C. F. Sturm, T. A. Pearce, and A. Valdés. (Eds.) 2006. The Mollusks: A Guide to Their Study, Collection, and Preservation. American Malacological Society.

CHAPTER 21

FRESHWATER GASTROPODA

ROBERT T. DILLON, Jr.

21.1 INTRODUCTION

Gastropods are a common and conspicuous element of the freshwater biota throughout most of North America. They are the dominant grazers of algae and aquatic plants in many lakes and streams, and can play a vital role in the processing of detritus and decaying organic matter. They are themselves consumed by a host of invertebrate predators, parasites, fish, waterfowl, and other creatures great and small. An appreciation of freshwater gastropods cannot help but lead to an appreciation of freshwater ecosystems as a whole (Russell-Hunter 1978, Aldridge 1983, McMahon 1983, Dillon 2000).

21.2 BIOLOGY AND ECOLOGY

The most striking attribute of the North American freshwater gastropod fauna is its biological diversity. The snails presently dwelling in our lakes and streams, although perhaps sharing some superficial similarities, have their origins in 6-8 separate invasions from the sea. Co-occurring gastropod populations may differ strikingly in anatomy, life history, habitat, food, and ecological requirement. The first distinction to be made among freshwater snails is between the pulmonates and the prosobranchs.

The prosobranchs (Prosobranchia, see Figures 21.1 A-E) are a polyglot group retaining the ancestral gilled condition. They bear relatively heavy shells and an operculum. They are generally slow growing, require at least a year to mature, and live for several years. Sexes are separate in most cases.

The largest-bodied freshwater gastropods (adults usually much greater than 2 cm in shell length) belong to the related families Viviparidae and Ampullariidae. The former family, including the common genera *Viviparus* and *Campeloma*, among others, is distinguished by bearing live young, sometimes parthenogenically. (Eggs are actually held until they hatch internally, so the term "ovoviviparous" is more descriptive.) Viviparids have the ability to filter feed, in addition to the more usual grazing and scavenging habit. The Ampullariidae, tropical or sub-tropical in distribution, includes *Pomacea*, which lays its large pink egg mass above the water, and *Marisa*, which attaches large gelatinous egg masses to subsurface vegetation. Ampullariids have famous appetites for aquatic vegetation. The only ampullariid native to the U.S.A. is the Florida apple snail, *Pomacea paludosa* (Say, 1829), although other ampullariids have been introduced through the aquarium trade.

At the other end of the prosobranch spectrum, the related families Hydrobiidae and Pomatiopsidae are among our smallest freshwater snails, with shell lengths typically less than 5 mm as adults. The former family (*Amnicola*, *Fontigens*, *Somatogyrus,* and many other genera) includes diverse inhabitants of clean waters across North America, many species being specially adapted to springs. The latter family, represented by only a few species here, are often amphibious, being found on mud above the water level.

The Pleuroceridae (including such genera as *Pleurocera*, *Anculosa* [*Leptoxis*], and *Goniobasis* [*Elimia*]) [here and below, when a name follows in brackets it

