

A review of freshwater gastropod conservation: challenges and opportunities

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Abstract. North American freshwater gastropods remain an understudied, yet critically imperiled, fauna. As part of a larger discussion on freshwater mollusks in this special issue, we review 4 specific areas of concern regarding freshwater gastropods and discuss how best to address those concerns in the context of conservation. Areas of concern include freshwater gastropod conservation strategies, taxonomy and systematics, ecological research, and conservation challenges. We illustrate how each of these topics relates to conservation efforts and discuss opportunities to improve our baseline knowledge of freshwater gastropod taxonomy, ecology, and conservation. We emphasize throughout that effective conservation strategies require the participation of as many affected and interested groups, from local communities to governmental agencies, as possible for successful implementation and management. We offer suggestions for the direction of cooperative conservation with regard to freshwater gastropods.

Key words: freshwater gastropods, cooperative conservation, review, research, strategy, snails.

The freshwater gastropod fauna of the USA and Canada consists of 842 nominal taxa (NatureServe 2007). This fauna is increasingly imperiled by river regulation, habitat loss, poor water quality, reduced water quantity, and invasive species. Estimates suggest that >40% of freshwater snail species are negatively affected by anthropogenic factors (Neves et al. 1997), resulting in many extinctions in North America (Master et al. 2000). More than 60% of the total nominal freshwater snail fauna have global ranks of G1 (critically imperiled), G2 (imperiled), or GH–GX (presumed or possibly extinct; Fig. 1), and recent extinctions support these rankings (Sada and Vinyard 2002, Hershler et al. 2007). Less than ¼ of all North American taxa are thought to be secure (G5) or apparently secure (G4; NatureServe 2007). The US

Fish and Wildlife Service lists 23 species of snails as endangered or threatened (Table 1).

Our objectives are to summarize what is known about freshwater gastropod conservation needs in North America (Brown et al. 2008, Perez and Minton 2008), highlight critical knowledge gaps that negatively affect conservation efforts, and suggest a logical path for future work.

Background

In the USA, freshwater gastropods are an especially diverse group of invertebrates, and their highest diversity is in the Southeast (Lydeard and Mayden 1995, Brown et al. 1998) and the Intermountain West (Frest and Johannes 2000, Hershler and Sada 2002, Hershler et al. 2007). Gastropods have invaded, and secondarily invaded, nearly every freshwater habitat in North America (Brown 2001), from emergent wetlands to shallow ponds, lakes, reservoirs, springs, creeks, streams, and large rivers. These generally small, inconspicuous members of our freshwater faunas have

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National Strategy

Efforts to conserve native biodiversity on a large scale benefit from the formulation of a national plan, or strategy, to consolidate the energies of academics, natural resource agencies, and the public. Examples include the National Oceanic and Atmospheric Administration’s Salmon Recovery Planning Strategy (NOAA 2007), the US Fish and Wildlife Service’s Draft National Bald Eagle Management Guidelines (USFWS 2006), and the National Native Mussel Conservation Committee’s National Strategy for the Conservation of Freshwater Mussels (NNMCC 1998). Management plans increase government and public awareness of the need for conservation, identify conservation actions necessary to achieve recovery of imperiled fauna, and foster creative partnerships to bring various actions to fruition (NNMCC 1998). Alternatives to national strategies for conservation of biodiversity include single-species conservation or recovery plans or land-management plans. However, conservation plans for species or habitats do not always have the same objectives as national strategies (e.g., to raise awareness, identify actions, and create partnerships) and might not be as useful as national strategies in leveraging funding for diverse taxa.

It is imperative that scientists and resource managers communicate with and convey information to the various publics that have an interest in the conservation of freshwater gastropods (Lydeard et al. 2004), and a comprehensive national strategy can be a vehicle for such communication. Mechanisms are in place to achieve this conservation need. The Freshwater Mollusk Conservation Society is revising its national strategy to include advances in research and understanding of freshwater mollusks and to include freshwater snails. A comprehensive national strategy might be the preeminent document that we use to leverage resources for freshwater gastropod conservation in the face of competing interests and priorities.

