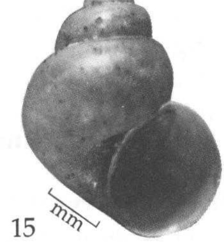


FIG. 14 *Bythinia tentaculata.* FIG. 15. *Amnicola limosa limosa.*

Family HYDROBIIDAE

Amnicola limosa limosa (Say)[15]
(Fig. 15)

Great Lakes Distribution:
Lake Superior (Smith, 1874a: *pallida* Haldeman; Dall, 1905; F.C. Baker, 1928b, 1930: *superiorensis* F.C. Baker; La Rocque, 1953: *superiorensis*; Thomas, 1966)
Lake Michigan (Walker, 1895, 1896: *limosa* and *porata* Say; F.C. Baker, 1928b, 1930: *superiorensis*; La Rocque, 1953: *superiorensis*)
Lake Erie (Ahlstrom, 1930: *limosa parva* Lea; Shelford & Boesel, 1942: *porata* Say; Robertson & Blakeslee, 1948; Krieger, 1984)
Lake Ontario (Adamstone, 1924: *limosa* and *"portata"* [*porata*]; F.C. Baker, 1928b: *superiorensis*; Robertson & Blakeslee, 1948; La Rocque, 1953: *superiorensis*)

General Distribution: From the Atlantic coast to as far west as Utah, and from Labrador to Florida (Berry, 1943).

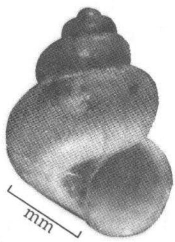
Habitat: Rough shores of the Great Lakes (F.C. Baker, 1928b, *superiorensis*). "*Amnicola limosa* occurs in all unpolluted, permanent aquatic habitats where microscopic aquatic vegetation grows" (Clarke, 1973).

Amnicola (Lyogyrus) walkeri Pilsbry
(Fig. 16)

Great Lakes Distribution
Lake Superior (Smith, 1874a: *granum* Say; Binney, 1865b: *granum*; Walker, 1895, 1896: *granum*)
Lake Michigan (Pilsbry, 1898; La Rocque, 1953)

General Distribution: St. Lawrence River and Great Lakes drainages, upper Mississippi drainage, the Canadian Interior Basin in the Albany and Winnipeg river systems and in Lake Winnipeg (Clarke, 1973).

Habitat: In heavily vegetated habitats with mud substrates in large or small lakes or in sluggish streams (Clarke, 1973).



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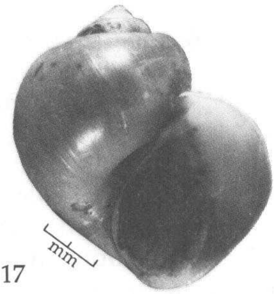

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FIG. 16. *Amnicola (Lyogyrus) walkeri.* FIG. 17. *Birgella subglobosa.*

Birgella subglobosa (Say)[16]
(Fig. 17)

Great Lakes Distribution:
Lake Michigan (F.C. Baker, 1928b; Berry, 1943; Thompson, 1984)
Lake Huron (Berry, 1943)
Lake Erie (F.C. Baker, 1928b; Ahlstrom, 1930[17]; Shelford & Boesel, 1942; Berry, 1943; Thompson, 1984)
Lake Ontario (F.C. Baker, 1928b; Robertson & Blakeslee, 1948: *isogonus* Say; La Rocque, 1953)

General Distribution: "Widely distributed in the central United States from Wisconsin, Michigan, and Ohio south to Arkansas and Alabama. It also occurs in New York in the Mohawk and Hudson river systems" (Thompson, 1984). A river and creek form (*isogona* Say 1829), which ranges from Ohio west to Iowa, and from Michigan south to Alabama and Arkansas (according to F.C. Baker, 1928b) "do[es] not meet the accepted criteria for subspecies" according to Thompson (1984).

Habitat: "A rather deep-water species found only in large lakes and large rivers" (Clarke, 1981, "*Somatogyrus*" *subglobosus* (Say)). However, it is not confined to deep water, but occurs also in less than one meter of water in bays and sloughs; "found most commonly in quiet water on a soft silt substrate" (Thompson, 1984).

Cincinnatia cincinnatiensis (Anthony)
(+ *chicagoensis* F.C. Baker[18])
(Fig. 18)

Great Lakes Distribution:
Lake Michigan (F.C. Baker, 1930)
Lake Ontario (Robertson & Blakeslee, 1948)

General Distribution: New York and Pennsylvania west to southern Manitoba, southern Saskatchewan, North Dakota, Utah and Texas (Clarke, 1973).

Habitat: Lakes and large and small rivers with slow to moderate currents; found in all types of bottom sediments, but always associated with submerged vegetation (Clarke, 1973). "Occurs in lakes and rivers and on muddy or sandy bottoms. Lives in deeper water than most other hydrobiids" (Clarke, 1981).

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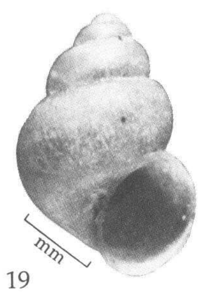

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FIG. 18. *Cincinnatia cincinnatiensis.* FIG. 19. *Hoyia sheldoni.*

Hoyia sheldoni (Pilsbry)
(Fig. 19)

Great Lakes Distribution:
Lake Michigan (Pilsbry, 1890; La Rocque, 1953)

General Distribution: Known only from Lake Michigan, off Racine, Wisconsin (Pilsbry, 1890; F.C. Baker, 1928b).

Habitat: In 30 fathoms of water in Lake Michigan off Racine, Wisconsin (Pilsbry, 1890).

Marstonia lustrica* (Pilsbry)
(Fig. 20)

Great Lakes Distribution:

Lake Superior (Walker, 1909a; F.C. Baker, 1928b: *perlustrica* F.C. Baker; La Rocque, 1953: *perlustrica;* Thomas, 1966; Thompson, 1977)

Lake Michigan (Walker, 1895, 1896; F.C. Baker, 1928b: *perlustrica;* La Rocque, 1953: *perlustrica;* Thompson, 1977)

Lake Huron (Robertson, 1915; Berry, 1943; Thompson, 1977)

Lake Erie (Robertson & Blakeslee, 1948; La Rocque, 1953: *perlustrica*)

Lake Ontario (Robertson & Blakeslee, 1948)

General Distribution: Canada: southern Quebec and Ontario; United States: Maine and New York west through northwestern Pennsylvania, Ohio, northern Indiana and northern Illinois to Iowa and Minnesota (Thompson, 1977).

Habitat: Eutrophic lakes or eutrophic areas of mesotrophic lakes, with vegetation and sand or mud bottoms (Clarke, 1973). "It occupies a wide variety of habitats, including lakes, ponds, marshes, rivers, and small streams. Most ... came from ... habitats that were characterized by clear water with submerged aquatic plants" (Thompson, 1977).

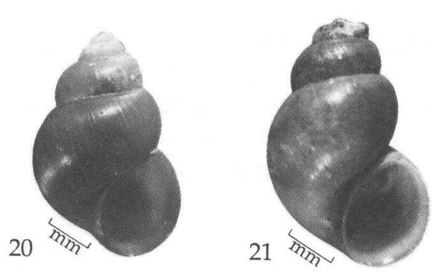

FIG. 20. *Marstonia lustrica.* FIG. 21. *Probythinella lacustris.*

Probythinella lacustris (F.C. Baker)[19]
(Fig. 21)

Great Lakes Distribution:

Lake Michigan (Walker, 1895: "*Bythinella obtusa* Lea"; F.C. Baker, 1930; Berry, 1943: *binneyana* Hannibal;

**Marstonia* F.C. Baker 1926 is considered a synonym of *Pyrgulopsis* Call & Pilsbry 1886 by Hershler & Thompson (1987).

Morrison, 1947: *lacustris limafodens* Morrison; Hibbard & Taylor, 1960)

Lake Huron (Robertson, 1915: *emarginata* Küster; Berry, 1943: *binneyana*)

Lake Erie (Robertson & Blakeslee, 1948: *binneyana*; Clarke, 1981)

General Distribution: Canada: throughout Ontario and Manitoba, northern Saskatchewan, and in the Northwest Territories south of the tree-line (Clarke, 1973); United States: New York west to Iowa, south to Kentucky and Arkansas (F.C. Baker, 1928b); also North Dakota, South Dakota, Nebraska, Missouri and Alabama (Hibbard & Taylor, 1960).

Habitat: Large and small lakes and rivers, with rapid to slow currents, but most abundant in slow current; in all types of bottom deposits, but predominantly in mud or muddy sand; at depths from six inches to 24 feet; always associated with submerged vegetation (Clarke, 1973). Found as deep as 25 meters in Lake Michigan (Hibbard & Taylor, 1960).

Pyrgulopsis letsoni (Walker)

(Fig. 22)

Great Lakes Distribution:

Lake Erie (F.C. Baker, 1928b; Berry, 1943; Robertson & Blakeslee, 1948)

General Distribution: Ontario, New York, Ohio and Michigan (F.C. Baker, 1928b; La Rocque, 1953).

Habitat: Recorded only once: in the lime encrusted cavities on the undersides of larger stones in an artificially impounded area of the Huron River near Ann Arbor, Mich. (Berry, 1943).

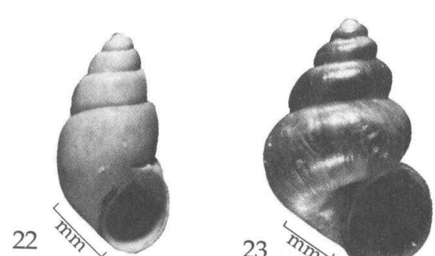

FIG. 22. *Pyrgulopsis letsoni*. FIG. 23. *Pomatiopsis lapidaria*.

Family POMATIOPSIDAE

***Pomatiopsis lapidaria* (Say)**
(Fig. 23)

Great Lakes Distribution:
Lake Ontario (Robertson & Blakeslee, 1948)

General Distribution: Widely distributed in the eastern United States, with occasional occurrences west to northern Texas and New Mexico (Burch & Van Devender, 1980).

Habitat: "Found under stones, & c. in moist situations, on the margins of rivers" (Say, 1817). "Few specimens have been ... collected in water but it has been found in many places under leaves and on damp or wet mud in places more or less subject to overflow from streams and rivers" (F.C. Baker, 1928b). "Amphibious. Lives on wet ground principally along the edges of streams" (Clarke, 1981).

Family PLEUROCERIDAE

***Elimia*[20] *livescens livescens* (Menke)**
(Fig. 24)

Great Lakes Distribution:
- Lake Superior (Say, 1821: *virginica* Gmelin; Tryon, 1865b; Smith, 1874a; Thomas, 1966)
- Lake Michigan (Cooper, 1834: *virginica;* Tryon, 1865b; Walker, 1895, 1896; F.C. Baker, 1902; F.C. Baker, 1928b: *livescens s.s.* and *livescens michiganensis* F.C. Baker[21]; Goodrich, 1945; La Rocque, 1953: *livescens michiganensis*)
- Lake Huron (Tryon, 1865b; Walker, 1894, 1915; F.C. Baker, 1906; H.B. Baker, 1911; Robertson, 1915; Goodrich, 1945)
- Lake Erie (Menke, 1830; Reeve, 1860; Tryon, 1865b, 1873; Goodrich, 1920, 1939; Krecker, 1924; Wiebe, 1926; F.C. Baker, 1928b; Ahlstrom, 1930; Brooks, 1931; Shelford & Boesel, 1942; Goodrich, 1945; Robertson & Blakeslee, 1948; La Rocque, 1953; Krieger, 1984)
- Lake Ontario (Tryon, 1865b; Goodrich, 1945; Robertson & Blakeslee, 1948, + *niagarensis* Lea)

General Distribution: St. Lawrence River drainage from the Great Lakes to Lake Champlain and Quebec; tributaries of the Ohio River, east to Scioto River in Ohio; Wabash River and branches, west to the Illinois River; through the Erie Canal it has invaded the Hudson River basin (Goodrich, 1940; 1945).

Habitat: "*Goniobasis livescens* is found in almost any clean and permanent type of fresh-water environment (springs, swift flowing streams, inland lakes); this species is usually found crawling on rocks and stones" (Dazo, 1965). "Occurs in lakes, rivers, streams of all sizes, and springs. Frequently found crawling on stones in a few centimetres of water in clear, rapid streams, but also lives at several metres in lakes" (Clarke, 1981).

Elimia livescens haldemani (Tryon)[22]

(Fig. 25)

Great Lakes Distribution:

Lake Huron (Robertson, 1915)

Lake Erie (Tryon, 1865a,b, 1873; Goodrich, 1920, 1939; Brooks, 1931; Robertson & Blakeslee, 1948; La Rocque, 1953)

General Distribution: Lake Erie; ? Lake Champlain (Goodrich, 1939).

Habitat: "The assumption has been that the species lives in deep water. ... The single living specimen that I have seen was taken by me in an inch or two of water in a sheltered marsh of Sandusky Bay, Ohio" (Goodrich, 1939).

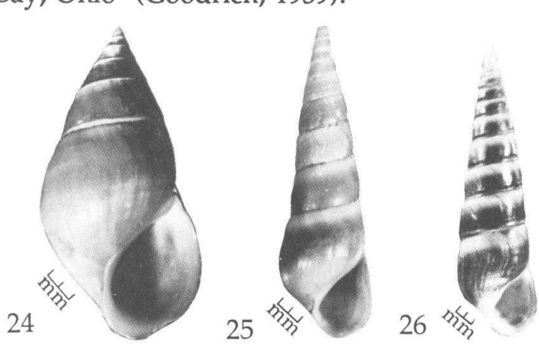

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FIG. 24. *Elimia livescens livescens.* Fig. 25. *E. Livescens haldemani.* FIG. 26. *Pleurocera acuta.*

Pleurocera acuta Rafinesque
(Fig. 26)

Great Lakes Distribution:
Lake Superior[23] (F.C. Baker, 1928b; Goodrich, 1939; La Rocque, 1953)
Lake Michigan (F.C. Baker, 1902: *elevatum* Say and *elevatum lewisi* Lea[24]; F.C. Baker, 1928b; La Rocque, 1953)
Lake Huron (F.C. Baker, 1928b; La Rocque, 1953)
Lake Erie (Rafinesque, 1831; De Kay, 1843: *subularis* Lea; Goodrich, 1917; F.C. Baker, 1928b; Ahlstrom, 1930; Brooks, 1931; Kindle, 1934; Goodrich, 1939; Shelford & Boesel, 1942; Robertson & Blakeslee, 1948; La Rocque, 1953; Wolfert & Hiltunen, 1968; Clarke, 1981; Krieger, 1984)
Lake Ontario (F.C. Baker, 1928b; Robertson & Blakeslee, 1948; La Rocque, 1953)

General Distribution: Ohio River head streams and tributaries; Great Lakes and tributaries; Mississippi River and westward to Nebraska and Kansas; through the Erie Canal into the basin of the Hudson River; Cumberland and Duck rivers, Tennessee (Goodrich, 1940).

Habitat: "Typical *acuta* is a species of the Great Lake shores where the wave action is strong" (F.C. Baker, 1928b). "Found in quiet areas of large streams and in lakes. A burrowing species that prefers mixed sand and mud bottoms" (Clarke, 1981).

Subclass Pulmonata

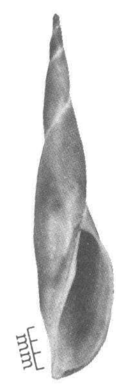
Family LYMNAEIDAE[25]

Acella haldemani (Binney)
(Fig. 27)

Great Lakes Distribution:
Lake Huron (Robertson, 1915; Herrington, 1947; La Rocque, 1953; Clarke, 1981)
Lake Erie (F.C. Baker, 1911; Herrington, 1947)
Lake Ontario (Herrington, 1947; La Rocque, 1953)

General Distribution: Vermont and eastern Ontario west to northern Minnesota, south to northern Illinois and Ohio (F.C. Baker, 1928b).