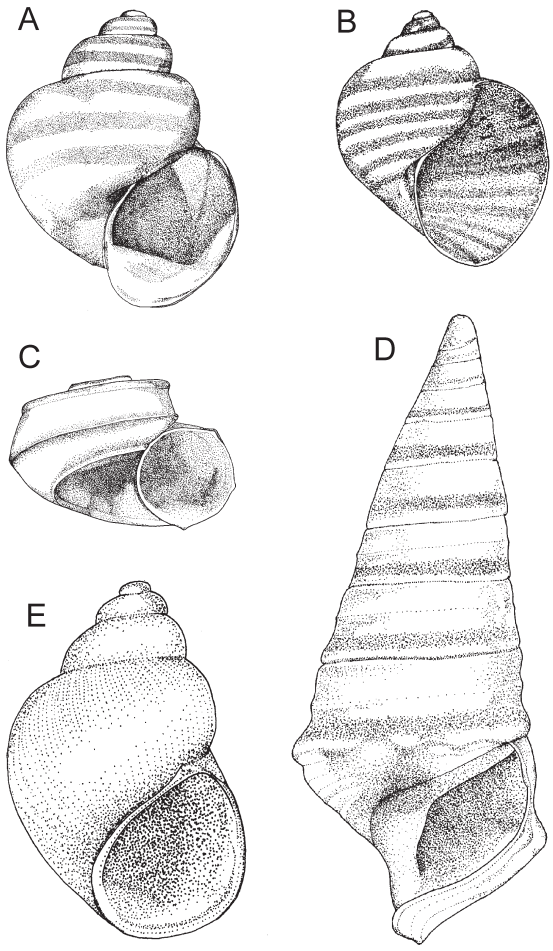

Figure 21.1 Prosobranchs.
A. *Viviparus viviparus* (Linnaeus, 1758). Fox Ferry Point, Potomac River, MD. CMNH 18319. h. = 2.75 cm. B. *Pomacea paludosa* (Say, 1829). Lake Oklawaka, Putnam County, FL. CMNH 63653. h. = 5 cm. C. *Valvata tricarinata* (Say, 1817). Ohio. CMNH 62.7046. w. = 6.3 mm. D. *Pleurocera nobilis* (Lea, 1845). Tennessee River, Florence, AL. CMNH 62.23401. h. = 4.6 cm. E. *Bithynia tentaculata* (Linnaeus, 1758). Ohio Canal, Clinton, OH. CMNH 62.25138. h. = 1 cm. CMNH = Carnegie Museum of Natural History, h. - height, w. - width.

is the one preferred by Turgeon *et al*. (1998)] bear moderately sized shells, perhaps 1- 2 cm as adults. They reach great abundance and diversity in clean, well-oxygenated waters, especially of the southeastern U.S.A. The parthenogenic Thiaridae is a related family common in the tropics and in aquarium shops. Two species, *Melanoides tuberculata* (Müller, 1774) and *Thiara granifera* (Lamarck, 1822) [*Tarebia granifera*], have been introduced to Florida, Texas, and scattered streams elsewhere.

The Valvatidae is a small family of freshwater gastropods with adults generally much less than 5 mm shell length. They are more northerly in their distribution, and are especially found in the deeper waters of lakes. Another noteworthy element of the northern fauna is *Bithynia tentaculata* (Linnaeus, 1758), of the family Bithyniidae, introduced from Europe. Bearing a shell about 1 cm long and a calcareous operculum, *Bithynia* has the ability to filter feed as well as graze.

Snails of the other major group of freshwater gastropods, the pulmonates (Pulmonata, see Figures 21.2 A-G), have lost their gills and now gather oxygen across the simple inner surface of their mantle. The freshwater pulmonates belong to the Order Basommatophora, so named because their eyes are located at the base of their tentacles. This distinguishes them from the more familiar land snails, the Stylommatophora, with eyes at tentacle tips.

Most freshwater pulmonates carry an air bubble under their shell, which they replenish occasionally at the surface, and which serves to adjust their buoyancy. This allows typical pulmonates to inhabit calm, warm, and even stagnant water where dissolved oxygen concentrations may be quite low. It should be noted, however, that some pulmonates (especially limpets and smaller or cold-water species) do not carry air bubbles, and rely on diffusion of oxygen from the water directly into their body tissues.

Pulmonate snails are lightly-shelled and do not bear opercula. They grow quickly, as a general rule, some populations passing multiple generations in a single growing season. They are reproductively hermaphroditic, with the capability of self-fertilization.

The freshwater pulmonates reach their greatest diversity in more northerly latitudes. There are four major families in North America. As a generality, the snails of the family Lymnaeidae bear slender,

