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Musseling in on Biodiversity

The extreme endangerment of freshwater mollusks escapes the notice of many people concerned with biodiversity and species at risk. Yet this group of animals top the charts for species lost and emperiled. A research scientist describes the problem and offers suggestions for improving mollusk conservation.

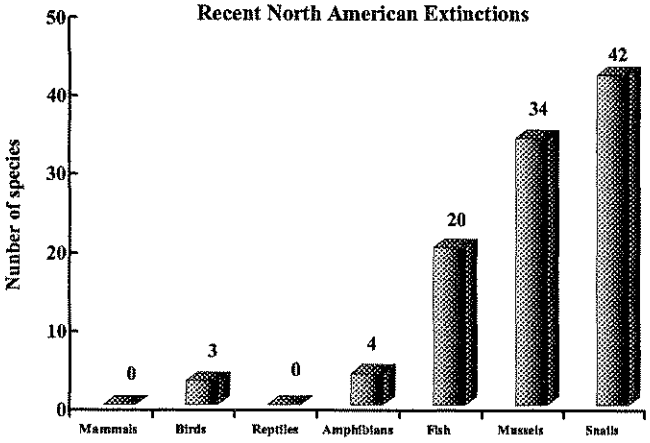
by Paul D. Johnson

You might consider the decline of beach mice, Florida panthers, gray wolves, free-tailed bats, gray whales, spotted owls, or leatherback turtles the single largest animal conservation crises facing the country today. Although very serious, these conservation problems pale in comparison to the damage occurring to the animals living in our rivers and streams. Indeed, the largest animal extinction crisis in North America today is happening in riverine ecosystems across the country. Freshwater mollusks—such as snails, mussels, and fingernail clams—and other riverine animals are undergoing drastic declines in their distributions and population sizes, which makes them vulnerable to extinction. The problem is especially pronounced in the southeastern United States, where river basins such as the Appalachicola, Altamaha, Black Warrior, Clinch, Coosa, Duck, Pearl, and a few others host the last remaining vestiges of an incredible treasure of unique biodiversity, unlike any other on the planet. Many aquatic biologists have referred to this crisis as "the silent extinction," because it involves many species of small, cryptic animals easily overlooked by the general public and the conservation community. These animals don't have feathers, fur, or in some cases even eyes to invoke sympathy and attention. What many do have however, is a rich and fascinating natural history, and their disappearance from our river systems is a call to alarm regarding the nation's water quality, despite the tremendous advances we have made in the past 30 years.

Freshwater mollusks, although the focus of this article, are just one—albeit critical—component of the conservation challenges that face riverine animals. While mollusks appear to be the most sensitive of all riverine animals, their historic troubles illustrate what awaits other freshwater species. In fact, a recent analysis suggests that after tropical rainforests, the next largest documented extinction event on the planet today is occurring the in the rivers and streams of eastern North America.[1] Freshwater fauna in North America has undergone drastic species losses in the last century, and the loss is expected to accelerate substantially in this century. Although freshwater mollusks have led the extinction crisis, other freshwater animals are expected to follow this same trend.

The rivers and streams of the Southeast have a rich diversity of freshwater animals, and mollusks in particular. In fact, the heaviest concentration of freshwater biodiversity on the continent is found in four southeastern states: Alabama, Georgia, Tennessee, and Kentucky. The key to both the rich diversity and high imperilment of freshwater mollusks lies in their distribution. Mollusk species organization their distribution around discrete river drainages. In the Southeast, these river systems are very ancient, and the animals in each basin have evolved and speciated over a long period of time, without the glacial interruptions common to the geologic history of northern North America. Likewise, the rivers of the Southeast are far older than the mountain river systems of the Pacific Northwest.

Few rivers in the Southeast better illustrate the effects of long geologic history and drainage basin affiliation than the Conasauga River of southeastern Tennessee and northwestern Georgia. This small



The extinctions graph describes the number of species in each major animal group that have become extinct in North America over the past 150 years. Notice the rate extinction increases as groups transition from terrestrial to freshwater ecosystems.

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river system is the headwater of the Coosa River basin, and these headwaters drain the U.S. Forest Service's Cohutta Wilderness Area of northwestern Georgia, flowing north into Tennessee, then turning south and past the town of Dalton, Georgia. This 75-mile-long river supports a level of biological diversity that makes it a southeastern jewel. For example, the Conasauga River basin has 54 species of freshwater mollusks and 76 species of fish. The fish diversity alone is greater than the native fish diversity of the much larger Colorado and Columbia River basins combined (58 species). Because the species loss in the Conasauga River basin has been so substantial, several of the mussel species living there can be found nowhere else.

Extinction rates per decade for each major freshwater animal group.[a]

Aquatic Animal Group	Current Extinction Rate (per decade)	Future Extinction Rate Estimated (per decade)
Amphibians	0.4	3.0
Fish	0.4	2.4
Crayfish	0.1	3.9
Gastropods	0.8	2.6
Mussels	1.2	6.4
Marine higher vertebrates	0.1	0.8

[a]Rates calculated by Ricciardi Rasmussen 1999.

Perhaps the most biologically diverse river in North America today is the Duck River, a Tennessee River tributary located south of Nashville. This 260-mile-long river system boasts 52 species of freshwater mussels, 24 species of freshwater snails, and 146 species of fish, with several endemic darters. Several shoals of the Duck River support nearly 30 species of mussels and 100 species of fish. In addition to its fish and mollusk diversity, the Duck River has a considerable diversity of crayfishes, amphibians, and aquatic reptiles. The river is truly a national treasure, but relatively few people recognize its value.