Habitat: *Acella haldemani* is a quiet bay or pond species, "where the environment is protected from the force of waves and wind by barriers of one kind or another. The water is shallow and there is usually an abundance of vegetation, such as *Scirpus, Potamogeton, Castalia, Nymphaea, Typha* and filamentous algae which provide much of the food of the snails" (F.C. Baker, 1919). *Acella haldemani* "is an inhabitant of the larger lakes, in more or less sheltered bays, always a protected habitat, in water from .3 to over 1 m. deep. ... Adults are usually found on the stem of the bullrush, *Scirpus*" (F.C. Baker, 1928b). "It is primarily an inhabitant of vegetation"; the bottom of the habitats is either silt or sand (Morrison, 1932).



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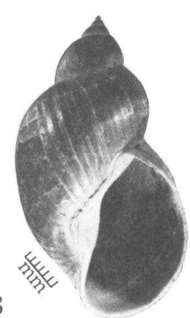

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FIG. 27. *Acella haldemani.* FIG. 28. *Bulimnea megasoma.*

Bulimnea megasoma (Say)
(Fig. 28)

Great Lakes Distribution:

Lake Superior (Tryon, 1865a; Currier, 1868; DeCamp, 1881; Dall, 1905; F.C. Baker, 1911)

Lake Huron (F.C. Baker, 1911, 1928b; Goodrich, 1940)

General Distribution: Great Lakes and St. Lawrence River drainage area, upper tributaries of the Mississippi drainage area, parts of the Albany, Winnipeg and Nelson river systems in the Canadian Interior Basin (see Clarke, 1973).

Habitat: *Bulimnea megasoma* is a quiet bay or pond species, "where the environment is protected from the force of waves and wind by barriers of one kind or another. The water is shallow and there is usually an abundance of vegetation, such as *Scirpus, Potamogeton, Castalia, Nymphaea, Typha* and filamentous algae which provide much of the food of the snails" (F.C. Baker, 1919). *Bulimnea megasoma* "is usually an inhabitant of small, quiet bodies of water or swamps;" sometimes present (e.g., in Georgian Bay) in deep water which is rather rough (F.C. Baker, 1928b). "Occurs in large and small lakes, in slow-moving rivers, and in pond areas of creeks. Vegetation is variable and the usual bottom is mud" (Clarke, 1981).

Fossaria cyclostoma (Walker)[26]

(Fig. 29)

Great Lakes Distribution:

Lake Erie (F.C. Baker, 1928b: *sayi* F.C. Baker; La Rocque, 1953: *sayi*)

General Distribution: New York to Michigan and Ontario, including the Great Lakes region (F.C. Baker, 1911, "*Galba*" *cyclostoma* Walker; F.C. Baker, 1928b, *sayi* F.C. Baker).

Habitat: Not recorded for *cyclostoma*; the type locality is Indian Creek, Kent County, Michigan (Walker, 1908). "A species of the Great Lakes and their bays and connecting waters" (F.C. Baker, 1928b, *sayi* F.C. Baker).

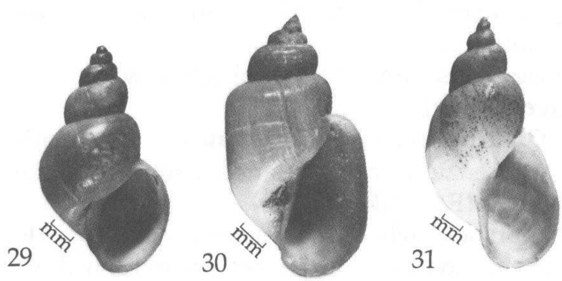


FIG. 29. *Fossaria cyclostoma.* FIG. 30. *F. galbana.* FIG. 31. *F. obrussa.*

Fossaria galbana (Say)
(Fig. 30)

Great Lakes Distribution:

Lake Erie (Goodrich, 1932: beach drift; Goodrich & van der Schalie, 1939)

General Distribution: Great Lakes-St. Lawrence River basin northward in the region west of James Bay to the Attawapiskat and Severn river systems, and northwestward in the boreal forest region to the vicinity of the Great Slave Lake (Clarke, 1973, *decampi* Streng).

Habitat: Generally found in medium or large lakes or large rivers, with abundant aquatic vegetation; needs cold, highly oxygenated water (Clarke, 1973, "*Lymnaea*" *decampi* Streng). "A cold-water species occurring only in large lakes in the southern part of its range and in both lakes and rivers in the northern part. It lives among submersed vegetation and on various kinds of bottom" (Clarke, 1981, "*L.*" *decampi* Streng).

Fossaria obrussa (Say)
(Fig. 31)

Great Lakes Distribution:

Lake Superior (Gould, 1850b: *desidiosa* Say[27]; Dall, 1905: *humilis*; ? Walker & Ruthven, 1906: *desidiosa*; Walker, 1909a; F.C. Baker, 1911: *obrussa peninsulae* Walker; La Rocque, 1953: *humilis* Say; Thomas, 1966)

Lake Michigan (Walker, 1895, 1896: *desidiosa* Say; Baker, 1902: *desidiosa*)

Lake Erie (Ahlstrom, 1930[28]; Robertson & Blakeslee, 1948: *modicella* Say)

General Distribution: From the Atlantic to the Pacific oceans, and from Mackenzie territory, Canada, south to Arizona and northern Mexico (F.C. Baker, 1928b).

Habitat: Marshes, "where the water is shallow, seldom more than three or four feet deep, and where there is an abundance of swamp vegetation such as *Typha, Pontederia, Decodon* and a few *Nymphaea.* The bottom is usually of mud and accumulated vegetable débris" (F.C. Baker, 1919). "The normal habitat of this species is in small bodies of water, as creeks, ponds, sloughs, bays, and marshy spots along river banks" (F.C. Baker, 1928b). Large and small lakes and ponds, and large and small rivers, all with aquatic vegetation, usually in abundance, and generally with mud bottoms (Clarke, 1973, *modicella* Say). Also occurs on moist sandy or muddy beaches (Clarke, 1981, *modicella*).

Lymnaea stagnalis appressa Say
(Fig. 32)

Great Lakes Distribution:

Lake Superior (Say, 1821; Beck, 1837, 1838a,b; Haldeman, 1842; Jackson, 1844: *jugularis* Say; Gould, 1850b: *jugularis*; Küster, 1862; Binney, 1865a: *jugularis*; Dall, 1905; Walker & Ruthven, 1906; Walker, 1909a; Thomas, 1966: *jugularis*)

Lake Michigan (Say, 1821; Walker, 1895, 1896).

Lake Erie (Rossmässler, 1835: *speciosus* Ziegler; F.C. Baker, 1911)

Lake Ontario (F.C. Baker, 1911)

General Distribution: Great Lakes-St. Lawrence River drainage area, northwest to the Mackenzie and Yukon river drainage areas, west to the Rocky Mountains, south in the Rocky Mountains to Colorado, and in Illinois and Ohio in the Mississippi drainage (Clarke, 1973).

Habitat: *Lymnaea stagnalis appressa* is a quiet bay or pond species, "where the environment is protected from the force of waves and wind by barriers of one kind or another. The water is shallow and there is usually an abundance of vegetation, such as *Scirpus, Potamogeton, Castalia, Nymphaea, Typha* and filamentous algae which provide much of the food of the snails" (F.C. Baker, 1919). May inhabit any permanent water bodies which support substantial vegetation (Clarke, 1973): in lakes of various sizes, permanent ponds, in streams of all sizes, and in backwaters, canals and swamps, living on substrates of all kinds, but mud, sand or rocks being the most frequent; vegetation present in all localities. Baker (1919) listed *Lymnaea stagnalis lillianae* Baker [a form of *appressa*] as an open shore lake species "exposed to the full force of the winds and waves."

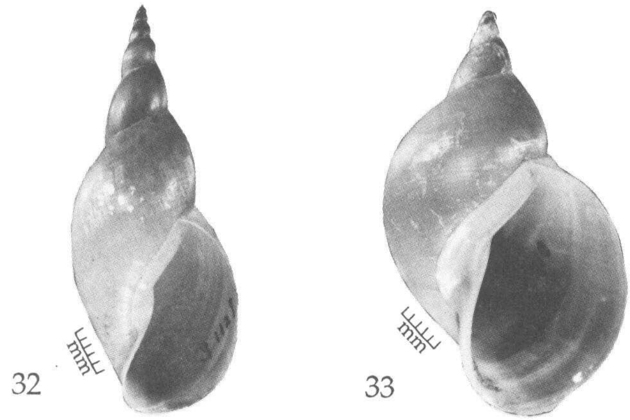


FIG. 32. *Lymnaea stagnalis appressa.* FIG. 33. *L. stagnalis sanctaemariae.*

Lymnaea stagnalis sanctaemariae Walker
(Fig. 33)

Great Lakes Distribution:

Lake Superior (F.C. Baker, 1905: *higleyi* F.C. Baker; F.C. Baker, 1911, 1928b)

Lake Huron (Robertson, 1915)

General Distribution: Lake Superior drainage area and adjacent parts of the Lake, Wisconsin River and Winnipeg River drainage areas (Clarke, 1973).

Habitat: "Attached to the larger rocks that are not readily moved by the action of the surf. ... Seem[s] ... to be typically an inhabitant of a region under the influence of clear, shore waters in situations where there is considerable action of the waves" (Baker, 1928b). "In large lakes, on smooth rocky shores sloping steeply into deep water in situations subject to severe wave action" (A. Mozley, 1938).

Pseudosuccinea columella (Say)
(Fig. 34)

Great Lakes Distribution:

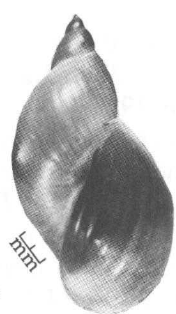
Lake Superior (Binney, 1865a; Dall, 1905)

Lake Michigan (F.C. Baker, 1902)

Lake Huron (Robertson, 1915)

General Distribution: Eastern North America generally. Nova Scotia and Quebec west to Manitoba, Minnesota and eastern Kansas, south to central Texas and Florida (F.C. Baker, 1911).

Habitat: *Pseudosuccinea columella* is a quiet bay or pond species, living "where the environment is protected from the force of waves and wind by barriers of one kind or another. The water is shallow and there is usually an abundance of vegetation, such as *Scirpus, Potamogeton, Castalia, Nymphaea, Typha* and filamentous algae which provide much of the food of the snails" (F.C. Baker, 1919). This species "is an inhabitant of ponds and streams where the water is more or less stagnant; a locality with an abundance of lily pads is particularly favorable; it is found also along the shore in shallow water in the vicinity of cat-tails (*Typha*) and other reeds, upon which it is often found ...; rarely found in running water. [It] is a lover of shallow bays and small ponds or creeks, where it may browse in the pond scum and on bits of rotting stems of water plants" (Baker, 1928b).



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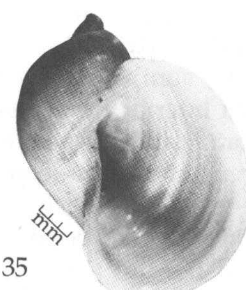

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FIG.34. *Pseudosuccinea columella*. FIG. 35. *Radix auricularia.*

**Radix auricularia* (Linnaeus)
(Fig. 35)

Great Lakes Distribution:

Lake Huron (Walker, 1918b; La Rocque, 1953)

Lake Erie (Walker, 1918b; Ahlstrom, 1930; La Rocque, 1953)[29]

General Distribution: Europe and northern Asia; widely introduced but of spotty occurrence in North America.

Habitat: "Occurs in lakes, ponds, and slow-moving rivers" (Clarke, 1981).

Stagnicola elodes (Say)
(Fig. 36)

Great Lakes Distribution:[30]

Lake Superior (Say, 1821: *reflexa* Say; Say, 1832: *reflexa*; Haldeman, 1842: *fragilis* "Lin[naeus]" Haldeman and *reflexa*; Binney, 1865a: *lanceata* Gould, ? *caperata* Say[31]; Currier, 1868: *lanceata*; Tryon, 1871: *lanceata*; ? Smith, 1874a: *lanceata, caperata*; DeCamp, 1881: *lanceata*; Clarke 1981: *reflexa*)

Lake Michigan (Walker, 1895, 1896: *lanceata*; Goodrich & van der Schalie, 1939: *lanceata*)

Lake Huron (Walker, 1894: *reflexa*; F.C Baker, 1911: *palustris alpenensis* nov. var.)[32]

Lake Erie (Say, 1821: *reflexa* Say; Beck, 1837, 1838b: *reflexa*; Haldeman, 1841: *elodes*; Haldeman,1842: *reflexa*; Haldeman, 1842: *fragilis*; Küster, 1862; F.C. Baker, 1911; Ahlstrom, 1930)

General Distribution: New England west to Oregon and California, south to New Mexico; widely distributed in the Canadian Interior Basin (see Clarke, 1973).

Habitat: Marshes, "where the water is shallow, seldom more than three or four feet deep, and where there is an abundance of swamp vegetation such as *Typha, Pontederia, Decodon* and a few *Nymphaea.* The bottom is usually of mud and accumulated vegetable débris" (F.C. Baker, 1919, for "*Galba* [*Stagnicola*] *palustris* (Müll)," "*G.*" [*S.*] *reflexa* (Say) and "*G.*" [*S.*] *elodes*). "Found plentifully in bodies of water of greater or less size, on floating sticks and submerged vegetation, on stones and on the muddy bottom. Inhabits both clear and stagnant water, but prefers a habitat in which the water is not in motion. ... In lakes and rivers where the water is quiet and where vegetation is more or less abundant. The margins of rivers and protected bays of lakes and ponds appear to be the natural habitats" (Baker, 1928b). Ordinarily found in swampy bayous of small lakes, mucky ponds, and the stagnant parts of streams (Goodrich & van der Schalie, 1939, *lanceata* Gould). Small pools or ponds which dry up in the summer (Baker, 1928b, *reflexa*). "Occurs among vegetation in a variety of perennial-water and vernal habitats, namely lakes, ponds, sheltered areas of streams, swamps, and ditches. The usual substrate is mud" (Clarke, 1981, *reflexa*).

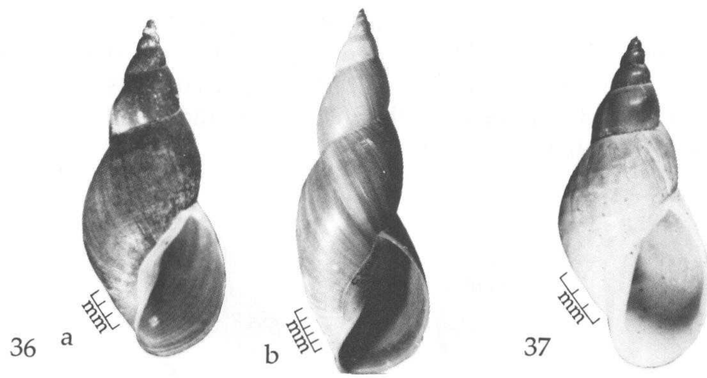

FIG. 36. **a**, *Stagnicola elodes*; **b**, *S. elodes* form *reflexa*. FIG. 37. *S. davisi*.

Stagnicola davisi (Walker)
(Fig. 37)

Great Lakes Distribution:
Lake Huron (Walker, 1908; F.C. Baker, 1911; La Rocque, 1953)

General Distribution: Known only from Saginaw Bay, Lake Huron.

Habitat: Not recorded.

Stagnicola catascopium (Say)
(Fig. 38)

Great Lakes Distribution:
Lake Superior (Gould, 1850a, 1850b; Smith, 1874a[33], 1874b)
Lake Michigan (Walker, 1896; F.C. Baker, 1902; Goodrich & van der Schalie, 1939)
Lake Huron (Walker, 1894; Goodrich & van der Schalie, 1939)
Lake Erie (Letson, 1909; Goodrich & van der Schalie, 1939;

Robertson & Blakeslee, 1948: *niagarensis* F.C. Baker)
Lake Ontario (Goodrich & van der Schalie, 1939; Robertson & Blakeslee, 1948: *niagarensis* F.C. Baker)

General Distribution: Eastern Canada and Nova Scotia west to North Dakota, Great Slave Lake south to northern Iowa, northern Ohio and Maryland (F.C. Baker, 1928b).

Habitat: In large bodies of water such as lakes, rivers and bays (F.C. Baker, 1911). Open shores of lakes (F.C. Baker, 1919). Typically in rivers with rather rapid currents, on gravel and stony bottoms mixed with sand. Also found in lakes on stony shores (F.C. Baker, 1928b).