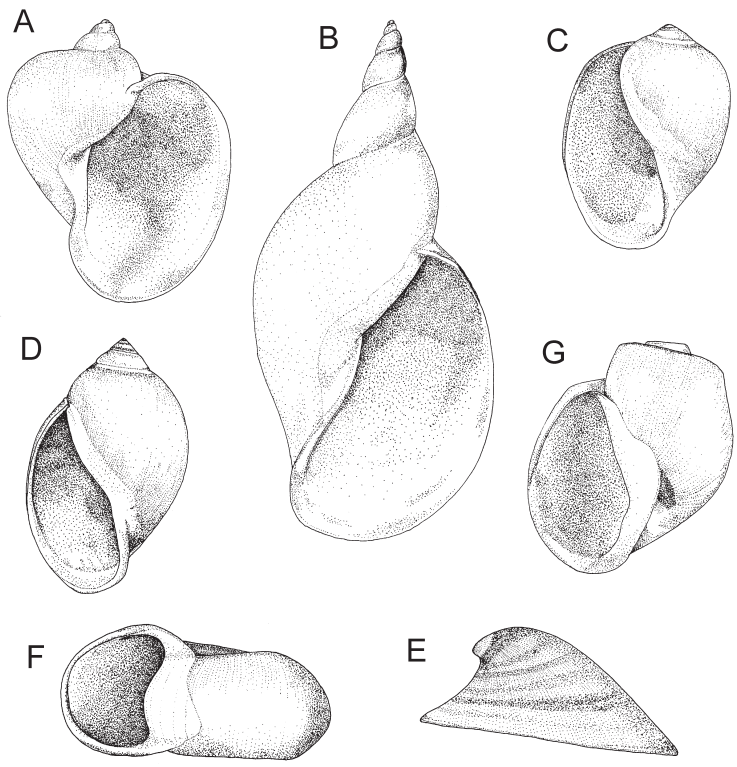

Figure 21.2 Pulmonates.
A. *Lymnaea auricularia* (Linnaeus, 1758) [*Radix auricularia*]. Switzerland (also introduced in North America). CMNH 62.25691. h. = 2.4 cm. B. *Lymnaea stagnalis* (Linnaeus, 1758). Douglas Lake, MI. CMNH 62.32741. h. = 4.4 cm. C. *Physa ancillaria* Say, 1825 [*Physella ancilaria*]. Lake Chautauqua, Chautauqua County, NY. CMNH 62.7495. h. = 1.7 cm. D. *Physa acuta* Draparnaud, 1805 [*Physella acuta*]. Lake Erie, Ottawa County, OH. CMNH 62.32834. h. = 2.2 cm. E. *Ancylus fluviatilis* (Müller, 1774). Long Park, England. CMNH 63654. w. = 1.1 cm. F. *Helisoma campanulata* (Say, 1821) [*Planorbella campanulata*]. Pittsburgh, PA. CMNH 62.33654. w. = 1.9 cm. G. *Helisoma scalaris* (Jay, 1839) [*Panorbella scalaris*]. Palm Beach County, FL. CMNH 47174. h. = 1.6 cm. CMNH = Carnegie Museum of Natural History, h. - height, w. - width.

right-handed shells of typical appearance, the shells of the Physidae are left-handed, those of the Planorbidae are planispiral (coiled like a watch spring), and those of the Ancylidae are limpet-shaped.

21.3 CONSERVATION

Before embarking on a collecting trip for any element of the biota, it is the responsibility of all good stewards of the environment to become familiar with conservation concerns. The taking of any animal or plant life is generally prohibited in all parks, whether they are national, state, or local. There are 20 endangered or threatened species of freshwater gastropods on the federal list at the present writing, including 9 hydrobiids and 5 pleurocerids, and most states also list freshwater gastropod species among their taxa of special concern. Many additional species of freshwater snails deserve protection. The nonprofit conservation organization, NatureServe, maintains a database listing the conservation status of all American freshwater gastropod species (see Section 21.9 for web address). More information can be found in Chapter 30.

21.4 COLLECTING TECHNIQUES

Dress with the weather in mind. Plan to be challenged by briars, poison ivy, and biting insects on the way to being wet and muddy. Hip boots or chest waders will be required for the mountains in March; shorts and canvas wading shoes are suitable for the swamps in July. Carry with you an assortment of unbreakable containers for specimens, perhaps in a bucket, canvas bag, or knapsack, or in the pockets of a vest. Whirl-pak bags (made of thick plastic with leak proof closures) can be very handy. A scientific collector or serious amateur will always carry at least a couple small vials (4 dram, 15 ml) in his pockets for limpets, hydrobiids, tiny planorbids, and other small snails easily lost in bottles with larger pleurocerids and pulmonates.

Since many elements of the freshwater gastropod fauna are minute, the well-prepared collector will keep a set of fine forceps hanging from a pocket

flap or dangling on a string around his neck. A knife or scalpel may be preferable to forceps for collecting limpets, but perhaps more difficult to carry. A sturdy, long-handed net or dipper will be an asset, and/or a sieve, tea strainer, or similar device. Benthic sampling nets may be purchased from biological supply companies in a variety of styles. The mesh need not be fine; 1 mm will capture even newly-hatched gastropods, and should be protected with a canvas or muslin bottom or shroud. A "kick net" with a rectangular or triangular opening is better for rocky bottoms, and a dip net with a more conventional round opening is probably better for vegetation. D-frame nets combine the benefits of both types.