Basic Research

Taxonomy and systematics

The first step in a successful gastropod conservation program is to gain an understanding of the diversity of taxa that exist (Perez and Minton 2008). To protect biodiversity, we must first be able to recognize it in nature. The historical approach to taxonomy and classification of freshwater snails has been based on morphology. Unfortunately, much of this morphological evidence is difficult to use for comparison because of a lack of uniform and comparable data among authors, subjectivity of authors, and disagreement

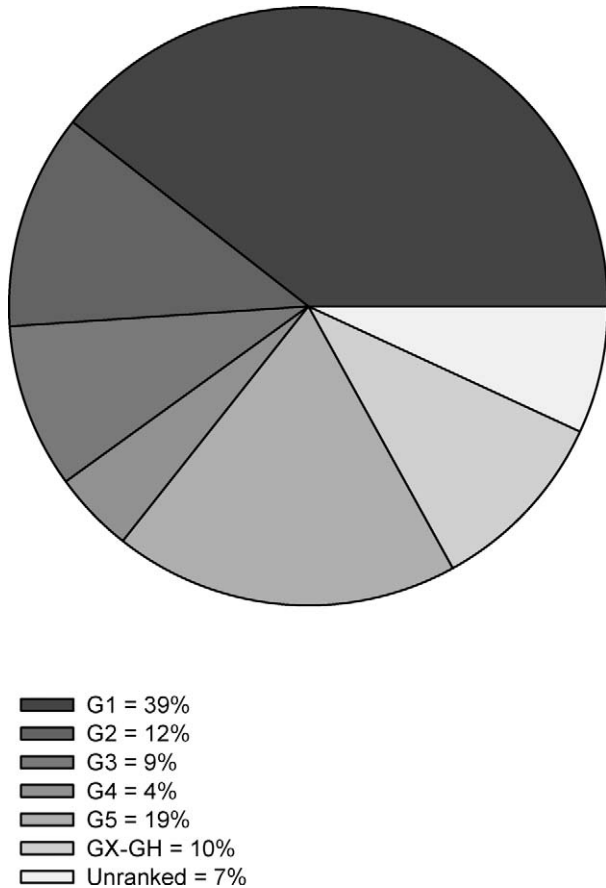


FIG. 1. Conservation rankings of North American freshwater gastropods (data from NatureServe 2007).

a disproportionately large role in the transfer of energy through aquatic systems (Newbold et al. 1983, Richardson et al. 1988, Brown 2001), primarily because of their numerical abundance in some systems. Unfortunately, their dispersal abilities, life histories, and habitat requirements do not appear to be well suited for coping with the rapid landscape changes and losses of habitat observed over the past 2 centuries in North America.

The primary causes of imperilment for listed snail species are loss or alteration of habitat. In the southeastern US, the loss of shoal habitat caused by impoundments is the cause of the extinction of many species and the tremendous reduction in range of many others (Neves et al. 1997). In the Intermountain West, the loss of spring habitats because of water withdrawal from regional aquifers and diversions of surface springs for irrigation also is of serious concern (Sada and Vinyard 2002, Myler et al. 2007). Other threats, such as water pollution and invasive species, combine with habitat loss or alteration to result in one of the best documented declines of a group of organisms worldwide (Lydeard et al. 2004).

TABLE 1. US freshwater snail species listed as endangered (E) or threatened (T) under the Endangered Species Act of 1973.

Common name	Scientific name	Range	Listing status	Recovery plan
Slender campeloma	<i>Campeloma decampi</i>	Alabama	E	No
Tumbling Creek cavesnail	<i>Antrobia culveri</i>	Missouri	E	Yes
Lacy elimia	<i>Elimia crenatella</i>	Alabama	T	Yes
Banbury Springs lanx	<i>Lanx</i> sp.	Idaho	E	Yes
Cylindrical lioplax	<i>Lioplax cyclostomaformis</i>	Alabama	E	Yes
Royal marstonia	<i>Pyrgulopsis ogmorhapha</i>	Tennessee	E	Yes
Flat pebblesnail	<i>Lepyrium showalteri</i>	Alabama	E	Yes
Anthony's riversnail	<i>Athearnia anthonyi</i>	Alabama, Georgia, Tennessee	E	Yes
Painted rocksnail	<i>Leptoxis taeniata</i>	Alabama	T	Yes
Plicate rocksnail	<i>Leptoxis plicata</i>	Alabama	E	Yes
Round rocksnail	<i>Leptoxis ampla</i>	Alabama	T	Yes
Armored snail	<i>Pyrgulopsis</i> (=Marstonia) <i>pachyta</i>	Alabama	E	No
Bliss Rapids snail	<i>Taylorconcha serpenticola</i>	Idaho	T	Yes
Newcomb's snail	<i>Erinna newcombi</i>	Hawaii	T	Yes
Pecos assiminea snail	<i>Assiminea pecos</i>	New Mexico, Texas, Mexico	E	No
Snake River physa snail	<i>Haitia</i> (=Physa) <i>natricina</i>	Idaho	E	Yes
Tulotoma snail	<i>Tulotoma magnifica</i>	Alabama	E	Yes
Desert valvata snail	<i>Valvata utahensis</i>	Idaho, Utah	E	Yes
Alamosa springsnail	<i>Pseudotryonia alamosae</i>	New Mexico	E	Yes
Bruneau hot springsnail	<i>Pyrgulopsis bruneauensis</i>	Idaho	E	Yes
Koster's springsnail	<i>Juturnia kosteri</i>	New Mexico	E	No
Roswell springsnail	<i>Pyrgulopsis roswellensis</i>	New Mexico	E	No
Socorro springsnail	<i>Pyrgulopsis neomexicana</i>	New Mexico	E	Yes