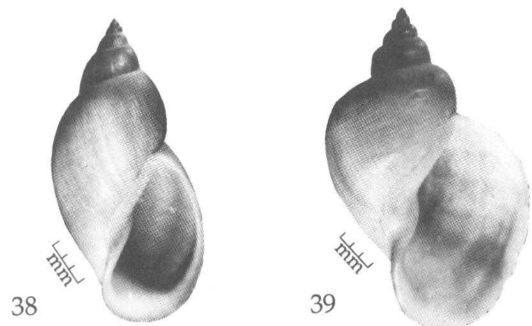

FIG. 38. *Stagnicola catascopium*. FIG. 39. *S. emarginata*.

Stagnicola emarginata (Say)
(Fig. 39)

Great Lakes Distribution:

Lake Superior (Gould, 1850a[34]; Binney, 1865a; Walker & Ruthven, 1906: *Limnaea* n. sp.?; Walker, 1908, 1909a: *pilsbryana* Walker; F.C. Baker, 1911: *pilsbryana*; Thomas, 1966)

Lake Michigan (Küster, 1862; Walker, 1895, 1896; Baker, 1911, 1928b: *canadensis* Sowerby)

Lake Huron (Walker, 1915: *ontarioensis* Muhlfelt; Robertson, 1915: *canadensis*; Winslow, 1917)

Lake Ontario (Küster, 1862; Robertson & Blakeslee, 1948: *ontarioensis*)

General Distribution: Maine west to Minnesota and Wisconsin, Canadian Interior Basin south to Michigan, Pennsylvania and New York (F.C. Baker, 1928b).

Habitat: Open shores of lakes (Baker, 1919). In water about three feet in depth, on a gravel or stone bottom; stoney shore in shallow water, exposed to the waves of the open bay (*canadensis* Sowerby); 0.3 - 3 m depth on sand (partly buried) or pebble bottom (*angulata* Sowerby) (F.C. Baker, 1928b).

Stagnicola nasoni (F.C. Baker)[35]

(Fig. 40)

Great Lakes Distribution:

Lake Superior (Clarke, 1981)
Lake Michigan (Clarke, 1973)
Lake Huron (F.C. Baker, 1906, 1911; Robertson, 1915: *decollata* Mighels; La Rocque, 1953)
Lake Ontario (Clarke, 1973)

General Distribution: Lakes Superior, Michigan, Ontario and Geneva (Wisconsin), and Rainy River system and Lake of the Woods (Minnesota/Canada) (Clarke, 1981).

Habitat: Exposed shore of Lake Huron (Baker, 1906; see also 1919). "On rocky shores and in shallow rocky bays of outer islands [of Georgian Bay]" (Robertson, 1915, *decollata* Mighels). "In pools of water in ledges of limestone which are accessible to the waves of the lakes during storms or high water" (William A. Nason in F.C. Baker, 1906). On wave-exposed black shale rocks (in Lake of the Woods) (Clarke, 1981).

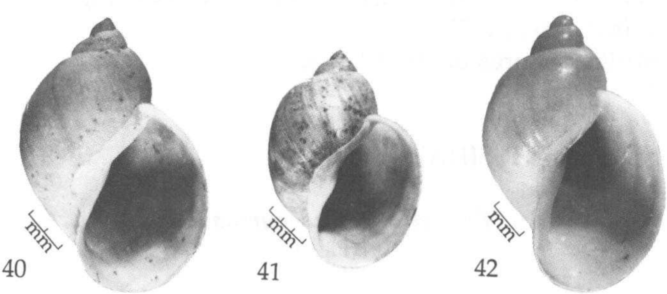

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FIG. 40. *Stagnicola nasoni.* FIG. 41. *S. walkeriana.* FIG. 42. *S. woodruffi.*

Stagnicola walkeriana **F.C. Baker**
(Fig. 41)

Great Lakes Distribution:
Lake Superior (Walker & Ruthven, 1906: *decollata* Mighels; F.C. Baker, 1911: *apicina*[36] Lea; Walker, 1909a; F.C. Baker, 1926, 1928b,1932; La Rocque, 1953)
Lake Michigan (F.C. Baker, 1928b; 1932; La Rocque, 1953)

General Distribution: Great Lakes (Michigan and Superior) (F.C. Baker, 1928b).

Habitat: "The habitat of *walkeriana* in Lake Superior is on rocks or rocky ledges bordering the shore, usually not more than a meter below the surface. The habitats are usually on the protected sides of islands and along the shore, the species not being found generally on shores facing the heavy surf of Lake Superior. Near Sturgeon Bay, however, the species lives on the rocky ledges of the open shore, fully exposed to the waves of Lake Michigan" (F.C. Baker, 1928b).

Stagnicola woodruffi **F.C. Baker**
(Fig. 42)

Great Lakes Distribution:
Lake Michigan (F.C. Baker, 1901, 1902, 1911, 1928b, 1930; La Rocque, 1953)
Lake Ontario (Robertson & Blakeslee, 1948)

General Distribution: Great Lakes (Huron, Michigan, Ontario); Lake Geneva, Wisconsin; Rainy River system; Lake of the Woods (Clarke, 1973).

Habitat: Shores of large lakes.

Family PHYSIDAE

Physella gyrina gyrina **(Say)**
(Fig. 43)

Great Lakes Distribution:
Lake Superior (Walker, 1909a)
Lake Michigan (Walker, 1895, 1896)

Lake Erie (Ahlstrom, 1930)

Lake Ontario (Adamstone, 1924; Robertson & Blakeslee, 1948)

General Distribution: In Canada, Quebec to Ontario; south to Nebraska and east to New York.

Habitat: Swales and summer-dry ponds deprived of moisture for a large part of the year (Hibbard & Taylor, 1960, form *hildrethiana* Lea). "Occurs [in the Canadian Interior Basin] in almost all perennial-water habitats and in temporarily flooded pools and swamps. Often abundant in mildly polluted water bodies; in fact, where it occurs alone in abundance, it is indicative of water pollution" (Clarke, 1981).

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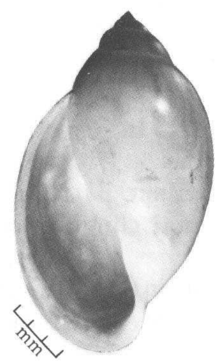

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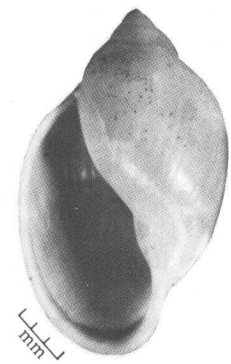

FIG. 43. *Physella gyrina gyrina.* FIG. 44. *P. gyrina sayi.*

Physella gyrina sayi (Tappan)

(Fig. 44)

Great Lakes Distribution:

Lake Superior (Smith & Verrill, 1871: *heterostropha* Say; Smith, 1874a: *heterostropha*; Walker & Ruthven, 1906; Walker, 1909a)

Lake Michigan (F.C. Baker, 1902, 1928b, 1930)

Lake Huron (Winslow, 1917: *crassa* Walker)

Lake Erie (Ahlstrom, 1930; ? Beck, 1837, 1838a,b: *striata* Menke)

Lake Ontario (Robertson & Blakeslee, 1948: *gyrina*, + *crassa, oneida* F.C. Baker)

Lake Erie (Robertson & Blakeslee, 1948: *oneida*)

General Distribution: Quebec to Northwest Territories, south to Saskatchewan, the Dakotas and New York.

Habitat: F.C. Baker (1928b) reports *Physella gyrina sayi* in various lakes, on bottoms of mud, sand, gravel, rock and boulder. "Near Sturgeon Bay, it was found on rocks on the open shore of Lake Michigan."

Physella magnalacustris (Walker)
(Fig. 45)

Great Lakes Distribution:
- Lake Michigan (Walker, 1895, 1896: *ancillaria* Say; Walker, 1901; F.C. Baker, 1928b; La Rocque, 1953)
- Lake Huron (Walker, 1894: *ancillaria*; Walker, 1901, 1915; F.C. Baker, 1928b; La Rocque, 1953)
- Lake Erie (Ahlstrom, 1930)

General Distribution: Ontario south to the Great Lakes states and Indiana, east to Vermont and Maine.

Habitat: "This form is the characteristic *Physa* [*Physella*] of the lake shore, and is commonly found clinging to the large stones along the rocky or stony beaches" (Walker, 1901). In Sturgeon Bay (Lake Michigan, Wisconsin) on "rocky ledges of the wave-beaten shore, always in shallow water" (F.C. Baker, 1928b).

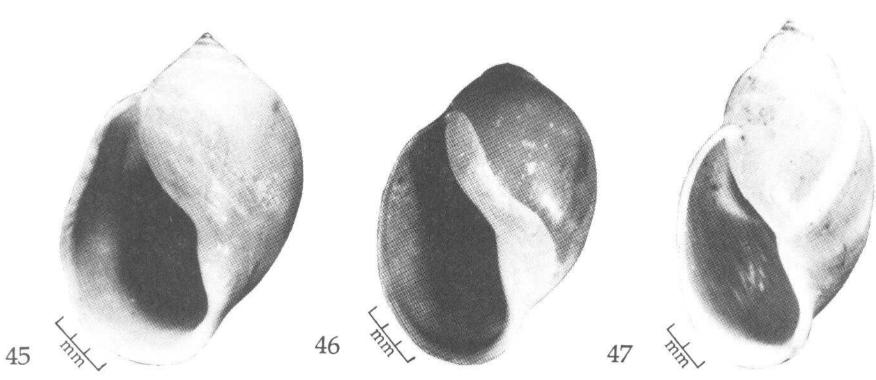

FIG. 45. *Physella magnalacustris*. FIG. 46. *P. vinosa*. FIG. 47. *P.* (*Costatella*) *integra integra*.

Physella vinosa (Gould)

(Fig. 46)

Great Lakes Distribution:

Lake Superior (Gould, 1847[37], 1850b, 1862; Binney, 1865a; Currier, 1868[38]; Tryon, 1871; Smith & Verrill, 1871; G.B. Sowerby, 1873; Smith, 1874a: *vinosa* and ? *ancillaria* Say; DeCamp, 1881; Clessin, 1882; Goodrich & van der Schalie, 1939)

Lake Michigan (Lauritsen & White, 1981)

General Distribution: Ontario, Can., and the Gr. Lake states.

Habitat: *Physella* "*vinosa* is a rock inhabiting species, preferring the rough waters of the open lake. ... Found on rocky and boulder shores in the most exposed situations" (F.C. Baker, 1928b).

Physella (Costatella) integra integra (Haldeman)[39]

(Fig. 47)

Great Lakes Distribution[40]:

Lake Superior (F.C. Baker, 1928b: *billingsi* Heron)

Lake Michigan (Walker, 1895, 1896; F.C. Baker, 1902: *heterostropha* Say; F.C. Baker, 1928b: *billingsi*; Lauritsen & White, 1981)

General Distribution: Quebec to Manitoba, Canada, and the Great Lake states, Iowa, South Dakota, Tennessee, Kentucky and West Virginia.

Habitat: "Rivers, bays, and lakes connected with the Great Lakes" (F.C. Baker, 1928b, *billingsi* Heron). Found in beach debris; exact habitats and ecology not known.

Family PLANORBIDAE

Gyraulus deflectus (Say)

(Fig. 48)

Great Lakes Distribution:

Lake Superior (Haldeman, 1844: *albus* Müller[41]; Dall, 1905:

hirsutus Gould; Thomas, 1966, + *hirsutus* Gould)
Lake Ontario (Robertson & Blakeslee, 1948, + *hirsutus*)
Lake Huron (Robertson, 1915: + *hirsutus* Gould)

General Distribution: Along the Atlantic Coast from Prince Edward Island south to Virginia, west to Ohio, Illinois, Alberta and Idaho (Miller, 1966); north to near the Arctic Coast in the Ungava, Copper-mine River and Mackenzie River districts (Clarke, 1973).

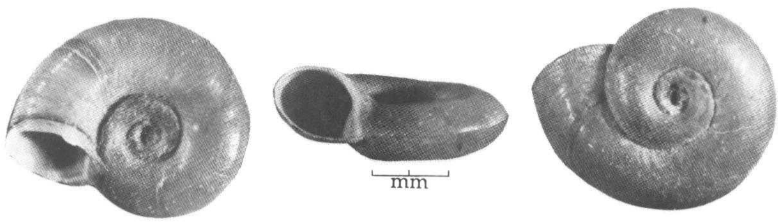

FIG. 48. *Gyraulus deflectus.*

Habitat: "Occurs in all kinds of permanent-water, eutrophic habitats. The usual substrate is mud. Commonly lives on vegetation but is occasionally found on the bottom" (Clarke, 1981).

Gyraulus (Torquis) parvus parvus (Say)
(Fig. 49)

Great Lakes Distribution:
Lake Superior (J. de C. Sowerby, 1836: *albus* Müller; Haldeman, 1844; Walker & Ruthven, 1906; Walker, 1909a; F.C. Baker, 1902; Thomas, 1966; Smith & Verrill, 1871; Smith, 1874a,b)
Lake Michigan (Walker, 1895, 1896)
Lake Erie (Ahlstrom, 1930)
Lake Ontario (Robertson & Blakeslee, 1948)

General Distribution: North America, from Alaska and northern Canada to Cuba and from the Atlantic to the Pacific Coast (Taylor, 1960).

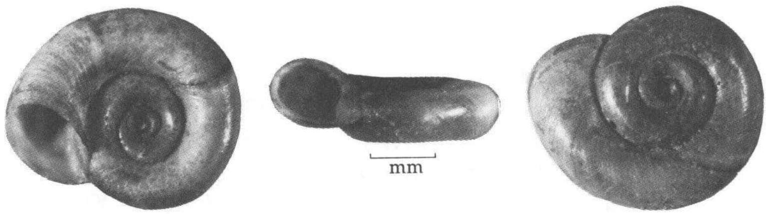

FIG. 49. *Gyraulus (Torquis) parvus parvus.*

Habitat: "Usually in quiet bodies of water, often of small size." Habitats variously have mud, sandy mud, sand, gravel and boulder bottoms. Partial to habitats that have rather thick vegetation (F.C. Baker, 1928b). Dredged in deep water in Lake Michigan (Walker, 1895) and "in Lake Superior at a depth of 8-13 fathoms (Baker)" (Walker & Ruthven, 1906).

Gyraulus (Torquis) parvus hornensis **F.C. Baker**[42]
(Fig. 50)

Great Lakes Distribution:
Lake Michigan (F.C. Baker, 1930: *arcticus* "Beck" Möller)
General Distribution: Mackenzie River region west of Great Slave Lake; western Ontario, Wisconsin and North Dakota (F.C. Baker, 1934).

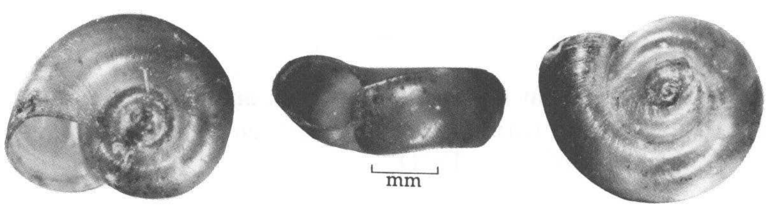

FIG. 50. *Gyraulus (Torquis) parvus hornensis.*

Habitat: Not recorded. The type locality is Birch Lake, Horn River, Mackenzie District, Canada (F.C. Baker, 1934).

Helisoma anceps anceps (Menke)
(Fig. 51)

Great Lakes Distribution:

Lake Superior (J. de C. Sowerby, 1836: *bicarinatus* Say; Haldeman, 1844: *bicarinatus*; Smith, 1874a,b: *bicarinatus*; Dall, 1905: *bicarinatus*; Walker & Ruthven, 1906: *bicarinatus striatus* F.C. Baker; Walker, 1909a: *bicarinatus* and *bicarinatus striatus*; Thomas, 1966)

Lake Michigan (Walker, 1895, 1896: *bicarinatus*; F.C. Baker, 1928b)

Lake Huron (Walker, 1909b: *bicarinatus striatus*; Robertson, 1915: *bicarinatus*)

Lake Erie (Letson, 1909: *bicarinatus*; Ahlstrom, 1930: *antrosa percarinata* Walker)

Lake Ontario (Robertson & Blakeslee, 1948)

General Distribution: Throughout North America and James and Hudson bays south to Georgia, Alabama, Texas and northwestern Mexico, west to Northwest Territories, Alberta and Oregon (see Walker, 1909b; Clarke, 1973).