A successful search for freshwater snails begins with an inventory of available habitat types. Rivers should be surveyed in both riffle and pool; lakes should be surveyed both in quiet, protected bays and on exposed shores. Even ephemeral pools and dune ponds can host their own molluscan faunas. The entire range of substrate types should be sampled, including mud, sand, and rock, as should the entire macrophyte flora, both floating and attached. Consider collecting from a boat.

Upon arrival at the collecting site, your first task is to observe, in a manner as unobtrusive as possible. In some environments, especially those characterized by hard water, a preliminary search for relic shells in outwashed fines and sediment scour at lake or river's edge may yield valuable clues regarding the gastropod species to be expected alive. Do not disturb the silt by entering the water, at least initially. It is best to kneel patiently at the water's edge for a while, allowing your eyes to adjust to the scene, alert for small movements and trails in the mud. Some lymnaeids and pomatiopsids are quite amphibious, often being found on the dry tops of floating plants, or muddy flats some distance from the water's edge. Run your fingers through loose sediment for viviparids.

Enter the water only after sampling snails from all visible surfaces. Lift rocks, pull macrophytes, and inspect all surfaces carefully. Examine floating vegetation and debris. Smaller snails can often be conveniently collected by shaking vegetation in a bucket of clean water. My colleague, Amy Wethington (pers. comm.), reports that she is occasionally alerted to the presence of pulmonate snails on lifted debris by the tiny sucking noise they make as they withdraw into their shells.

Plastic bags and floating garbage of many sorts often seem to attract pulmonates. Remove all such materials from the water, inspect them, and transport them to the nearest trash receptacle.

A truly complete survey for freshwater snails will conclude with a number of passes using a stout, long-handled net. The net should be run through both the bottom sediments and any aquatic vegetation in turn, and its contents examined carefully for small gastropods such as the hydrobiids, limpets, and small planorbids. Older sources describe the "Walker dipper" as an alternative to the standard dip net. The following passage from Baker (1942) describes how to construct a Walker dipper. "Thanks to one of our oldest members, Dr. Bryant Walker, now gone from among us, who lived in Detroit, Michigan, a useful dipper was invented which is fittingly called a Walker dipper or dredge. It is so efficient that usually no other implement is necessary. This dipper is about 6 inches in diameter at the top and 5 inches in diameter at the bottom, with a depth of about 3 inches. The bottom is covered with copper wire screening of a sufficiently large mesh to allow the mud and water to run through and retain the shells. It is fastened to a handle 5 or 6 feet in length. A broom handle often makes a good handle. The dipper should be made of copper to prevent rusting. If copper is not available then the sides of the dipper may be made of tinned iron and the bottom may be of copper. A dipper of this kind has been in use by the writer for several years and shows no indication of wearing out" (Figure 2.1 D).

Campeloma can be collected by baiting. Simply tie fish or carrion, partially buried, to a tall stake and sample the surrounding substrate with a net or screen at intervals of several days. The technique seems to work best in shallow, flowing waters with loose sand or silty bottom.

The most convenient method of bringing your samples home is to preserve them immediately with alcohol, together with a field label. If on the other hand it is your intent to relax your specimens before preservation, or to keep your animals alive and healthy, transportation becomes somewhat more challenging. Bring a thermometer and try to maintain the temperature in the transport vessel as close as possible to that prevailing in the natural environment. Small thermos jugs are ideal to transport freshwater living snails, although this can be impractical if a large number of sites are to be visited in a single trip. A low-cost option is to accumulate samples in sturdy plastic bags or milk jugs inside a single large cooler. The tops can be cut off the jugs to remove the animals upon return from the field. Some collectors prefer to transport living snails in wet vegetation. Be sure to field-label containers of living snails on the outside - live snails may consume any slips of paper dropped among them.

Living snails will need transfer to suitable holding facilities promptly upon arrival at the home or laboratory. Ideally, aquaria should be established and conditioned before departure on a live collecting trip. Alternatively, you can transport carboys of water from the field and set up fresh aquaria on your return.