over character utility. Inconsistent taxonomy hinders conservation efforts by making information regarding specific distinctiveness equivocal. As new data are gathered and new species are described, we must update our database of taxonomic knowledge to enable conservation efforts. Those charged with implementing conservation plans generally are not taxonomists. Therefore, they should be supplied with current names and classifications; they should not be forced to determine whether names are synonymous or which methods are currently most appropriate.

We recommend the following regarding the roles of systematics and taxonomy in freshwater snail conservation efforts. First, we recommend a lineage-based concept of defining management units. New species discovered and described in this fashion are inherently testable in a scientific context (Goldstein et al. 2000, Sites and Marshall 2004) without ignoring the intellectual and scientific content of taxonomy (Dunn 2003, Lipscomb et al. 2003, Seberg et al. 2003). These units can then serve as the basis for captive propagation and other in situ and ex situ conservation efforts that preserve ecological and evolutionary processes, as well as individual populations. We recommend using a variety of data sources in defining these units, including morphology, gene sequences, and other natural history characteristics, analyzed in an evolutionary context so that natural forces and processes are retained.

We encourage authors to follow the rules of taxonomy and nomenclature when publishing descriptions or redescrptions of species. Turgeon et al. (1998) provided a list of names that is generally accepted in the field, and we recommend using it as the single starting point for modern nomenclature, with the understanding that future work probably will change it.

Conservation efforts should include recognition of unique lineages as primary management units, and the evolutionary processes that govern them should be stated explicitly. We also encourage researchers and agencies to explore the systematics and taxonomy of those groups that have not been treated in the modern literature. Large lineages, such as the families Hydrobiidae (e.g., Hershler 1994, Hershler and Ponder 1998) and Pleuroceridae (e.g., Tryon 1873, Holznagel and Lydeard 2000, Graf 2001), have had historical and recent systematic and taxonomic assessments. Smaller families, such as Physidae (Te 1978, Taylor 2003), have received disproportionate attention primarily because of their worldwide distribution (Dillon 2000). However, many evolutionary lines, such as the Valvatidae and Viviparidae, have not had any comprehensive treatments.

Ecology

Once taxonomists have stabilized specific units of conservation, then the conservation community can

begin to address the status of those entities. The need for adequate inventories of extant taxa and an understanding of distributional trends of those taxa is urgent (Lydeard et al. 2004, Wilson 2005). We have benefited greatly in this regard from the work of ambitious scientists (Frest and Johannes 2000, Stewart and Dillon 2004, Stewart 2006) who have inventoried snail species in specific states or regions. In particular, the Freshwater Gastropods of North America Project (Dillon 2007) is an ambitious effort that will benefit from the continued contributions of scientists, and we encourage participation in this endeavor. These efforts constitute a dramatic improvement in our understanding of freshwater snail diversity, but a snapshot of extant taxa across North America is not sufficient for purposes of conservation planning. Our reliance on historical records with sometimes questionable geospatial references can lead to premature conservation decisions and inefficient use of scarce natural resource agency dollars. It is important that inventory programs be repeatable (and then actually repeated) in subsequent years to document species persistence, increases and decreases in spatial distribution, and changes in habitat condition. Some of these needs might be within our reach and will be elucidated by careful study in natural history museums and other biological research collections (Lydeard et al. 2004). In other cases, new and exciting research will have to be developed to meet the needs we have outlined.