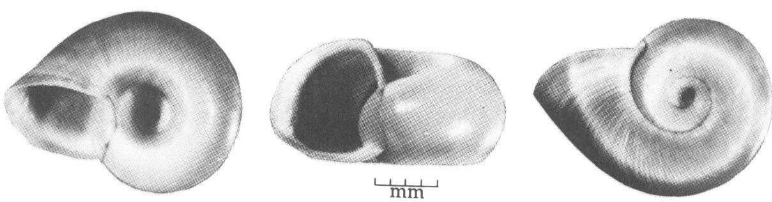

FIG. 51. *Helisoma anceps anceps.*

Habitat: "Lives in lakes, ponds, rivers and streams among vegetation and on various substrates. Absent from temporary-water habitats" (Clarke, 1981).

Helisoma anceps royalense (Walker)
(Fig. 52)

Great Lakes Distribution:

Lake Superior (Walker, 1909a,b; La Rocque, 1953; Clarke, 1981)

Lake Huron (Clarke, 1981)

General Distribution: Isle Royale, Lake Superior, and the adjacent portion of Ontario north and west of Lake Superior in parts of the Albany, Attawapiskat and Winnipeg river systems (Clarke, 1973).

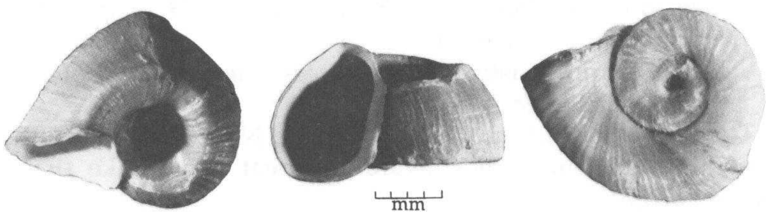

FIG. 52. *Helisoma anceps royalense.*

Habitat: "Lakes and large rivers. Substrates were chiefly sand or rocks; submersed vegetation was moderately dense to dense" (Clarke, 1981).

Menetus (Micromenetus) dilatatus (Gould)

(Fig. 53)

Great Lakes Distribution:

Lake Huron (Robertson, 1915)

General Distribution: Eastern United States, from Maine west to Iowa, south to Texas and Florida.

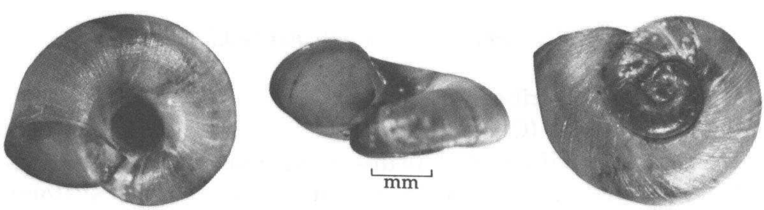

FIG. 53. *Menetus (Micromenetus) dilatatus.*

Habitat: "On sticks along muddy river banks and in muddy bays" (Robertson, 1915).

Planorbella[43] *campanulata campanulata* (Say)
(Fig. 54)

Great Lakes Distribution:

Lake Superior (J. de C. Sowerby, 1836; Smith, 1874a; Clessin, 1882; Dall, 1905; Thomas, 1966)

Lake Huron (Robertson, 1915; La Rocque, 1953: *campanulatum smithi* F.C. Baker)

Lake Ontario (Küster, 1862, + *megastoma* De Kay; Robertson & Blakeslee, 1948)

General Distribution: Vermont west to North Dakota, south to Ohio and Illinois, northward to Great Slave Lake (F.C. Baker, 1928b).

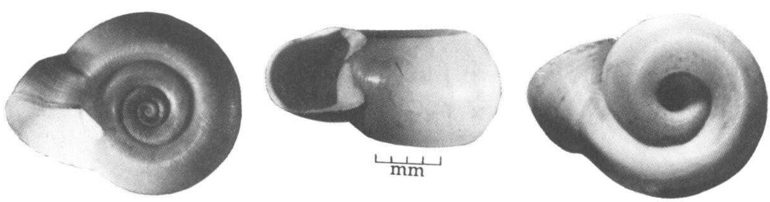

FIG. 54. *Planorbella campanulata campanulata.*

Habitat: "A species of lakes" (F.C. Baker, 1928b). "Occurs in lakes and ponds of all sizes and in slow-moving or backwater portions of rivers. Vegetation is usually present and bottoms are of all types" (Clarke, 1981).

Planorbella campanulata collinsi (F.C. Baker)[44]

Great Lakes Distribution:

Lake Superior (Clarke, 1981).

General Distribution: Northwestern Ontario in the headwaters of the Albany, Winnipeg and Severn river systems (Clarke, 1973).

Habitat: "In lakes and in medium-sized rivers. Substrates are sand or sand and gravel; vegetation is present but varies in abundance" (Clarke, 1981).

Planorbella (Pierosoma) pilsbryi (F.C. Baker)
(Fig. 55)

Great Lakes Distribution:

Lake Huron (Clarke, 1981: *infracarinatum* Baker)

General Distribution: Massachusetts west to Minnesota, northern New York and central Wisconsin northward (F.C. Baker, 1928b) [form *pilsbryi s.s.*]; St. Lawrence River drainage in Georgian Bay and the St. Lawrence River and Rideau River; Canadian Interior Basin from eastern Ontario to central Saskatchewan (Clarke, 1973) [form *infracarinata*]; Vilas County, Wisconsin (F.C. Baker, 1928b) [form *winslowi* F.C. Baker].

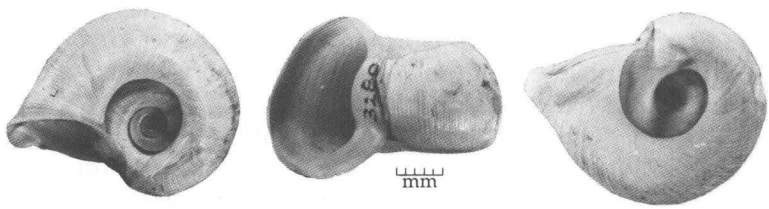

FIG. 55. *Planorbella (Pierosoma) pilsbryi.*

Habitat: In sheltered bays with little wave action; also on exposed lake shore receiving the full force of the waves; on rocks and stones in rapidly moving creek water; near lake shore in shallow water on sand or mud bottom (F.C. Baker, 1928b). "In lakes, ponds, or quiet backwaters of streams, among vegetation, and on various substrates" (Clarke, 1981).

Planorbella (Pierosoma) trivolvis trivolvis (Say)
(Fig. 56)

Great Lakes Distribution:

Lake Superior (J. de C. Sowerby, 1836; Haldeman, 1844; Smith, 1874a)

Lake Michigan (Cooper, 1834)

Lake Huron (Robertson, 1915; F.C. Baker, 1936: *trivolvis trivolvis* and *trivolvis macrostomum* Whiteaves)

Lake Erie (Haldeman, 1844: *trivolvis s.s.* and *trivolvis* *fallax* Haldeman; Letson, 1909; F.C. Baker, 1936; Robertson & Blakeslee, 1948)

Lake Ontario (Clessin, 1882; F.C. Baker, 1945; Robertson & Blakeslee, 1948)

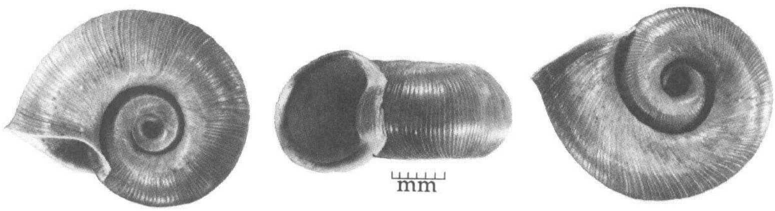

FIG. 56. *Planorbella (Pierosoma) trivolvis trivolvis.*

General Distribution: Northern North America east of the Rocky Mountains, south to Nebraska, northern Illinois, Pennsylvania and New Jersey.

Habitat: "Quiet, more or less stagnant water" (F.C. Baker, 1928b). "Well-vegetated perennial-water lakes, ponds, and slow-moving streams. Mud is the usual substrate" (Clarke, 1981).

Planorbella (Pierosoma) truncata (Miles)

(Fig. 57)

Great Lakes Distribution:

Lake Huron (Miles, 1861; Tryon, 1871; F.C. Baker, 1945)

General Distribution: Michigan, northern Illinois and Wisconsin (F.C. Baker, 1928b).

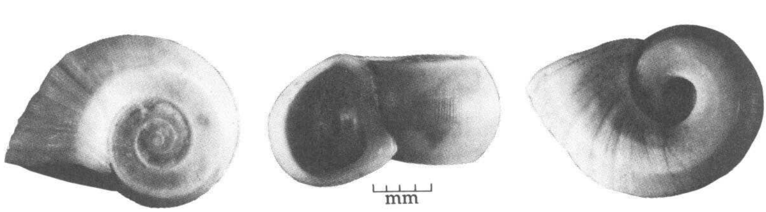

FIG. 57. *Planorbella (Pierosoma) truncata.*

Habitat: "A species of rough water of lakes, never found in stagnant bodies of water." In depths of 0.3m - 4.3m, on mud, sand, hard marl, stone and boulder bottoms (F.C. Baker, 1928b).

Planorbula armigera **(Say)**
(Fig. 58)

Great Lakes Distribution:
Lake Erie (Shelford & Boesel, 1942: *crassilabris* Walker)[45]

General Distribution: New Brunswick west to southeastern Ontario, west to Saskatchewan, northwest to the Mackenzie River system (Clarke, 1973); south to Georgia and Louisiana and west to Nebraska (F.C. Baker, 1928b).

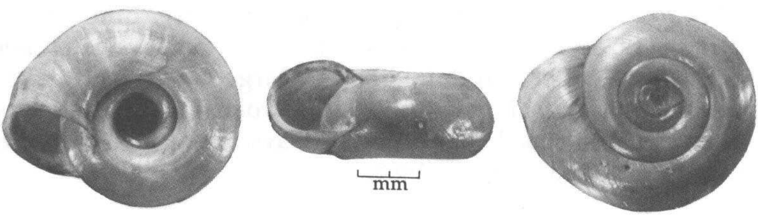

FIG. 58. *Planorbula armigera.*

Habitat: "Largely a species of swales or of small and stagnant bodies of water" (F.C. Baker, 1928b). "Lives among vegetation in most kinds of perennial-water habitats, especially stagnant, heavily-vegetated water bodies. The usual substrate is mud" (Clarke, 1981).

Promenetus exacuous **(Say)**
(Fig. 59)

Great Lakes Distribution:
Lake Superior (Dall, 1905; Walker & Ruthven, 1906; Walker, 1909a; F.C. Baker, 1928b: *megas* Dall)
Lake Michigan (Walker, 1896: *"exacutus"* [*exacuous*])
Lake Huron (Robertson, 1915)

General Distribution: United States east of the Rocky Mountains, north to Alaska and the Mackenzie River, south to New

Mexico (F.C. Baker, 1928b); in Canada absent from Quebec, but widely distributed east of James and Hudson bays, mainly south of the tree-line (Clarke, 1973).

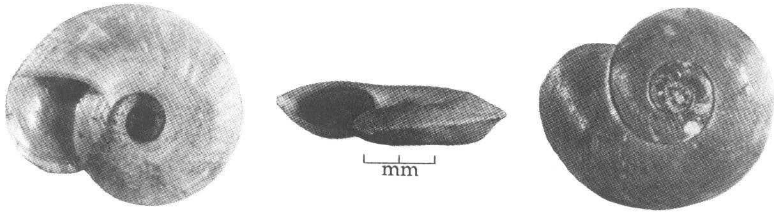

FIG. 59. *Promenetus exacuous.*

Habitat: Generally in more or less marshy, quiet places (Baker, 1928b). "In various kinds of temporary-water and permanent-water habitats, that is large and small lakes, ponds, streams of various widths, roadside ditches, and swamps. Submersed vegetation is always present and the usual substrate is mud" (Clarke, 1981).

Family ANCYLIDAE[46]

***Ferrissia rivularis* (Say)**
(Fig. 60)

Great Lakes Distribution:
Lake Erie (Ahlstrom, 1930[47])
Lake Ontario (Robertson & Blakeslee, 1948)

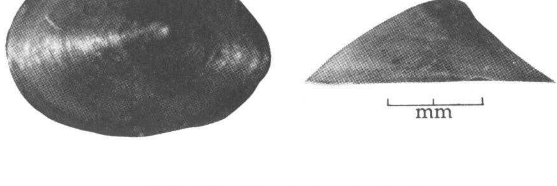

FIG. 60. *Ferrissia rivularis.*

General Distribution: Throughout most of North America; it extends northward into the Hudson Bay lowlands and northwestward to at least Saskatchewan; south to North Carolina and New Mexico and west to California and Oregon (see Clarke, 1973).

Habitat: "The usual habitat of *F. rivularis* is a stream with a gravelly bottom, containing a large portion of stones at least two inches in diameter." Occasionally in earthy silt-laden streams with muddy bottoms (Basch, 1963). Also attached to rocks in exposed habitats in lakes (Clarke, 1981).

Laevapex fuscus (Adams)
(Fig. 61)

Great Lakes Distribution:

Lake Erie (Collections of the Museum of Zoology, The University of Michigan, cat. no. 100458).

General Distribution: United States and Canada, generally east of the Great Plains; Great Lakes area, Florida and southeastern states; generally absent from mountainous areas (Basch, 1963); west to Iowa, Kansas and Oklahoma (Clarke, 1973).

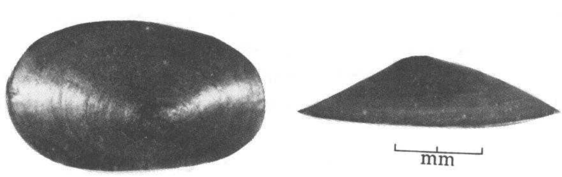

FIG. 61. *Laevapex fuscus.*

Habitat: "In impoundments or cut-off stagnant backwaters of rivers. ... Also found in lakes and occasionally in slow-flowing rivers on dense vegetation near the shores. The substrate is often debris such as cans, bottles, shoes, crockery, and other junk. ... Often found on the undersides of lily pads, on cat-tails, sedges, and other emergent rooted vegetation." Rarely may be found in a stream or in a stagnant pool (Basch, 1963).

SUPPLEMENTAL NOTES

[1]Say (1817) called these pleurocerid specimens "*Lymnaea virginica,*" citing figure 7, plate 117, in "*Lister's* [1770] *conch. tab.*" *Elimia virginica* is actually a more eastern species, now credited to Gmelin (1790). Say (1824) later mentioned "*Melania virginica,* nob.", giving its locality as "Falls of Niagara," omitting any reference to "the Lakes." Still later, he (Say, 1832) again omitted reference to the Great Lakes in referring to *E. virginica,* giving the distribution of this species as the Delaware and Schuylkill rivers.]

[2]Some reports which include gastropods of the Great Lakes have been omitted in making the list of gastropods presented here, because as far as can be ascertained no voucher specimens are available from which identifications can be confirmed, and it cannot be ascertained that the identifications were made with competency. Such papers include those of Langlois (1954), Johnson & Matheson (1968), Hiltunen (1969), Adams & Kregear (1969), Johnson & Brinkhurst (1971a,b,c), Barton & Hynes (1978a,b) and possibly Ahlstrom (1930) [although the latter author is cited in our text] and Wood (1963). Identification of many freshwater mollusks seems to be especially difficult for non-specialists, whose specific determinations generally cannot be relied upon. Other papers omitted in making this list are those which deal with mollusks only at the generic or higher (not at the species) levels. Such papers are of little value in analyzing the Great Lakes gastropod fauna. Included in this category are the papers of Stimpson (1871), Krecker & Lancaster (1933), Teter (1960), Schneider, *et al.* (1969) and Schuytema & Powers (1966). Some papers come under both categories above, e.g., Carr & Hiltunen (1965), Veal & Osmond (1968), Bocsor & Judd (1972), Kinney (1972) and S.C. Mozley (1975) (i.e., some species are listed, of unverifiable identification, and other snails are listed by genus only).