Take good notes for each collection. Record the locality as specifically as possible, ideally on site, completing as many of the first 14 fields of Table 21.1 as possible. Habitat notes and environmental observations are often useful. Upon return from the field, the safest and most systematic approach is to assign each lot a catalog number and to record data in a hardbound journal and/or an electronic database. An Excel spreadsheet formatted in the template of Table 21.1 is available for download from the FWGNA site.

Table 21.1 Database fields in use by the Freshwater Gastropods of North America project.

1. Hydrological Unit Code (U.S. Geological Survey system)
2. Site number (catalog number)
3. Date (mm/dd/yyyy)
4. County (record two if on county line)
5. Project (or funding source, if any)
6. Water body name
7. Common location (e.g., “2 km W of Dumpton.”)
8. Road No. (route number at bridge or access point)
9. River Basin
10. State (record two if on State line)
11. Latitude (decimal degrees)
12. Longitude (decimal degrees)
13. Collector’s name(s)
14. Scientific Name (genus and species)

21.5 PREPARATION AND STORAGE

The vast majority of all freshwater mollusk collections, whether they are in national museums or in private cabinets, are of shell. As most freshwater gastropods are not large of body, the preservation of their shells is best accomplished by drying, ideally in some out of the way place where the odor will not become a problem. It can be desirable to take specimens through one or two changes of alcohol over several days before drying them. This seems to mitigate the odor, lowering the intensity although perhaps prolonging the duration. Another approach is to freeze specimens in a container of water overnight. They generally die in an extended condition, and can be thawed and cleaned with forceps.

It may be necessary to clean the largest specimens, especially the ampullariids and viviparids, by boiling. The animals should be placed in a pot of cool water and warmed to boiling gradually. The meat can then be hooked out with a pin, and the operculum saved in the aperture with a plug of cotton.

The dry shells of freshwater gastropods are often small and fragile. For this reason, they are more commonly stored in enclosed containers than most mollusks. Clear glass shell vials plugged with polyester are best, or clear plastic snap-top boxes, either of which may be purchased at specialized biological supply companies. Clear plastic pill bottles can be purchased at the pharmacy. Labels with data should be included with each lot of shells, as described in Chapter 14.4.

From a scientific standpoint, the preservation of soft part anatomy in freshwater gastropod collections can be very important. The application of

DNA methods is also becoming more widespread with each passing year. Thus increasingly we find scientific collections stored in alcohol, 80% ethanol being the recommended standard. Ethanol concentrations of 90% or higher are favored by researchers planning DNA studies, although such high quality reagents are not readily available to the general public. The "rubbing" alcohol stocked by ordinary pharmacies is often 70% ethanol "denatured" with acetone or similar organic solvents. Other rubbing alcohol formulations, such as 70% or 90% isopropanol, can be used to preserve specimens but are not ideal. Because the upper regions of gastropod anatomy are especially liable to decomposition, it is a good idea carefully to crack the shells of a few individuals before placing them in alcohol.

Formaldehyde, which can be hazardous, is not recommended for general use. Some workers recommend brief fixation (no more than a few hours) in 10% formalin before preservation in alcohol, although any contact with formalin will render tissue unsuitable for future DNA studies. Refer to Chapter 5 for information regarding vials and jars appropriate for storing wet collections.

Some researchers prefer to make anatomical observations on specimens that have been relaxed before preservation. Menthol crystals, available from your pharmacist, are among the most convenient of the variety of chemicals used for this purpose. Other anesthetics, such as chloretone, nembutal, or chloral hydrate are more difficult to obtain. Simply transfer animals to be relaxed into a shallow vessel of water (perhaps 1 cm), float a large menthol crystal (or several small ones) on the surface, and leave them cool and undisturbed. Periods of 12-24 hours are typically required for complete relaxation, but decomposition can follow shortly thereafter. Specimens should be probed periodically (a touch to the tentacle will suffice) and transferred to alcohol promptly after death. Menthol crystals can be dried and reused (see Chapter 2.5 for more on relaxing or narcotizing).