Research is advancing in freshwater snail ecology, but authors continue to stress the paucity of information that exists for many species (Brown and Johnson 2004, Richards and Cazier-Shinn 2004, Lysne and Koetsier 2006, Miller et al. 2006). We understand the general role of snails in freshwater systems (Brown et al. 1998, Dillon 2000, Brown 2001), but many of the 842 nominal taxa have been the focus of little ecological work since their description. The available treatments are, at best, “scattered” or “restricted to statements about the snails’ habitats” (Burch 1989). Contrast this understanding with the relatively vast literature on bivalve ecology (McMahon and Bogan 2001) and the need for vigorous study becomes clear.

To address these research needs, we recommend adhering to a logical progression of information gathering (i.e., stabilized taxonomy, completed inventory, reliable trend information, and all in an ecological context) so that natural resource managers can move on to the important task of setting conservation priorities. However, we acknowledge the difficulties of implementing such a strategy on a large scale and suggest that these goals can be tailored to suit individual agency needs (i.e., the crisis du jour) or research programs and still follow a practical infor-

mation-gathering path. For example, a molecular study of an evolutionary lineage (i.e., taxonomy) might document and report element occurrences of particular species (i.e., inventory) and simultaneously provide a description of community composition (i.e., ecological context).

Conservation Challenges

Water quantity

Of particular importance in the conservation of freshwater snails in North America is the state of our increasingly scarce water resources. Freshwater sources around the world have been extensively developed for the production of electricity, use in irrigated agriculture, and as the water supply for our burgeoning cities and industries (Postel 2000, Hutson et al. 2005). Global water demand has tripled since the 1950s, and aquifers and river systems are increasingly overexploited (Postel 2000). As rights for surface water become more difficult to secure, users increasingly make claims for groundwater to support irrigated agriculture, aquaculture, and domestic needs—a phenomenon referred to as *groundwater mining*. Unfortunately, these 2 sources of freshwater are hydrologically linked, and increased use of ground water can lead to decreased flows in rivers and streams. If even conservative global population-growth and water-use projections are realized, the stresses on freshwater systems and the species that live in them are expected to increase significantly (Postel 2000).

Water quality

The need for relatively pollution-free environments is as important to gastropod conservation as is the need for available freshwater. Numerous pollutants have been documented in some aquatic systems (Clark and Maret 1998, Wong et al. 2000, Clark et al. 2004, Rattray et al. 2005), yet significant uncertainty remains regarding the effects of these pollutants on populations of freshwater snails. Conservation biologists cannot possibly keep pace with industry with regard to a reasonable understanding of the effects of existing and novel contaminants in aquatic environments. However, it is important that we attempt to understand the effect of contaminants on snails in an ecological context, and we encourage researchers to follow this line of inquiry.

Invasive species

Invasive species are another important conservation challenge that can negatively affect native freshwater snails directly through competition for resources, such

as food and space, and indirectly through changes in ecosystem function (Hall et al. 2003, Richards 2004, Kerans et al. 2005). Species invasions have a demonstrated detrimental effect on the biodiversity of mollusks (Lydeard et al. 2004) and are the 2nd leading cause of declines in threatened and endangered species (but see Simberloff 2003, Gurevich and Padilla 2004). The relatively recent explosion of New Zealand mudsnails (*Potamopyrgus antipodarum*) in the western USA is a poignant example of the conservation challenges we face (Brown et al. 2008).

Putting species back

An important challenge to conservation biologists is finding cost-effective, efficient captive-propagation and reintroduction techniques. These techniques might include reproduction and rearing of juvenile snails in captivity with subsequent release into the known historic range of a species, or less significant intervention such as relocation or *translocation* of eggs, juveniles, or adults from viable populations. The goals of both of these techniques are to restore species to areas of their historic ranges where they no longer exist or to augment extant populations. Unfortunately, captive propagation of snails is still very much an experimental undertaking. These conservation measures must be planned carefully because they have associated risks, such as reduction of genetic variability that could lead to inbreeding depression, introduction of disease from individuals released into the wild, and the potential that human error or equipment failure could lead to loss of captively held species (Snyder et al. 1996, USFWS 2000).