Mackie *et al.* (1980) presented a "checklist of freshwater mollusks in the Laurentian Great Lakes" "based on museum records, benthological surveys, and combines previously published and unpublished species lists." However, information on gastropods seems to have come mostly from a partial survey of the literature, yet little detail is given as to authority for or specific distribution of the species. Also, this paper contains many inaccuracies.

[3]Classification of the Valvatidae is that of Heard (1982).

[4]*Valvata perdepressa* is apparently basically a species confined to the Great Lakes, but it was also reported from the Little Lakes, New York (Walker, 1906).

[5]F.C. Baker (1930) differentiated *Valvata perdepressa walkeri* from *V. perdepressa s.s.* by its "flattened, planorboid shell, the spire often depressed below the level of the body whorl."

[6]Species marked with an asterisk are foreign species introduced into North America.

[7]The typical form of *Valvata tricarinata* is principally found in rivers (F.C. Baker, 1928b), and occurs only rarely in beach debris of southern Lake Michigan (F.C. Baker, 1930).

[8]Clench (1962) placed the following names in the synonymy of *Campeloma crassula* Rafinesque 1819: *ponderosa* Say 1821, *crassa* Deshayes 1830, *heterostropha* Kirtland 1838, *rufa* Haldeman 1841, *subsolidum* Anthony 1844, *eburnea* Rafinesque (in Binney) 1965, *ventricosum* Rafinesque (in Binney) 1965 and *obesum* "Lewis" Binney 1865.

[9]Smith (1874a) cited Lake Superior (*ponderosa* Say) on the authority of Binney (1865b). However, Binney said "Michigan near Lake Superior," not *in* Lake Superior.

[10]*Cipangopaludina chinensis* (Martens) is often placed in the synonymy of *C. japonica* (Martens). However, whether or not the two forms are conspecific cannot be decided on the information currently available.

[11]*Viviparus georgianus* is a native American species, but in recent times it has extended its distribution into the Great Lakes region (see Clench, 1962).

[12]Valenciennes (1827) described *"Paludina lineata"* from Lake Erie, a species which Potiez & Michaud (1838) believed to be the same as *"Paludina" bengalensis* Lamarck from Bengal, India.

[13]*Bythinia tentaculata*, generally regarded as introduced to North America from Europe, was reported by F.C. Baker (1928a) as a Pleistocene fossil in Chicago. For the American form of this species, he gave the name *magnalacustris*, for which he described several minor supposed differences from its European counterpart. The validity of such a taxonomic separation has not been confirmed. That European *B. tentaculata* has been introduced into North America has never been questioned, and it is not known if some or all, or none, of the currently extant populations of *B. tentaculata* in the Great Lakes represent descendants of the introduced populations or their North American Pleistocene ancestors.

[14]Goodrich (1911) observed that *Bythinia tentaculata* was "the most common shell to be seen on the mud flats of [the] two marsh areas [of] a stream forming the northeast border of Toledo, Ohio, less than 100 feet from Maumee Bay, Lake Erie, [and] of a bayou further

to the north." *Bythinia tentaculata* was also reported "in the lagoons on the islands in Toronto Bay" (Latchford, 1914).

[15]F.C. Baker (1928b) gave the subspecific name *superiorensis* to "the Great Lakes manifestation of the *limosa* type of *Amnicola*, characterized by a large, thick shell, which is usually more globose than the variety *porata* of the smaller lakes." The relationships between the large and small lake varieties, and the riverine variety, need to be critically assessed. Clarke (1973) considered *A. limosa superioriensis* to be merely an ecophenotype [as did Baker, who gave nomenclatural recognition to ecophenotypes], and thus not warranting subspecific distinction.

[16]*Birgella subglobosa* has been considered to be mainly a form of the Great Lakes, but also occurring in Oneida Lake and Lake Winnebago (F.C. Baker, 1928b). The river and creek form (*isogona* Say), with a much wider distribution (ranging from Ohio west to Iowa, and from Michigan south to Alabama and Arkansas; Baker, 1928b), is not considered to be taxonomically distinct by Thompson (1984).

[17]In addition to *"Somatogyrus" subglobosa*, Ahlstrom (1930) reported *"Somatogyrus integer* (Say)" from Lake Erie.

[18]*Cincinnatia cincinnatiensis* is largely a riverine species. F.C. Baker (1930) gave the name *chicagoensis* to the "shortened-up race of the river form *cincinnatiensis*, differing in being more globose, with shorter spire and wide umbilicus."

[19]F.C. Baker (1928b) separated the small riverine form of "*Cincinnatia emarginata* Küster" (= *Probythinella lacustris limafodens* Morrison) with closed umbilicus from the larger lake form with open umbilicus and lengthened spire, and named the latter "*canadensis* var. nov." In 1930, he considered "*Cincinnatia emarginata lacustris* Baker" to be a distinct species, the "form with wide, flattened spire whorls," and placed all three of the above forms in his newly created genus *Vancleavia* (= *Probythinella* Thiele 1928). For a discussion of nomenclature of these three forms, see Morrison (1947). Hibbard & Taylor (1960) did not find shell variation within *P. lacustris* to be consistently correlated with either habitat or geographic region, so concluded that variation within the species did not warrant taxonomic recognition. Clarke's (1973) observations supported these conclusions.

[20]*Elimia* H. & A. Adams 1854 is used in this list in place of its better known synonym *Goniobasis* Lea 1862.

[21]*Goniobasis* [= *Elimia*] *livescens michiganensis* F.C. Baker from the Lake Michigan shore, east of Sturgeon Bay, north of Ship Canal, Door Co., Wisconsin, was described (F.C. Baker, 1928b) as the Great Lake form of "*G.*" *livescens*, an "ecological form, the heavier shell,

wider body whorl, and larger aperture being a response to the rough environment of the lake shore"; = *livescens* (Goodrich, 1945).

[22]In the original description of "*Goniobasis* [=*Elimia*] *haldemani*," Tryon (1865a) also gave Lake Champlain as one of its localities, but Goodrich (1939) believed that *E. livescens haldemani* is "confined probably to Lake Erie." This race has a very slender shell, its diameter about half that of typical *E. livescens*.

[23]Smith (1874a) listed *Pleurocera subulare* (Lea) as occurring specifically in Lake Superior on the authority of Tryon (1865b). However, Tryon (*op. cit.*) gives only "Great Lakes ..."

[24]*Pleurocera elevatum* (Say) and *P. elevatum lewisi* (Lea) may possibly belong to the *P. canaliculatum* group.

[25]The genus *Lymnaea* Lamarck 1799 has been used variously to include nearly all members of the Lymnaeidae or only *Lymnaea stagnalis*, its varieties, and several very closely related species (for the latter usage, see F.C. Baker, 1928b; Burch, 1979, 1982a,b; Burch & Tottenham, 1980). The classification of the family used in this list follows the second system.

[26]North American fossarias are difficult to deal with in a survey such as this because their taxonomy is in such an unsatisfactory state. They are widespread and common, and their shells exhibit considerable variability. Snails with those characteristics have always spawned many synonyms. The names associated with the Great Lakes fossarias are *cyclostoma* Walker, *dalli* F.C. Baker, *decampi* Streng, *exigua* Lea, *galbana* Say, *modicella* Say, *obrussa* Say, *parva* Lea, *peninsulae* Walker, *rustica* Lea and *sayi* F.C. Baker. *Fossaria dalli* and *F. parva* are members of the subgenus *Bakerilymnaea*. The other nominal species are members of the subgenus *Fossaria s.s.* Among the latter group, *cyclostoma* and *galbana* seem distinct enough, with *sayi* probably a synonym of *cyclostoma*, and *decampi* a synonym of *galbana*. The remaining five, all members of the *obrussa* species group, are more difficult. *Fossaria peninsulae* has a columellar plait (resembling members of *Stagnicola*), a long and evenly tapered spire, and a reflected columellar lip and an expanded basal lip. *Fossaria exigua* and *F. rustica* are also attenuate, but lack the columellar plait and reflected and expanded columellar and basal lips, and they are more delicate. *Fossaria modicella* seems to be hardly more than a smaller, more bulbous morph of *F. obrussa*. *Fossaria exigua* and *F. rustica* may also be simply morphs of *obrussa*.

[27]Gould's (1850b) "*Limnea desidiosa*, Say. Northern Shore" [Lake Superior] was *Fossaria obrussa* (Say) according to F.C. Baker (1911).

[28]*Fossaria parva* (Lea) was also reported for Lake Erie by Ahlstrom (1930).

[29]*Radix auricularia* was also found by Allen (1911) in "a chain of beach pools on the beach of Lake Erie at Kingsville, Ontario, about opposite Sandusky," and by Goodrich (1911) "in a marshy stream forming the northeast border of Toledo, Ohio, less than 100 feet from Maumee Bay, Lake Erie" and "on the marshy borders of a bayou further to the north".

[30]Currier (1868) and Tryon (1871) listed "Lake Superior" for *Stagnicola lanceata,* but they simply copied Gould's (1848, 1850b, 1862) description, but without as precise a locality. The locality given by Gould was "Pic Lake", north shore of Lake Superior.

[31]Binney (1865a) and Smith (1874a) reported "*Limnaea caperata* Say" from Lake Superior. However, it is doubtful if *Stagnicola caperata* lives in any of the Great Lakes.

[32]*Stagnicola elodes* was reported by Robertson (1915) from Georgian Bay, Lake Huron, but in shallow island pools, not in the lake itself.

[33]Smith (1874a) also reported "*Limnaea caperata* Say ... in abundance upon the rocky shores of St. Ignace Island and at Michipicoton Island; also from the stomach of a white fish taken at Sault Sainte Marie." However, the rocky shores of one or more of the Great Lakes does not seem to be likely habitats for *Stagnicola (Hinkleyia) caperata,* which places doubt on Smith's identification.

[34]Gould (1850a) stated that "*L. catascopium, L. emarginata,* and *L. pinguis,* are in reality but one."

[35]Clarke (1973) recognized *nasoni* as a subspecies of *Stagnicola catascopium.* Clarke did not distinguish between *S. catascopium* and *S. emarginata,* placing the latter in the synonymy of the former.

[36]Baker (1911) placed Walker & Ruthven's *decollata* Mighels in the synonymy of *apicina* Lea, which was considered to be a synonym of *catascopium* Say by Clarke (1973). F.C. Baker (1926) later named these "*apicina*" lake forms *walkeriana* n. sp.

[37]Although the title given to Gould's (1847) article containing the description of *Physa vinosa* says "on the shores of Lake Superior," the locality given in the description of the species is "from the Lake Superior region." Gould (1850b) gave its locality as "northern coast, Michipicotin."

[38]Currier (1868) said the following about this record for *Physella vinosa*: "The shell catalogued (*American Journal of Conchology,* Vol. 1, page 294) as *P. vinosa,* does not agree with description and

figure in anything except color. I gave it on the authority of Dr. Lewis, of Mohawk, N.Y., from specimens obtained at Grand Haven.

[39]F.C. Baker (1930) considered the form of *Physa integra* (Haldeman) with smaller shell and more regular aperture to be a subspecies (*Physa integra billingsi* F.C. Baker) restricted to lakes and river estuaries.

[40]Crandall (1901) gave the distribution of "*Physa*" *niagarensis* Lea as "along the Great Lakes." Letson (1909) recorded this nominal species from Lake Erie, and *Physella heterostropha* as well ("universal in all stations," which included Lake Erie). Robertson & Blakeslee (1948) included *P. niagarensis* in the synonymy of *Physella integra*, even though Crandall stated "I feel satisfied that this form is not a variety of *P. integer*. If it is not entitled to rank as a species, it should be referred to *P. heterostropha* as a variety." The identity of "*P. heterostropha*" in the Great Lakes needs to be determined.

[41]Haldeman (1844) used the name *Planorbis albus* Müller, with *P. hirsutus* Gould in synonymy, and with the geographic distribution for the species he included "Lake Superior to Saskatchewan" in quotes.

[42]Clarke (1973) placed *Gyraulus hornensis* in the synonymy of *G. deflectus* (Say).

[43]Species of *Planorbella* in the older literature on North American mollusks are all referred to the genus *Planorbis* (a genus now restricted to the Old World), and in the later literature to the genus *Helisoma*.

[44]*Planorbella campanulata collinsi*, a subspecies of doubtful validity, differs from *Planorbella companulata s.s.* by having a spire that projects above the body whorl.

[45]Also reported by Robertson & Blakeslee (1948) [as *Planorbula jenksii* (Carpenter)] from a "beach pool along Port Colborne Park, Lake Erie."

[46]The low conical shape of freshwater limpets obviously evolved as a result of the stress of a turbulent aquatic environment (either riverine or lentic), and large lakes such as Baikal and Ohrid have peculiar endemic limpet faunas. The Great Lakes are too young for freshwater limpets to have evolved in them, and none of the species in the surrounding drainage area seem to have been able to adapt to habitats in the Great Lakes.

[47]In addition to *Ferrissia rivularis*, Ahlstrom (1930) reported *F. parallela* (Haldeman) in Lake Erie (Squaw Harbor).

LITERATURE CITED*

ADAMS, C.E. & KREGEAR, R.D. 1969. Sedimentary and faunal environments of eastern Lake Superior. *Proceedings of the Twelfth Conference on Great Lakes Research,* International Association for Great Lakes Research, pp. 1-20.

ADAMSTONE, F.B. 1924. The distribution and economic importance of the bottom fauna of Lake Nipigon with an appendix on the bottom fauna of Lake Ontario. *University of Toronto Studies, Publications of the Ontario Fisheries research Laboratory,* (24): 35-100, Pls. 1-4.

AHLSTROM, Elbert H. 1930. Mullusks [sic] collected in Bass Island region, Lake Erie. *The Nautilus,* 44(2): 44-48.

ALLEN, John A. 1911. *Lymnaea auricularia* Linné in Canada. *The Nautilus,* 25(5): 60.

BAKER, Frank Collins. 1901. Description of a new species of *Limnaea. Bulletin of the Chicago Academy of Sciences,* 2(4): 229-230.

BAKER, Frank Collins. 1902. The Mollusca of the Chicago area. Part 2, The Gastropoda. *Bulletin of the Chicago Academy of Science, Natural History Survey,* 9(2): 131-410, index 8 pp., pls. 28-36.

BAKER, Frank Collins. 1905. New species of *Lymnaea. The Nautilus,* 18(12): 141-142.

BAKER, Frank Collins. 1906. Notes on a collection of mollusks from the vicinity of Alpena, Michigan. *Transactions of the Academy of Science of St. Louis,* 16(2): 1-15, 1 pl.

BAKER, Frank Collins. 1911. *The Lymnaeidae of North and Middle America, Recent and fossil.* The Chicago Academy of Sciences, Special Publication No. 3, pp. i-xvi, 1-539, pls. 1-58.

BAKER, Frank Collins. 1919. The ecology of North American Lymnaeidae. *Science,* 49(1274): 519-521.

BAKER, Frank Collins. 1926. New forms of *Planorbis* and *Lymnaea* with notes on other forms. *The Nautilus,* 39(4): 116-121.

BAKER, Frank Collins. 1928a. The American *Bithynia* not wholly an introduced species. *Transactions of the Illinois State Academy of Science,* 20: 56-62, 1 pl.

BAKER, Frank Collins. 1928b. *The fresh water Mollusca of Wisconsin.* Wisconsin Geological and Natural History Survey, Bulletin 70(1): i-xx, 1-507, pls. 1-28.

BAKER, Frank Collins. 1930. The molluscan fauna of the southern part of Lake Michigan and its relationship to old glacial Lake Chicago. *Transactions of the Illinois State Academy of Science,* 22: 186-194.

*Many references on "benthos," "macrobenthos," "benthic macrofauna" or "zoobenthos" of the Great lakes do not include gastropods and so are not cited in the text or listed here.

BAKER, Frank Collins. 1932. *Stagnicola apicina* and *Stagnicola walkeriana*. *The Nautilus*, 45(4): 139-140.

BAKER, Frank Collins. 1934. A new species of *Gyraulus* from Canada. *The Canadian Field-Naturalist*, 48(8): 135.

BAKER, Frank Collins. 1936. The freshwater mollusc *Helisoma corpulentum* and its relatives in Canada. *National Museum of Canada, Bulletin*, (79): 1-37.