21.6 IDENTIFICATION

The identification of freshwater gastropods presents a greater challenge than one encounters with marine or even terrestrial species, at least in North America. The most comprehensive guide available at present is J.B. Burch's *North American Freshwater Snails* (Burch 1989). The work was originally published by the U.S. Environmental Protection Agency, and re-published in the journal Walkerana (Burch and Tottenham 1980, Burch 1982, 1988). Burch's work includes illustrations, historic ranges, synonyms, and a dichotomous key to the species level for most taxa. Other (shorter) references useful at the national level include the keys of Pennak (1989) and Brown (1991).

In addition to the above, there have been a fair number of regional surveys, species lists, and systematic reviews of taxa helpful in special situations. Especially notable are the works for the following regions: Canada (Clarke 1973, 1981), Colorado (Wu 1989), Connecticut (Jokinen 1983), Florida (Thompson 1984), Missouri (Wu *et al.* 1997), New York (Jokinen 1992), and North Dakota (Cvancara 1983). F.C. Baker authored a large and comprehensive monograph on the Lymnaeidae (1911), and his similarly ambitious work on the Planorbidae was published posthumously in an incomplete form (1945). Both of these works were rendered somewhat obsolete by the global-scale monographs of Hubendick (1951, 1955). The Physidae have recently been monographed by Wethington (2003). For information on aids to identifying non-North American taxa see Chapter 9.2.3 and 9.2.6.

The Freshwater Gastropods of North America (FWGNA) project is a long-term, collaborative effort to survey, map, and monograph the entire continental fauna north of Mexico. It is anticipated that both conventional print and electronic resources will be developed to facilitate the identification and conservation of these remarkable animals. A guide to the freshwater gastropods of South Carolina is on line now, with plans to extend throughout all southern Atlantic drainages in the near future. A complete list of all reference materials useful for the identification of North American freshwater gastropods published since 1900 can be found on the FWGNA website (see Section 21.9 for the website address), as well as links to a small but growing number of online resources and databases relevant to freshwater snails.

21.7 AQUARIUM CULTURE

Freshwater snails make interesting pets. Most snail species seem to adapt well to life in standard aquarium conditions, and a growing number of varieties are sold specifically to the hobbyist. Such casual interest in snails as may be displayed by the typical customer in a hobby shop almost certainly derives from the search for additions to aquaria featuring fish. But culturing fish and snails together can be detrimental to the former, and is never good for the latter. Most fish will eat snails, especially the smaller and more fragile pulmonates, and some tropical fishes may require heated waters, never necessary or even desirable for gastropod culture. On the other hand, given the right conditions the populations of some pulmonates can rapidly increase in a fish tank, generating a great deal of toxic ammonia and devouring expensive ornamental plants. It is best to raise freshwater snails by themselves.

The following is a brief review of the freshwater snails commonly available in pet shops, and a bit about culturing them. Have fun with these, but please do not release them into the wild. Exotic gastropod species can multiply in great numbers, and some are documented pests. But even though the adverse consequences of releasing aquarium species to the environment may be less than obvious in many cases, most of us simply prefer that natural communities remain undisturbed.

21.7.1 *Pomacea*. The most popular gastropod pets today are the large and gaudy ampullariids, generally labeled "apple snails" in the aquarium shops, but sometimes also called "mystery snails" (Perera and Walls 1996). Twenty years ago, the most common species was the North American native *P. paludosa*. More recently, the South American *P. bridgesi* (Reeve, 1856) has achieved widespread popularity by virtue of the marvelous color varieties available. Clever and enterprising breeders have brought to market diverse colors of shell and body bearing such names as "golden," "ivory," "blue," and "tuxedo." Also more recently available in pet shops is the "Giant Peruvian" or "Inca" snail, *Pomacea maculata* (Perry, 1810).

Marisa cornuarietis (Linnaeus, 1758) is a planispiral ampullariid native to South and Central America, now often sold in aquarium shops as a "giant Colombian ramshorn." There are both banded and unbanded forms - the unbanded sometimes called a "golden ramshorn".

Macrophytic vegetation comprises the ordinary diet of ampullariids such as *Pomacea* and *Marisa,* as well as occasional small invertebrates, including other snails. Do not attempt to culture ampullariids with aquatic plants or smaller snails about which you care. They seem to grow well on a diet of lettuce, especially Romaine. (Iceberg lettuce tends to cloud the water.) See the bibliography and web resources for special references, both print and electronic, on the apple snails.