Few researchers have attempted captive propagation of freshwater snails in North America, and little published research on the topic is available. A recognizable field of reintroduction biology has emerged (Seddon et al. 2007), but in general, conservation-oriented captive-propagation work has focused largely on mammals and birds, whereas invertebrate species are grossly underrepresented (Sarrazin and Barbault 1996, Seddon et al. 2005). Significant challenges to a captive-propagation program exist. These challenges include securing adequate broodstock for imperiled species (IUCN 1998), locating suitable release sites for individuals (Lyles and May 1987, Griffith et al. 1989, IUCN 1998), determining optimal environmental requirements for growth and reproduction, and genetic concerns associated with the propagation of species from a small number of individuals. Without proper consideration of the genetic implications of artificial intervention in imperiled snail reproduction, our efforts ultimately might be more

harmful than beneficial to the species we hope to save. Last, regular publication in peer-reviewed journals is crucial for effective communication of the results of propagation and reintroduction projects, whether success or failure, so that we can learn from our mistakes (Fischer and Lindenmayer 2000).

Opportunities for Success

To address these conservation challenges, we recommend establishment of local working groups that have the interest, expertise, and ability to collect, review, and disseminate information to those individuals or agencies that drive natural resource policy. These local working groups could create an agreed-upon mission statement, keep detailed minutes for future reference, invite guest speakers to share information with the participants of the group, and eventually participate in natural resource conservation and management decisions. Goals of such working groups might include: 1) dissemination of applied freshwater snail research to managers, 2) advocacy for existing agency programs that protect habitats, and 3) development of new and application of existing incentives and opportunities to involve private landowners in aquatic habitat conservation and restoration. An example of an opportunity for conservation might be the recommendation of minimum instream flows, and the timing of those flows, in threatened reaches of rivers for the conservation of freshwater snails. Stream ecologists and natural resource managers recognize that natural flow regimes have important implications for benthic organisms (Poff et al. 1997, Armitage 2006), and it is reasonable to expect that such efforts would be well received by decision makers and the general public.

Local working groups also could promote the construction and maintenance of wetlands. The economic (Prato and Hey 2006) and ecosystem (Johnson and Younger 2006) benefits of wetlands are documented (Nebel and Wright 1996, National Research Council 2001, 2004). By constructing and restoring wetlands along the lengths of natural river systems, at the termini of irrigation canals, the outflows of commercial fish-production facilities, or the outflows of municipal wastewater treatment facilities, we could greatly improve the quality of water that enters our lakes and streams and, in the process, improve habitat conditions for aquatic wildlife species, including freshwater snails.

The opportunities for success with regard to invasive species are numerous. The scope of exotic species invasion, the potential impact on native biodiversity, and the uncertainty with regard to the

magnitude of impacts present an array of research needs to the conservation community. If conservation alternatives have been exhausted and the decision to initiate a propagation program has been made, then natural resource agencies will have to commit to proper planning and sustained efforts. Areas particularly in need of research attention include investigation of the basic biology and optimal reproductive conditions of most freshwater snail species, assessment of genetic variation within snail populations, design of efficient equipment and techniques for captive propagation, and understanding of the nutritional needs of captive juvenile and adult snails, especially with regard to maximizing the growth rates of juveniles.

Efforts to conserve freshwater gastropods have lagged behind efforts to conserve freshwater mussels. However, this inequity is changing, and new initiatives are highlighting the need for gastropod conservation. We look forward with great optimism to a new national strategy for the conservation of all freshwater mollusk species. We also look with optimism to our conservation partners to establish and support active groups of interested publics working toward shared objectives. The challenges to conserving biodiversity are great, but we think that collective, coordinated efforts are no longer novel or incipient but are becoming mainstream with great successes on the horizon.

We are encouraged by the direction of molluscan research. We think that we can begin to prioritize freshwater snails in order of greatest conservation need so that we make the best use of limited resources once natural resource managers have reliable information on the species of mollusks present in their area of jurisdiction, the distribution and abundance of those species, and the persistence of those species in the face of environmental change. Natural resource managers and conservation organizations will continue to make decisions in the presence of significant uncertainty. The real challenge in conservation lies in the ability to develop a shared understanding among academics, natural resource managers, and the various publics we serve (Rogers 2006). We can increase our understanding and reduce uncertainty with regard to the conservation challenges we face if we follow a logical progression of information gathering, scientific understanding, and conservation advocacy.

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