BAKER, Frank Collins. 1945. *The molluscan family Planorbidae.* University of Illinois Press, Urbana. Pp. 1-530.

BAKER, H. Burrington. 1911. A biological survey of the sand dune region of the south shore of Saginaw Bay, Michigan. *Michigan Geological and Biological Survey Publication*, (6): 121-176.

BARTON, D.R. & HYNES, H.B.N. 1978a. Wave-zone macrobenthos of the exposed Canadian shores of the St. Lawrence Great Lakes. *Journal of Great Lakes Research*, 4(1): 27-45.

BARTON, D.R. & HYNES, H.B.N. 1978b. Seasonal variations in densities of macrobenthic populations in the wave-zone of north-central Lake Erie. *Journal of Great Lakes Research*, 4(1): 50-56.

BASCH, Paul F. 1963. A review of the Recent freshwater limpet snails of North America (Mollusca: Pulmonata). *Bulletin of the Museum of Comparative Zoology at Harvard University*, 129(8): 399-461.

BECK, H. 1837 [-1838a]. *Index molluscorum præsentis ævi musei principis augustissimi Christiani Frederici. Fasciculus primus et secundus, Mollusca Gastræopoda Pulmonata.* Pp. 1-100 (1837), 101-124, 1-8 (1838). Hafniæ.

BECK, H. 1838b. *Index molluscorum præsentis ævi musei principis augustissimi Christiani Frederici. Fasciculus primus.* Pp. 1-124. Hafniæ.

BERRY, Elmer G. 1943. The Amnicolidae of Michigan: distribution, ecology, and taxonomy. *Miscellaneous Publications of the Museum of Zoology, University of Michigan*, (57), 1-68, pls. 1-9.

BINNEY, William G. 1865a. Land and fresh water shells of North America. Pt. 2. Pulmonata Limnophila and Thalassophila. *Smithsonian Miscellaneous Collections*, 7(2): i-ix, 1-161.

BINNEY, William G. 1865b. Land and fresh water shells of North America. Pt. 3. Ampullariidae, Valvatidae, Viviparidae, fresh-water Rissoidae, Cyclophor-idae, Truncatellidae, fresh-water Neritidae, Helicinidae. *Smithsonian Mis-cellaneous Collections*, 7(3): i-viii, 1-120.

BOCSOR, J.G. & JUDD, J.H. 1972. Effect of paper plant pollution and subsequent abatement on a littoral macroinvertebrate community in Lake Ontario: Preliminary survey. *Proceedings of the Fifteenth Conference on Great Lakes Research*, International Association for Great Lakes Research, pp. 21-34.

BROOKS, Stanley T. 1931. The gastropod family Pleuroceridae in Pennsylvania. *The Nautilus*, 45(2): 58-64.

BURCH, J.B. 1979. Genera and subgenera of Recent freshwater gastropods of North America (north of Mexico). *Malacological Review*, 12(1/2): 97-100.

BURCH, J.B. 1982a. *Freshwater snails (Mollusca: Gastropoda) of North*

America. Environmental Monitoring and Support Laboratory, Office of Research and Development, United States Environmental Protection Agency, Cincinnati, Ohio, EPA-600/3-82-026, pp. i-vi, 1-294.

BURCH, J.B. 1982b. North American freshwater snails. Identification keys, generic synonymy, supplemental notes, glossary, references, index. *Walkerana,* 1(4): 217-365.

BURCH, J.B. & TOTTENHAM, John L. 1980. North American freshwater snails. *Walkerana,* 1(3): 81-215.

BURCH, J.B. & VAN DEVENDER, 1980. Identification of eastern North American land snails. The Prosobranchia, Opisthobranchia and Pulmonata (Actophila). *Walkerana,* 1(2): 33-80.

CARR, John F. & HILTUNEN, Jarl K. 1965. Changes in the bottom fauna of western Lake Erie from 1930 to 1961. *Limnology and Oceanography,* 10(4): 551-569.

CLARKE, Arthur H. 1973. The freshwater mollusks of the Canadian Interior Basin. *Malacologia,* 13(1/2): 1-509.

CLARKE, Arthur H. 1981. *The freshwater mollusks of Canada.* National Museum of Natural Sciences, National Museums of Canada, Ottawa. Pp. 1-446.

CLENCH, William J. 1962. A catalogue of the Viviparidae of North America, with notes on the distribution of *Viviparus georgianus* Lea. *Occasional Papers on Mollusks,* The Department of Mollusks, Museum of Comparative Zoology, Harvard University, 2(27): 261-287.

CLENCH, William J. & FULLER, Samuel L.H. 1965. The genus *Viviparus* (Viviparidae) in North America. *Occasional Papers on Mollusks,* The Department of Mollusks, Museum of Comparative Zoology, Harvard University, 2(32): 385-412.

CLENCH, William J. & TURNER, Ruth D. 1955. The North American genus *Lioplax* in the family Viviparidae. *Occasional Papers on Mollusks,* The Department of Mollusks, Museum of Comparative Zoology, Harvard University, 2(19): 1-20.

CLESSIN, S. 1878-1886. Die Familie der Limnaeidaen enthalten die Genera *Planorbis, Limnaeus, Physa* und *Amphipeplea.* In: *Systematisches Conchylien-Cabinet von Martini und Chemnitz,* 1(17): 29-36a, 63-430, pls. 11-15, 17-55. Bauer und Raspe, Nurnberg.

COOPER, William. 1834. List of shells collected by Mr. Schoolcraft, in the Western and Northwestern Territory. Pp. 153-156. Appendix to *Narrative of an expedition through the upper Mississippi to Itasca Lake, the actual source of this river; embracing an exploratory trip through the St. Croix and Burntwood (our Broule) rivers; in 1832.* Under the direction of Henry R. Schoolcraft. Harper and Brothers, New York.

CRANDALL, O.A. 1901. The American physae. *The Nautilus,* 15(5): 54-58.

CURRIER, A.O. 1868. List of the shell-bearing Mollusca of Michigan, especially of Kent and Adjoining Counties. *Kent Scientific Institute, Miscellaneous Publications,* (1): 1-11.

DALL, William Healey, 1905. Land and fresh water mollusks of Alaska and adjoining regions. Pp. vii-xii, 1-171, pls. 1, 2. In: Merriam, C. Hart (Ed.), *Alaska*, vol. 8, pp. i-xii, 1-250, pls. 1-15. Doubleday, Page and Co., New York. [Reprinted in 1910 as the Harriman Alaska Series of the Smithsonian Institution, Vol. 13.]

DAZO, Bonifacio Capili. 1965. The morphology and natural history of *Pleurocera acuta* and *Goniobasis livescens* (Gastropoda: Cerithiacea: Pleuroceridae). *Malacologia*, 3(1): 1-80; 3(3): 475-476 (1966).

DeCAMP, Wm. H. 1881. List of the shell-bearing Mollusca of Michigan. *Kent Scientific Institute, Miscellaneous Publications*, (5): 1-15, 1 pl.

DE KAY, James E. 1843. *Zoology of New York. Pt. 5. Mollusca.* Carroll and Cook, Albany, New York. Pp. i-viii, 1-271, pl. 1-40.

GMELIN, J.F. 1788-1793. Linnaeus *Systema naturae* ... ed. 18, aucta reformata. Lipsae. 1: 1-232 (1788); pp. 233-1032 (1789); pp. 1033-1516 (1789); pp. 1517-2224 (1790); pp. 2225-3020 (1791); pp. 3021-3910 (1791); pp. 3911-4120 (1792); 2: xl, pp. 1-884 (1791); pp. 885-1661 (1792); 3: pp. 1-476 (1793).

GOODRICH, Calvin. 1911. *Lymnaea auricularia* in Ohio. *The Nautilus*, 25(1): 11-12.

GOODRICH, Calvin. 1917. *Pleurocera subulare* Lea. *The Nautilus*, 30(11): 122-124.

GOODRICH, Calvin. 1920. Goniobases of Ohio. *The Nautilus*, 33(3): 73-74.

GOODRICH, Calvin. 1932. *The Mollusca of Michigan.* University Museums, University of Michigan, Michigan Handbook Series, (5): i-iii, 1-121, pls.1-7.

GOODRICH, Calvin. 1939. Pleuroceridae of the St. Lawrence River basin. *Occasional Papers of the Museum of Zoology, University of Michigan*, (404): 1-4.

GOODRICH, Calvin. 1940. Civilization and aquatic mollusks. *The Nautilus*, 54(1): 6-10.

GOODRICH, Calvin. 1945. *Goniobasis livescens* of Michigan. *Miscellaneous Publications of the Museum of Zoology, University of Michigan*, (64), pl. 1, fig.1, 1 map.

GOODRICH, Calvin & VAN DER SCHALIE, Henry. 1939. Aquatic mollusks of the Upper Peninsula of Michigan. *Miscellaneous Publications of the Museum of Zoology, University of Michigan*, (43): 1-45.

GOULD, [Augustus A.] 1847. [Description of a new species of *Physa*, among the shells collected by Dr. C.T. Jackson on the shores of Lake Superior; together with two other new species of North American shells.]. *Proceedings of the Boston Society of Natural History*, 2: 262-263.

GOULD, [Augustus A.] 1848. [Description of new shells]. *Proceedings of the Boston Society of Natural History*, 3: 64-65.

GOULD, Augustus A. 1850a. [Specimens of *Lymnaea* from Lake Superior]. *Proceedings of the Boston Society of Natural History*, 3: 181.

GOULD, Augustus A. 1850b. Catalogue of shells with descriptions of new species. In: Agassiz, Louis, *Lake Superior: its physical character, vegetation, and animals, compared with those of other and similar* *regions.* Gould, Kendall and Lincoln, Boston. Pp. i-xii, 10-428, pl.s 1-8, 1 map, eight figures of landscapes [pp. 243-245].

GOULD, Augustus A. 1862. *Otia conchologica. Descriptions of shells and mollusks, from 1839-1862.* Gould and Lincoln, Boston. 256 pp.

HALDEMAN, S. Stedman. 1842-45 [1840-71]. *A monograph of the freshwater univalve Mollusca of the United States* [or *A monograph of the limniades or freshwater univalve shells of North America*]. J. Dobson, Philadelphia. 231 pp., 40 pls. [No. 1, 1840, *Paludina*, pp. 1-16 (signatures F1-2) pls. 1-5; No. 3, 1841, cover page 4 [Notices]; No. 4, 1842, *Limnea*, pp. 17-32 (signatures J3-4), pls. 6-10; No. 7, 1844, *Planorbis*, pp. 1-32 (signatures K1-4), pls. 1-4.]

HEARD, William H. 1982. Family Valvatidae. In: Burch, J.B. 1982. *Freshwater snails (Mollusca: Gastropoda) of North America.* Environmental Monitoring and Support Laboratory, Office of Research and Development, United States Environmental Protection Agency, Cincinnati, Ohio, EPA-600/3-82-026, pp. i-vi, 1-294 [pp. 15-16, 67-74].

HERRINGTON, H.B. 1947. *Acella haldemani* in Ontario, Canada. *The Nautilus,* 61(1): 20-25.

HERSHLER, Robert & THOMPSON, Fred G. 1987. North American Hydrobiidae (Gastropoda: Rissoacea): redescription and systematic relationships of *Tyronia* Stimpson, 1865 and *Pyrgulopsis* Call and Pilsbry, 1886. *The Nautilus,* 101(1): 25-32.

HIBBARD, Claude W. & TAYLOR, Dwight W. 1960. Two late Pleistocene faunas from southwestern Kansas. *Contributions from the Museum of Paleontology, The University of Michigan,* 16(1): 1-223, pls. 1-16.

HILTUNEN, Jarl K. 1969. Invertebrate macrobenthos of western Lake Superior. *The Michigan Academician,* 1: 123-133.

JACKSON, C.T. 1844. [Comments on specimens taken while on a tour to Lake Superior]. *Proceedings of the Boston Society of Natural History,* 1: 198.

JOHNSON, M.G. & BRINKHURST, R.O. 1971a. Associations and species diversity in benthic macroinvertebrates of Bay of Quinte and Lake Ontario. *Journal of the Fisheries Research Board of Canada,* 28(11): 1683-1697.

JOHNSON, M.G. & BRINKHURST, R.O. 1971b. Production of benthic macroinvertebrates of Bay of Quinte and Lake Ontario. *Journal of the Fisheries Research Board of Canada,* 28(11): 1699-1714.

JOHNSON, M.G. & BRINKHURST, R.O. 1971c. Benthic community metabolism in Bay of Quinte and Lake Ontario. *Journal of the Fisheries Research Board of Canada,* 28(11): 1715-1725.

JOHNSON, M.G. & MATHESON, D.H. 1968. Macroinvertebrate communities of the sediments of Hamilton Bay and adjacent Lake Ontario. *Limnology and Oceanography,* 13(1): 99-111.

KINDLE, Edward M. 1934. Adaptive coloration in a freshwater gastropod. *Bulletin of the Wagner Free Institute of Science,* 9(4): 136-143, fig. 2.

KINNEY, Wesley L. 1972. The macrobenthos of Lake Ontario. *Proceedings of the Fifteenth Conference on Great Lakes Research,* International

Association for Great Lakes Research, pp. 53-79.

KRECKER, Frederick H. 1924. Conditions under which *Goniobasis livescens* occurs in the island region of Lake Erie. *The Ohio Journal of Science,* 24(6): 299-300.

KRECKER, Frederick H. & LANCASTER, L.Y. 1933. Bottom shore fauna of western Lake Erie: A population study to a depth of six feet. *Ecology,* 14(2): 79-93.

KRIEGER, Kenneth A. 1984. Benthic macroinvertebrates as indicators of environmental degradation in the southern nearshore zone of the central basin of Lake Erie. *Journal of Great Lakes Research,* 10(2): 197-209.

KÜSTER, H.C. 1862-1863. Die Gattungen *Limnaeus, Amphipeplea, Chilina, Isidora* und *Physopsis.* In: *Systematisches Conchylien-Cabinet von Martini und Chemnitz,* 1(17B): 1-77, pls. 1-12. Bauer und Raspe, Nurnberg.

LANGLOIS, Thomas H. 1954. *The western end of Lake Erie and its ecology.* J.W. Edwards, Ann Arbor, Michigan. Pp. i-xx, 1-479.

LA ROCQUE, Aurèle. 1953. Catalogue of the Recent Mollusca of Canada. *National Museum of Canada Bulletin,* (129): i-ix, 1-406.

LATCHFORD, F.R. 1914. *Valvata piscinalis* in Canada. *The Nautilus,* 28(1): 10.

LAURITSEN, Diane D. & WHITE, David S. 1981. Comparative studies of the zoobenthos of a natural and a man-made rocky habitat on the eastern shore of Lake Michigan. *Special Report No. 74 of the Great Lakes Research Division,* The University of Michigan, pp. 1-65.

LETSON, Elizabeth J. 1909. A partial list of the shells found in Erie and Niagara counties, and the Niagara Frontier. *Bulletin of the Buffalo Society of Natural Science,* 9(2): 239-245.

LISTER, Martini. 1770. *Historiae sive synopsis methodicae Conchyliorum, et tabularum anatomicarum.* Editio altera. i-iv, 435 pages [unpaginated] of figures, indices pp. 1-12, 1-77, fig. legends pp. 1-7, notes and observations pp. 1-6. Typgrapheo Clarendoniano, Oxxonii.

MACKIE, Gerry L., WHITE, David S. & ZDEBA, Thomas W. 1980. *A guide to freshwater mollusks of the Laurentian Great Lakes with special emphasis on the genus* Pisidium. Environmental Research Laboratory, Office of Research and Development, United States Environmental Protection Agency, Duluth, Minnesota, EPA-600/3-80-068, pp. i-vi, 1-142.

MENKE, Carolo Theodoro. 1830. *Synopsis methodica molluscorum generum omnium et specierum earum, quae in Museum Menkeano adservatur; cum synonymia critica et novarum specierum diagnosibus.* Revised edition. Georgi Uslar, Pyrmonti. Pp. i-xvi, 1-168, + 1 p. errata typographica.

MILES, M. 1861. *Report on the zoology of Michigan, for the years 1859-60.* John A. Kerr and Co., Lansing. Pp. 1-31.

MILLER, Barry B. 1966. Five Illinoian molluscan faunas from the southern Great Plains. *Malacologia,* 4(1): 173-260.