21.7.2 *Bellamya* (or *Cipangopaludina*). This Asian viviparid is widely marketed in the U.S.A. as a "Japanese" or "Chinese trap-door snail," for use primarily in outdoor water gardens. *Bellamya* may also sometimes be called a "mystery snail," although this name tends to confuse them with *Pomacea*. By virtue of the trap-door snail's ability to filter-feed, and its benign relationship with aquatic vegetation, nurseries selling water lilies and other aquatic plants often promote these gastropods to clean the pond water. Like almost all other freshwater snails, however, they will probably do well in the aquarium provisioned with ordinary fish food.

21.7.3 *Melanoides tuberculata*. *Melanoides tuberculata* is an old world thiarid now ubiquitous through tropical and subtropical regions worldwide. It is marketed in aquarium shops as a "Malayan Needle Point." *Melanoides* is among the hardiest of the prosobranchs, and by virtue of its parthenogenic mode of reproduction, one of the most easily cultured in standard aquarium conditions.

21.7.4 *Helisoma trivolvis* [*Planorbella trivolvis*]. *Helisoma trivolvis* (Say, 1817) is a North American native that has long standing in the aquarium trade. It is usually just called a "ramshorn snail." Albinos actually look red, since absence of body pigmentation uncovers their hemoglobin content. (The snails

then sell for a premium as red ramshorns). *Helisoma* [*Planorbella*] enjoys lettuce, in addition to fish food, and seems indifferent to aeration. Given an occasional feeding, and a rare water change, it will thrive.

21.7.5 *Physa* [*Physella*]. *Physa* most often enters the hobbyist's aquarium as a contaminant on water plants, although they make active and interesting pets. It has recently been shown that the common and widespread North American species, *P. heterostropha* (Say, 1817), *P. integra* (Haldeman, 1841), and *P. virgata* (Gould, 1855), are all synonymous with the old world *P. acuta* Draparnaud, 1805, making *P. acuta* the world's most cosmopolitan freshwater gastropod. These are the cockroaches of malacology, thriving in all conditions of food and culture, and quick to reproduce. Their weak mouthparts make them less dangerous to aquatic vegetation than *Helisoma*, for example, and more dependent on a diet of algae and/or fish food.

21.8 SUMMARY

The North American freshwater snails do not tend to grow as large or as colorful as most groups of mollusks, and consequently do not often attract the attention of hobbyists. Yet they are widespread, easily collected, and adapt easily to the home aquarium. The diversity of freshwater gastropods, and the variety of environments they inhabit, can yield great intellectual rewards to the malacologist, amateur or professional, with the dedication to pursue them.

21.9 WEB RESOURCES

Nets and Freshwater Sampling Gear:
<www.wildco.com/>
<www.carolina.com/>

Freshwater Gastropods of North America Project:
<www.cofc.edu/~dillonr/fwgnahome.htm>

Freshwater Gastropods of South Carolina:
<www.cofc.edu/%7Edillonr/FWGSC/>

F. G. Thompson (1984) Freshwater Snails of Florida:
<www.flmnh.ufl.edu/natsci/malacology/fl-snail/snails1.htm>

A. M. Cvancara (1983) Aquatic Mollusks of North Dakota:
<www.npwrc.usgs.gov/resource/distr/invert/mollusks/mollusks.htm>

U.S. Fish & Wildlife Service Threatened and Endangered Species System:
< ecos.fws.gov/tess_public/TESSWebpage>

NatureServe Online Encyclopedia of Life
< www.natureserve.org/explorer/>

Stijn Ghesquiere's Apple Snail website:
<www.dds.nl/~snc/>

21.10 LITERATURE CITED

Aldridge, D. W. 1983. Physiological ecology of freshwater prosobranchs. *In:* W. D. Russell-Hunter, ed., *The Mollusca*, Vol. 6. Academic Press, Orlando, Florida. Pp. 329-358.

Baker, F. C. 1911. *The Lymnaeidae of North and Middle America, Recent and Fossil*. Special Publication, No. 3. Chicago Academy of Natural Sciences, Chicago. 539 pp.

Baker, F. C. 1945. *The Molluscan Family Planorbidae*. University of Illinois Press, Urbana, Illinois. 530 pp.

Baker, F. C. 1942. Collecting and preserving fresh water snails. *The American Malacological Union, Eleventh Annual Report* **11**: 5-9.

Brown, K. M. 1991. Gastropoda. In: J. H. Thorp and A. P. Covich, eds., *Ecology and Classification of North American Freshwater Invertebrates*. Academic Press, New York. Pp. 285-314.

Burch, J. B. 1982. North American freshwater snails: Identification keys, generic synonymy, supplemental notes, glossary, references, index. *Walkerana* **4**: 1-365.

Burch, J. B. 1988. North American freshwater snails: introduction, systematics, nomenclature, identification, morphology, habitats, distribution. *Walkerana* **2**: 1-80.

Burch, J. B. 1989. *North American Freshwater Snails*. Malacological Publications, Hamburg, Michigan. 365 pp.

Burch, J. B. and J. L. Tottenham. 1980. North American freshwater snails: Species list, ranges, and illustrations. *Walkerana* **3**: 1-215.

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

Clarke, A. H. 1981. *The Freshwater Mollusks of Canada*. The National Museums of Canada, Ottawa. 446 pp.

Cvancara, A. M. 1983. *Aquatic Mollusks of North Dakota*. Report of Investigation, Vol. 78. North Dakota Geologic Survey. 142 pp.

Dillon, R. T. 2000. *The Ecology of Freshwater Molluscs*. Cambridge University Press, Cambridge. 509 pp.

Hubendick, B. 1951. Recent Lymnaeidae. Their variation, morphology, taxonomy, nomenclature, and distribution. *Kungl Svenska Vetenskapasakademiens Handlingar* **3**: 1-223.

Hubendick, B. 1955. Phylogeny in the Planorbidae. *Transactions of the Zoological Society of London* **28**: 453-542.

Jokinen, E. H. 1983. The freshwater snails of Connecticut. *Connecticut Geological and Natural History Survey Bulletin* **109**: 1-83.

Jokinen, E. H. 1992. The freshwater snails (Mollusca: Gastropoda) of New York State. *New York State Museum Bulletin* **482**: 1-112.

McMahon, R. F. 1983. Physiological ecology of freshwater pulmonates. *In:* W. D. Russell-Hunter, ed., *The Mollusca*, Vol. 6, Ecology. Academic Press, New York. Pp. 359-430.

Pennak, R. W. 1989. *Fresh-water Invertebrates of the United States*, 3rd Edition. John Wiley and Sons, New York. 628 pp.

Perera, G. and J. G. Walls. 1996. *Apple Snails in the Aquarium*. T. F. H. Publications, Neptune City, New Jersey. 121 pp.

Russell-Hunter, W. D. 1978. Ecology of freshwater pulmonates. *In:* V. Fretter and J. Peake, eds., *Pulmonates*, Vol 2A. Academic Press, New York. Pp. 336-83.

Strayer, D. L. 1990. Freshwater Mollusca. *In:* B. L. Peckarsky, P. R. Fraissinet, M. A. Penton, and D. J. Conklin, eds., *Freshwater Macroinvertebrates of Northeastern North America*. Cornell University Press, Ithaca, New York, Pp. 33-372.

Thompson, F. G. 1984. *The Freshwater Snails of Florida, A Manual for Identification*. University of Florida Press, Gainesville, Florida. 94 pp.

Turgeon, D. D., J. F. Quinn, Jr., A. E. Bogan, E. V. Coan, F. G. Hochberg, W. G. Lyons, P. M. Mikkelsen, R. J. Neves, C. F. E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F. G. Thompson, M. Vecchione, and J. D. Williams. 1998. *Common and Scientific Names of Aquatic Invertebrates from the United States and Canada. Mollusks*, 2nd Ed. American Fisheries Society Special Publication 26. 526 pp.

Wethington, A. R. 2003. *Phylogeny, Taxonomy, and Evolution of Reproductive Isolation in* Physa *(Pulmonata: Physidae)* Ph.D. Dissertation, University of Alabama, Tuscaloosa, Alabama. 119 p.

Wu, Shi-Kuei. 1989. *Colorado Freshwater Mollusks*. Natural History Inventory of Colorado, Vol. 11. University of Colorado Museum, Boulder, Colorado. 117 pp.

Wu, Shi-Kuei., R. D. Oesch, and M. E. Gordon. 1997. *Missouri Aquatic Snails*. Missouri Department of Conservation, Jefferson City, Missouri. 97 pp.