MORRISON, J.P.E. 1932. Studies on the life history of *Acella haldemani* ("Desh." Binney). *Transactions of the Wisconsin Academy of Sciences, Arts and Letters,* 27: 397-414.

MORRISON, J.P.E. 1947. Notes on the genus *Probythinella* (Hydrobiinae). The *Nautilus*, 61(1): 25-28.

MOZLEY, Alan. 1938. The fresh-water Mollusca of Sub-Arctic Canada. *Canadian Journal of Research*, section D, 16(5): 93-138.

MOZLEY, Samuel C. 1975. *Preoperational investigations of zoobenthos on southeastern Lake Michigan near the Cook Nuclear Plant.* Special Report No. 56 of the Great Lakes Research Division, University of Michigan, Ann Arbor, pp. 1-132.

PILSBRY, Henry A. 1890. Preliminary notices of new Amnicolidae. *The Nautilus*, 4(5): 52-53.

PILSBRY, Henry A. 1898. Notes on new and little-known Amnicolidae. *The Nautilus*, 12(4): 42-44.

POTIEZ, Valery-Louis-Victor & MICHAUD, Andre-Louis-Gaspard. 1838-1844. *Galerie des mollusques, ou catalogue methodique, descriptif et raisonne des Mollusques et Coquilles du Museum de Douaii.* Vol. 1 (1838), i-xxxvi, 1-562, i-iv; vol. 2 (1844), xxxvii-xliv, 1-507, i-iii; atlas, pp 1-79, pls. 1-70. J.B. Baillière, Paris.

RAFINESQUE, Constantine Samuel. 1831. *Enumeration and account of some remarkable natural objects in the cabinet of Prof. Rafinesque, in Philadelphia.* C.S. Rafinesque, Philadelphia. Pp. 1-4.

REEVE, L.A. 1860. Monograph of the genus *Melania.* In: *Conchologica Iconica: or illustrations of the shells of molluscous animals.* 20 vols. London.

ROBERTSON, A.D. 1915. The Mollusca of Georgian Bay. Sessional Paper No. 39b, Supplement to the 47th Annual Report of the Department of Marine and Fisheries, Fisheries Branch, pp. 95-111, pls. 10-12.

ROBERTSON, Imogene C.S. & BLAKESLEE, Clifford L. 1948. The Mollusca of the Niagara frontier region and adjacent territory. *Bulletin of the Buffalo Society of Natural Sciences*, 19(3): i-xi, 1-191, map.

ROSSMÄSSLER, E.A. 1835. *Iconographie der Land- und Süsswasser-Mollusken, mit vorzüglicher Berücksichtigung der europäischen noch nicht abgebildeten Arten.* (1): 1-132, 4 pls. Arnoldische Buchhandung, Dresden und Leipzig.

SAY, Thomas. 1817. Conchology. 15 pp., 4 pls. In: Nicholson, William, 1816-1817, *American edition of the British encyclopedia, or dictionary of arts and sciences comprising an accurate and popular view of the present improved state of human knowledge.* First edition. Vol. 1, 1816; vols. 2-6, 1817 [vol.2, B.....E]; no pagination. Samuel A. Mitchell and Horace Ames, Philadelphia.

SAY, Thomas. 1821. Descriptions of univalve shells of the United States. *Journal of the Academy of Natural Sciences of Philadelphia*, 2(1): 149-179.

SAY, Thomas. 1824. In: Keating's *Narrative of an expedition to the St. peter's River, ..., under the command of Major Stephen H. Long.* Philadelphia. Vol. 2, Appendix, pp. 256-265, pls 14, 15.

SAY, Thomas. 1830-1834. *American conchology, or descriptions of the shells* *of North America. Illustrated by coloured figures from original drawings executed from nature.* Printed at the School Press, New-Harmony, Indiana. iii, 253 pp. [not paginated], pls. 1-68. [Pt. 1: title p.; dedication; 38 text pp. [no pagination in this or succeeding parts], pls. 1-10, 1830; Pt. 2: 37 text pp., pls. 11-20, 1831; Pt. 3: 39 text pp., pls. 21-30, 1831; Pt. 4: 35 text pp., pls. 31-40, 1832; Pt. 5: 40 text pp., pls. 41-50, 1832; Pt. 6: 48 text pp., pls. 51-60; Pt. 7: 16 text pp., 1 p. appendix, pls. 61-68, 1834].

SCHNEIDER, James C., HOOPER, Frank F. & BEETON, Alfred M. 1969. The distribution and abundance of benthic fauna in Saginaw Bay, Lake Huron. *Proceedings of the Twelfth Conference on Great Lakes Research,* International Association for Great Lakes Research, pp. 80-90.

SCHUYTEMA, Gerald S. & POWERS, Ross E. 1966. The distribution of benthic fauna in Lake Huron. *Proceedings of the Ninth Conference on Great Lakes Research,* Great Lakes Research Division, Institute of Science and Technology, The University of Michigan, Publication No. 15, pp. 155-163.

SHELFORD, V.E. & BOESEL, M.W. 1942. Bottom animal communities of the island area of western Lake Erie in the summer of 1937. *The Ohio Journal of Science,* 42(5): 179-190.

SMITH, Sidney I. 1874a. Sketch of the invertebrate fauna of Lake Superior. Pp. 690-707. United States Commission on Fish and Fisheries, Part 2, Report of the Commissioner for 1872 and 1873. *Forty-second Congress, Senate, Miscellaneous Document No. 74,* Government Printing Office, Washington, D.C.

SMITH, Sidney I. 1874b. Food of fresh-water fishes. Pp. 708-709. United States Commission on Fish and Fisheries, Part 2, Report of the Commissioner for 1872 and 1873. *Forty-second Congress, Senate, Miscellaneous Document No. 74,* Government Printing Office, Washington, D.C.

SMITH, Sidney I. & VERRILL, A.E. 1871. Notice of the Invertebrata dredged in Lake Superior in 1871, by the U.S. Lake Survey, under the direction of Gen. C.B. Comstock, S.I. Smith, naturalist. *The American Journal of Science and Arts,* 2(7-12): 448-449.

SOWERBY, G.B. (2nd). 1873-1874 Monograph of the genus *Physa.* In: Reeve, Lovell, 1843-1878, *Conchologica Iconica: or illustrations of the shells of molluscous animals,* Vol. 19, 27 pp., pls. 1-12. Reeve, Benham and Reeve, London.

SOWERBY, J. de C. 1836. [Freshwater Mollusca of northern parts of British America]. Pp. 315-316. In: Richardson, J., 1829-1837, *Fauna Boreali-Americana,* Pt. 3, London.

STIMPSON, William. 1871. On the deep-water fauna of Lake Michigan. *The American Naturalist,* 4(7): 403-405.

TAYLOR, Dwight W., 1960. Late Cenozoic molluscan faunas from the High Plains. *United States Geological Survey Professional Paper,* No. 337, pp. i-iv, 1-94, pls. 1-4.

TETER, Harold E. 1960. The bottom fauna of Lake Huron. *Transactions of the American Fisheries Society,* 89(2): 193-197.

THOMAS, M.L.H. 1966. Benthos of four Lake Superior bays. *The Canadian Field-Naturalist*, 80(4): 200-212.

THOMPSON, Fred G. 1977. The hydrobiid snail genus *Marstonia*. *Bulletin of the Florida State Museum*, Biological Sciences, 21(3): 113-158.

THOMPSON, Fred G. 1984. North American freshwater snail genera of the hydrobiid subfamily Lithoglyphinae. *Malacologia*, 25(1): 109-141.

TRYON, George W., Jr. 1865a. Description of new species of Strepomatidae. *American Journal of Conchology*, 1(1): 38, pl. 1.

TRYON, George W., Jr. 1865b. Monograph of the family Strepomatidae. *American Journal of Conchology*, 1(4): 299-341.

TRYON, George W., Jr. 1870-71. *A monograph of the fresh-water univalve Mollusca of the United States*. Conchological Section, Academy of natural Sciences of Philadelphia. 238 pp., 17 pls. [Pt. 2, Physidae, Limnaeinae, *Limnaea*, pp. 83-124, pls. 16-18, 1971; pt. 3, *Physa*, *Bulinus*, Pompholinae, Planorbidae, pp. 125-186, pls. 6-9, 1871; pt.4, Planorbidae, *Carinifex*, *Planorbis*, *Segmentina*, Ancylinae, pp. 187-238, pls. 2, 5-7, 1871.]

TRYON, George W., Jr. 1873. Land and fresh-water shells of North America. Part IV. Strepomatidae (American melanians). *Smithsonian Miscellaneous Collections*, 16(1): i-lv, 1-435.

VAIL, Virginia A. 1979. A preliminary revision of Florida *Lioplax* (Gastropoda: Viviparidae), with a description of *Lioplax talquinensis* sp. nov. *Malacological Review*, 12(1/2): 87-88.

VALENCIENNES, A. 1827-1832. Coquilles univalves terrestres et fluviatiles, rapportees par MM. A. de Humboldt et A. Bonpland. Pp. 239-261. In: Humboldt, Al. and Bonpland, A., 1813-1832, *Recueil d'observations de zoologie et d'anatomie comparee, faites dans l'ocean Atlantique, dans l'interieur du nouveau continent et dans la mer du sud pendant les anees 1799, 1800, 1801, 1802 et 1803*. Vol. 2, 352 pp. J. Smith, Paris.

VANATTA, E.G. 1915. Two new varieties of *Valvata*. *The Nautilus*, 28(9): 104-105.

VEAL, D.M. & OSMOND, D.S. 1968. Bottom fauna of the western basin and near-shore Canadian waters of Lake Erie. *Proceedings of the Fifteenth Conference on Great Lakes Research*, International Association for Great Lakes Research, pp. 151-160.

WALKER, Bryant. 1894. Shells of the Saginaw Valley, Michigan. *The Nautilus*, 7(11): 125-129.

WALKER, Bryant. 1895. A month with the Michigan Fish Commission. *The Nautilus*, 9(1): 2-6.

WALKER, Bryant. 1896. Report upon the Mollusca collected in the vicinity of Charlevoix, Michigan, in the summer of 1894. *Bulletin of the Michigan Fish Commission*, 6: 96-99.

WALKER, Bryant. 1901. New varieties of *Physa ancillaria* Say. *The Nautilus*, 14(9): 97-99.

WALKER, Bryant. 1906. Notes on *Valvata*. *The Nautilus*, 20(3): 25-32, pl. 1.

WALKER, Bryant. 1908. New Michigan lymnaeas. *The Nautilus*, 22(1): 4-9, pls. 1,2; 22(2): 16-19, pls. 1, 2.

WALKER, Bryant. 1909a. An annotated list of the Mollusca of Isle Royale, Michigan. Pp. 281-298, figs. 61-63. In: Adams, Charles C. (Ed.), *An ecological survey of Isle Royale, Lake Superior.* State Biological Survey, Report of the Board of the Geological Survey for 1908, Lansing, Michigan. Pp. i-xiv, 1-468.

WALKER, Bryant. 1909b. Notes on *Planorbis* II. *P. bicarinatus. The Nautilus,* 23(1): 1-10, pls. 1,2; 23(2): 21-32, pl. 3.

WALKER, Bryant. 1915. Results of the Mershon expedition to the Charity Islands, Lake Huron. *Occasional Papers of the Museum of Zoology, University of Michigan,* (7): 1-7.

WALKER, Bryant. 1918a. The Mollusca. Pp. 957-1020, In: Ward, Henry Baldwin & Whipple, George Chandler, *Fresh-water biology,* John Wiley and Sons, New York. 1111 pp.

WALKER, Bryant. 1918b. Synopsis of the classification of the fresh-water Mollusca of North America, north of Mexico, and a catalogue of the more recently described species, with notes. Part. 2 - Catalogue. *Miscellaneous Publications of the Museum of Zoology, University of Michigan,* (6): 93-213.

WALKER, Bryant & RUTHVEN, A.G. 1906. Annotated list of the mollusks of the Porcupine Mountains and Isle Royale, Michigan. Pp. 93-99. In: Adams, Charles C. (Ed.), *An ecological survey of northern Michigan.* Report of the State Board of Geological Survey of Michigan, 1905. 638 pp.

WIEBE, A.H. 1926. Variations in the freshwater snail, *Goniobasis livescens. The Ohio Journal of Science,* 26(2): 49-68.

WINSLOW, Mina L. 1917. An annotated list of shells from northern Michigan. *Occasional Papers of the Museum of Zoology, University of Michigan,* (42): 1-16.

WOLFERT, David R. & HILTUNEN, Jarl K. 1968. Distribution and abundance of the Japanese snail, *Viviparus japonicus,* and associated macrobenthos in Sandusky Bay, Ohio. *The Ohio Journal of Science,* 68(1): 32-40.

WOOD, Kenneth G. 1963. The bottom fauna of western Lake Erie, 1951-52. *Proceedings of the Sixth Conference on Great Lakes Research,* Great Lakes Research Division, Institute of Science and Technology, The University of Michigan, Publication No. 10, pp. 258-265.

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Walkerana, 1987, 2(8): 293-300

A CHECKLIST AND CLASSIFICATION OF THE LAND SNAILS OF THE UNIVERSITY OF MICHIGAN BIOLOGICAL STATION AREA[1]

J. B. Burch[2] and Younghun Jung[3]

INTRODUCTION

The University of Michigan Biological Station (UMBS), located in Cheboygan County on Douglas Lake, about 15 miles (24 km) south of the Straits of Mackinac in the center of the lower peninsula of Michigan, has been a productive institution for scientific research and for training biologists for over 75 years. Thousands of students have trained there, and hundreds of research papers have been published on the local flora and fauna. For animals, these papers have dealt with many aspects of biology, such as taxonomy, life histories, ecology, behavior, morphology, cytology, parasitism, etc. But, nearly all papers on terrestrial mollusks have been restricted to species occurrences and taxonomy, with several papers giving habitat information. Nevertheless the area has a rich and abundant land snail fauna, and land snails are interesting subjects for all types of biological studies. Perhaps one reason for the neglect of UMBS area land mollusks is the lack of a readily available, up-to-date treatment of their taxonomy.

The objective of this publication is to present a list of the land snails of the UMBS area, and to place these mollusks in a modern frame of classification. For the purposes here, the UMBS area includes the counties of Emmet, Cheboygan and Presque Isle, an area of some 2,200 square miles. This list is based on collections made during the summer of 1986, and on specimens collected previously and now part of the collections of the Mollusk Division, Museum of Zoology, The University of Michigan.

[1]Contribution from The University of Michigan Biological Station.

[2]Museum of Zoology and Department of Biology, College of Literature, Science and the Arts, and School of Natural Resources, The University of Michigan.

[3]Museum of Zoology and School of Natural Resources, The University of Michigan.

Sixty-two species and subspecies have been found in the area. These belong to 33 genera, which are placed in 14 families. With further collecting, a few additional species perhaps will be added to the list in the future. On the other hand, an improved systematics may relegate to synonymy several of the currently used species and subspecies names.

OUTLINE OF CLASSIFICATION AND LIST OF SPECIES

Subclass Pulmonata Cuvier 1817
- Order Acteophila Férussac [Basommatophora Keferstein, in part]
  - Superfamily Auriculoidea Férussac 1821
    - Family CARYCHIIDAE Jeffreys 1829
      - Genus ***Carychium*** Müller 1774[4] (*Carychium minimum* Müller)[5]
        - *C. exiguum* (Say 1822)
        - *C. exile exile* H.C. Lea 1842
        - *C. exile canadense* Clapp 1906
- Order Geophila Férussac 1812 (= Stylommatophora Schmidt 1856)
  - Suborder Orthurethra Pilsbry 1900
    - Superfamily Cochlicopoidea Pilsbry 1900
      - Family COCHLICOPIDAE Pilsbry 1900 [Cionellidae Clessin 1879]
        - Genus ***Cochlicopa*** Férussac 1821 [= *Cionella* Jeffreys 1829] (*Helix lubricus* Müller)
          - *C. lubrica* (Müller 1774)
          - *C. morseana* (Doherty 1878)
    - Superfamily Pupilloidea Turton 1831
      - Family VALLONIIDAE Morse 1864
        - Genus ***Planogyra*** Morse 1864 (*Helix asteriscus* Morse)
          - *P. asteriscus* (Morse 1857)
        - Genus ***Vallonia*** Risso 1826 (*Vallonia rosalia*

[4]The genera in each family and subfamily, and subgenera and species in each genus, are listed in alphabetical order.
[5]Type species are placed in parentheses after each generic-group name.

Risso =*Helix costata* Müller)
V. costata (Müller 1774)
V. excentrica Sterki 1893
V. pulchella (Müller 1774)
Genus ***Zoogenetes*** Morse 1864 (*Helix harpa* Say)
Z. harpa (Say 1824)
Family PUPILLIDAE Turton 1831
Subfamily Pupillinae s.s.
Genus ***Pupilla*** Leach (in Fleming) 1828 (*Pupa marginata* Draparnaud = *Turbo muscorum* Linnaeus)
P. muscorum (Linnaeus 1758)
Subfamily Gastrocoptinae Pilsbry 1918
Genus ***Gastrocopta*** Wollaston 1878 (*Pupa acarus* Benson)
Subgenus *Albinula* Sterki 1892 (*Pupa contracta* Say)
G. armifera (Say 1821)
G. contracta (Say 1822)
Subgenus *Vertigopsis* Sterki 1893 (*Pupa curvidens* Gould)
G. pentodon (Say 1821)
G. tappaniana ("Ward" C.B. Adams 1842)
Subfamily Vertigininae Pilsbry 1918
Genus ***Columella*** Westerlund 1878 (*Pupa inornata* Michaud)
C. edentula (Draparnaud 1805)
Genus ***Vertigo*** Müller 1774 (*Vertigo pusilla* Müller)
V. elatior Sterki 1894
V. gouldi gouldi (Binney 1843)
V. gouldi paradoxa Sterki (in Nylander) 1900
V. nylanderi Sterki 1909
V. ovata Say 1822
V. ventricosa (Morse 1865)
Family STROBILOPSIDAE Pilsbry 1918
Genus ***Strobilops*** Pilsbry 1893 (*Helix labyrinthica* Say)
S. affinis Pilsbry 1893
S. labyrinthica (Say 1817)

Suborder Heterurethra Pilsbry 1900
Superfamily Succinoidea Beck 1837
Family SUCCINEIDAE Beck 1837
Genus ***Catinella*** Pease 1871
C. avara (Say 1824)
Genus ***Oxyloma*** Westerlund 1885 (*Succinea hungarica* Hazay)
O. retusa (Lea 1834)
Genus ***Succinea*** Draparnaud 1801 (*Helix putris* Linnaeus)
S. ovalis Say 1817
Suborder Sigmurethra Pilsbry 1900
Infraorder Aulacopoda Pilsbry 1896
Superfamily Arionoidea Gray (in Turton) 1840
Family PUNCTIDAE Morse 1864 (Endodontidae auct.)
Subfamily Discinae Thiele 1931
Genus ***Anguispira*** Morse (*Helix alternata* Say)
A. alternata (Say 1817)
Genus ***Discus*** Fitzinger 1833 (*Helix ruderata* Hartmann)
D. cronkhitei (Newcomb 1865)
D. catskillensis (Pilsbry 1898)
Subfamily Helicodiscinae "Pilsbry" Baker 1927
Genus ***Helicodiscus*** Morse (*Helix lineata* Say = *Planorbis parallellus* Say)
H. parallelus (Say 1821)
H. shimeki Hubricht 1962
Subfamily Punctinae Morse 1864
Genus ***Punctum*** Morse 1864 (*Helix minutissimum* Lea)
P. minutissimum (Lea 1841)
Family PHILOMYCIDAE Gray 1847
Genus ***Philomycus*** Rafinesque 1820 (*Philomycus flexuolaris* Rafinesque)
P. carolinianus flexuolaris Rafinesque 1820
Genus ***Pallifera*** Morse 1864 (*Philomycus dorsalis* Binney)
P. dorsalis (Binney 1842)

Family ARIONIDAE Gray (in Turton) 1844
Genus ***Arion*** Férussac 1819 (*Limax ater* Linnaeus)
A. fasciatus (Nilsson 1822)
A. cf. *silvaticus* Lohmander 1937
Superfamily Limacoidea Rafinesque 1815
Family LIMACIDAE Rafinesque 1815
Genus ***Deroceras*** Rafinesque 1820 (*Limax gracilis* Rafinesque = *Limax laevus* Müller)
D. laeve (Müller 1774)
D. reticulatum (Müller 1774)
Family VITRINIDAE Fitzinger 1833 (Zonitidae Mörch 1864)
Subfamily Vitrininae Fitzinger 1833
Genus ***Vitrina*** Draparnaud 1801 (*Helix pellucida* Müller)
V. limpida Gould 1850
Subfamily Zonitinae Mörch 1864
Genus ***Glyphyalinia*** Martens 1892 (*Helix indentata* Say)
Subgenus *Glyphyalinia* s.s.
G. indentata (Say 1823)
Subgenus *Glyphyalops* H.B. Baker 1928 (*Vitrea rhoadsi* Pilsbry)
G. rhoadsi (Pilsbry 1899)
Subgenus *Glyphyalus* H.B. Baker 1928 (*Glyphyalinia burringtoni* Pilsbry)
G. wheatleyi (Bland 1883)
Subgenus *Perpolita* H.B. Baker 1928 (*Helix hammonis* Ström = *Helix electrina* Gould)
G. binneyana (Morse 1864)
G. electrina (Gould 1841)
Genus ***Hawaiia*** Gude 1911 (*Helix kawaiensis* Pfeiffer = *Helix minuscula* Binney)
H. minuscula (Binney 1840)
Genus ***Oxychilus*** Fitzinger 1833 (*Helix cellarius* Müller)
O. cellarius (Müller 1774)
Genus ***Paravitrea*** Pilsbry 1898 (*Helix capsella* Gould)

Subgenus *Paravitreops* Baker 1928 (*Helix multidentata* Binney)
P. multidentata (Binney 1840)
Subfamily Gastrodontinae Tryon 1866
Genus ***Striatura*** Morse 1864 (*Helix milium* Morse)
Subgenus *Striatura* s.s.
S. milium (Morse 1859)
Subgenus *Striaturops* Baker 1928 (*Striatura ferrea* Morse)
S. ferrea Morse 1864
Subgenus *Pseudohyalina* Morse 1864 (*Helix exigua* Stimpson)
S. exigua (Stimpson 1850)
Genus ***Zonitoides*** Lehmann 1862 (*Helix nitidus* Müller)
Subgenus *Zonitellus* H.B. Baker (*Helix arboreus* Say)
Z. arboreus (Say 1817)
Subgenus *Zonitoides* s.s.
Z. nitidus (Müller 1774)
Family EUCONULIDAE Clessin 1879 (Helicarionidae Bourguignat 1883, emend.)
Genus ***Euconulus*** Reinhardt 1883 (*Helix fulva* Müller)
Subgenus *Euconulops* H.B. Baker 1928 (*Conulus chersinus polygyratus* Pilsbry)
E. chersinus (Say 1821)
Subgenus *Euconulus* s.s.
E. fulvus (Müller 1774)
Infraorder Holopodopes H.B. Baker 1962
Superfamily Rhytidoidea Pilsbry 1895
Family HAPLOTREMATIDAE Baker 1925
Genus ***Haplotrema*** Ancey 1881 (*Selenites duranti* Newcomb)
H. concavum (Say 1821)
Infraorder Holopoda Pilsbry 1896
Superfamily Mesodontoidea Tryon 1866
Family MESODONTIDAE Tryon 1866 (Polygyridae Pilsbry 1895)

Subfamily Mesodontinae Tryon 1866
Genus ***Mesodon*** Rafinesque (in Férussac) 1821 (*Helix thyroidus* Say)
Subgenus *Appalachina* Pilsbry 1940 (*Polygyra sayanus* (Pilsbry)
M. sayanus (Pilsbry 1906)
Subgenus *Mesodon* s.s.
M. thyroidus (Say 1817)
Genus ***Stenotrema*** Rafinesque 1819 (*Stenotrema convexa* Rafinesque = *Helix stenotrema* Pfeiffer)
Subgenus *Euchemotrema* Archer 1939 (*Helix monodon* Rackett 1821 = *Helix leai* Binney 1840)
S. fraternum (Say 1824)
S. leai (Binney 1840)
Subfamily Triodopsinae Pilsbry 1940
Genus ***Triodopsis*** Rafinesque 1819 (*Triodopsis lunula* Rafinesque = *Helix tridentata* Say)
Subgenus *Neohelix* Ihering 1892 (*Helix albolabris* Say)
T. albolabris (Say 1817)
T. multilineata (Say 1821)

REFERENCES

ARCHER, Allan F. 1936. The land Mollusca of Cheboygan County, Michigan. *Occasional Papers of the Museum of Zoology, University of Michigan,* (340): 1-15.

BAKER, H. Burrington. 1912. Notes on *Circinaria concava* (Say) from Sheboygan County, Michigan. *The Nautilus,* 26: 3-4

BAKER, H. Burrington. 1928a. *Planogyra asteriscus* (Morse). *The Nautilus,* 41(4): 122-123.

BAKER, H. Burrington. 1928b. Minute American Zonitidae. *Proceedings of the Academy of Natural Sciences of Philadelphia,* 80: 1-44, pls. 1-8.

BAKER, H. Burrington. 1929. Pseudohyaline American land snails. *Proceedings of the Academy of Natural Sciences of Philadelphia,* 81: 251-266, pls. 8-10.

BAKER, H. Burrington. 1930 (1931). The North American Retinellae. *Proceedings of the Academy of Natural Sciences of Philadelphia,* 82: 193-219, pls. 9-14.

BINNEY, Amos. 1842. Descriptions of some of the species of naked, air-breathing Mollusca, inhabiting the United States. *Boston Journal of Natural History,* 4: 163-175.

BURCH, John B. 1962. *How to know the eastern land snails.* Wm. C. Brown Co., Dubuque, Iowa. Pp. i-v., 1-214.

BURCH, John B. & PATTERSON, C.M. 1966. Key to the genera of land gastropods (snails and slugs) of Michigan. *Museum of Zoology, University of Michigan, Circular No.* 5, pp. 1-19.

BURCH, John B. & VAN DEVENDER, Amy Shrader. 1980. Identification of eastern North American land snails. The Prosobranchia, Opisthobranchia and Pulmonata (Actophila). *Walkerana,* 1(2): 33-80.

GOODRICH, Calvin. 1932. *The Mollusca of Michigan.* Michigan Handbook Series, No. 5. The University of Michigan Press, Ann Arbor, Michigan. Pp. i-iii, 1-120, pls. 1-7.

HARRY, Harold W. 1951. Carychium exiguum (*Say*) *of lower Michigan: morphology, ecology, variation and life history (Gastropoda, Pulmonata).* Ph.D. thesis, University of Michigan, pp. 1-154. [Available from University Microfilms, 300 North Zeeb Rd., Ann Arbor, Michigan.]

HARRY, Harold W. 1952. *Carychium exiguum* (Say) of lower Michigan; morphology, ecology, variation and life history (Gastropoda, Pulmonata). *The Nautilus,* 66(1): 5-7.

HUBRICHT, Leslie. 1985. The distributions of the native land mollusks of the eastern United States. *Fieldiana* (Zoology), new series, (24): i-viii, 1-191.

PILSBRY, Henry A. 1939-48. *The land Mollusca of North America (North of Mexico*), Academy of Natural Sciences of Philadelphia, Monograph 3, vol. 1, pt. 1, 1939, pp. i-xvii, i-ix; vol. 1, pt. 2, 1940, pp. i-viii, 575-994, i-ix; vol. 2, pt. 1, 1946, pp. i-viii, 1-520, frontispiece; vol. 2, pt. 2, 1948, i-xlvii, 521-1113.

WALKER, Bryant. 1899. *The terrestrial Mollusca of Michigan.* Bryant Walker, Detroit, Michigan. Pp. 1-27.

WALKER, Bryant. 1906. An illustrated catalogue of the Mollusca of Michigan. Pt. 1. Terrestrial Pulmonata (land snails). *Report for 1905, State Board of Geological Survey,* Lansing, Michigan. Pp. i-iii, 431-531, frontispiece, foldout table.

WINSLOW, Mina L. 1926. A revised check list of Michigan Mollusca. *Occasional Papers of the Museum of Zoology, University of Michigan,* (181): 1-28.

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INTRODUCED EUROPEAN SLUGS ON MACKINAC ISLAND, MICHIGAN

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European slugs commonly have been introduced into North America along with nursery stock and greenhouse plants (Chichester & Getz, 1968, 1969; Getz & Chichester, 1971). Most such initial introductions were into northeastern and northwestern United States and southeastern and southwestern Canada. A few species have spread from these regions into isolated localities within the interior of North America due to transport of nursery stock. Established populations of European slugs are most common in eastern North America. (Chichester & Getz, 1968, 1969; Getz & Chichester, 1971; Getz, 1968, 1874; Blanchard & Getz, 1979).

Mackinac Island, Michigan, located in northern Lake Huron, has been a popular summer resort since the early 1800's. Extensive plantings of exotic shrubs and flower beds are associated with the resort hotels and private summer homes located on the island. Numerous lilac bushes were introduced from France around 1830. Given this long history of introduction of nursery plants and maintenance of the flower beds and other exotic plantings, one would expect European slugs to be common on the island. Archer (1934) reported the presence of only one introduced species, *Limax maximus* Linneaus 1758 (in the island cemetery), along with two native species, *Deroceras laeve* Müller 1774) and *Philomycus carolinianus* (Bosc 1802) (in the hardwood forests on the island).

During July 1984, I made a brief survey of the slug fauna on the island. Observations were made in a number of flower beds near private homes and resort hotels and throughout the natural wooded areas of the island. Four introduced species of European slugs were found: *Deroceras reticulatum* (Müller 1774), *Limax maximus, Arion fasciatus* (Nilsson 1822) and *Arion hortensis* Férussac 1819. In addition, one individual of a native slug, *Deroceras laeve,* was collected in a flower bed in downtown Mackinac Island. Since these flowers had been transplanted from a greenhouse, this specimen was probably also introduced; the species was not found elsewhere on the island.

Deroceras reticulatum was the most abundant of the four introduced species. It was found throughout the island, but was most commonly associated with flower beds and lawns. *Arion fasciatus* also occurred throughout the island, but was less abundant than was *D. reticulatum.* It, too, was most common in flower beds. *Limax maximus* was found on all parts of the island, but only a few individuals were observed. Home owners indicated, however, that this species was so common in lawns and on sidewalks following rains as to be a serious nuisance. That it had not rained for several days prior to the collecting trip undoubtedly accounted for the apparent sparseness of this species.

Arion hortensis was found over most of the wooded areas of the island, but was also common in flower beds. It was much less abundant than was *A. fasciatus.* The *A. hortensis* population on Mackinac Island represents the most interior locality for the species in North America. The species has not been recorded previously from the midwestern region of the United States. There are records from Newfoundland, Nova Scotia, Quebec, Ontario (approximately 225 km to the east, and across Lake, from Mackinac Island), the New England states, eastern Pennsylvania, California, and Washington.

The absence of *Arion subfuscus* (Draparnaud 1805) from the island was somewhat unexpected. This species has spread throughout northeastern North America (Chichester & Getz, 1969; Getz, 1974) and was recently recorded from southeastern Michigan (Blanchard & Getz, 1979). Because of the long history of nursery stock and flower introductions onto Mackinac Island, I anticipated *A. subfuscus* would also be present.

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LITERATURE CITED

ARCHER, A.F. 1934. The land mollusks of Mackinac Island, Michigan. *The Nautilus*, 47: 138-140.

BLANCHARD, D. & GETZ, L.L. 1979. Arion subfuscus in southeastern Michigan. *The Nautilus*, 93: 36-37.

CHICHESTER, L.F. & GETZ, L.L. 1968. Terrestrial slugs. *The Biologist*, 50: 148-166.

CHICHESTER, L.F. & GETZ, L.L. 1969. The zoogeography and ecology of arionid and limacid slugs introduced into northeastern North America. *Malacologia*, 7: 313-346.

GETZ, L.L. 1968. *Arion fasciatus* in Wisconsin. *The Nautilus*, 82: 32-33.

GETZ, L.L. 1974. *Arion subfuscus* in the vicinity of Washington, D.C. *The Nautilus*, 88:66.

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