Conservation Status of Freshwater Mollusks

The last century has seen the loss of 76 species of freshwater mollusks, all of which were native to the southeastern United States.[2] Freshwater mollusks center their distributions around three major river systems in the Southeast: the Tennessee River basin, the Mobile River system (including the Tombigbee, Black Warrior, Alabama, and Coosa systems), and the Flint, Chattahoochee, Apalachicola basin of Georgia, Alabama, and Florida. Additionally, the southern Atlantic Slope drainages (Savannah, Pee Dee, Tar, and others) have many unique mollusk species. The Tennessee River basin contains the richest diversity of mussel fauna in the world. The Mobile River basin has the widest diversity of freshwater snails in North America and is rivaled globally only by the river systems of Southeast Asia.

The U.S. Fish and Wildlife Service currently lists 70 species of mussels and 18 species of freshwater snails as threatened or endangered. Only three of the listed mussel species and eight of the snails live outside the southeastern United States. An additional 57 species of freshwater mussels and 135 species of freshwater snails were placed on the service's federal candidate list in 1994.[3] Additionally, nearly one-half of all mussel species and some 61 percent of freshwater snails are considered imperiled. The rate of imperilment is greater for freshwater snails than any other major animal group, because many species tend to have very localized distributions (endemism), and species loss from a single perturbation event is a distinct possibility.

The construction of large hydroelectric dams by the Tennessee Valley Authority in the Tennessee River basin and those built by Alabama Power in the Coosa River basin appear to have caused much of the damage to freshwater mollusks in these river basins over the last century. The construction of several large dams in each basin essentially turned these large rivers into a series of large lakes unsuitable for many riverine species. In the tailwaters (the stretches of river below the dams), the hydroelectric operations altered the dissolved oxygen and temperature levels for miles, often making the areas of flowing water below the dams inhospitable to riverine mollusks. While environmental ethics during the era of large dam building were decidedly different from today (and these dams did help industrialize the Southeast), the power needs of the Southeast today are so great that the power generated from these dams constitutes less than 10 percent of the region's kilowatt production. Today hydroelectric dams are generally used to meet only "peaking power" demand periods in the afternoon and early evening hours.

The largest single extinction event in continental U.S. history occurred from 1945 to 1975, due to damming and general water quality degradation of the Coosa River basin of northwestern Georgia and eastern Alabama. Of the 76 species of freshwater mollusks lost in the United States, 43 were endemic to the Coosa River basin. This loss includes all representative species of four genera of freshwater snails *(Amphigyra, Clappia, Gyrotoma, Neoplanorbis).*

Historically, the primary causes of decline in mussels and snails in the Southeast were dam construction, dredging and river channelization, instream sand and gravel mining, deforestation, and pollution from mining, municipalities, and other industries.[4] However, hydroelectric dams, flood control projects, inland navigation, and other large river endeavors do not explain the loss of mollusk and fish fauna inside the tributary systems of these large river basins. It seems that one by one, many large tributary systems have become so degraded that many can no longer support sensitive mollusks or fish. Today relatively few tributaries in the Tennessee, Coosa, and Apalachicola River basins support large populations of rare riverine mollusks. Although the point source water quality of many streams and rivers has improved, pollution from nonpoint source toxins, sedimentation, hydrologic disruption, and urbanization continue to degrade or eliminate freshwater mollusk habitat. Additionally, evidence is mounting that agricultural pesticide/herbicide run-off contributes to the elimination of freshwater mussels in some river

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systems. Also, decreased instream flow conditions caused by severe drought or increased water withdrawals threaten many mollusk species, which cannot survive the resulting alteration of natural temperature and dissolved oxygen regimes. Freshwater mussels feed by constantly straining bits of algae and very small organic matter from the water. If the river water quality is poor, this damages the mussel's ability to feed and respire. Many species of freshwater mussels live for decades, so low level pollution events can take many years to show a negative influence. Freshwater snails feed on the small algae and organic debris present in the bottoms of rivers and streams. Excess fine sediments or poor water quality also curtails their ability to feed and respire.

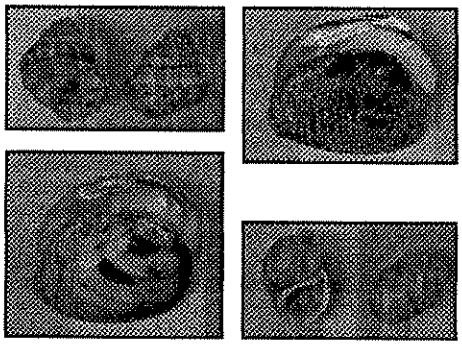
Rocks With Guts

Never judge a book by its cover, the old saying goes, and this is especially true for freshwater mussels. Their sometimes plain shell hides one of the most amazing and ingenious reproductive strategies in nature. All larval freshwater mussels are parasites of fish. Freshwater mussel larvae (called glochidia) must attach themselves to a fish host for a period of several weeks to months, until a fully formed juvenile mussel detaches from the host. These glochidia larvae are very small and are generally a quarter to half a millimeter in diameter. In most instances, this host-parasite relationship is very specific, and for most species of mussels only a few fish will successfully carry the mussel larvae to maturity. While some opportunistic species of mussels simply push individual larvae out at passing fish, others make aggressive displays or camouflage their larvae to mimic the favorite food item of their fish hosts. On the other hand, this marvelous reproductive strategy also explains the extreme vulnerability of mussels to the changes in populations of riverine fish that serve as their hosts. Mussel reproduction depends on healthy host fish populations and clear, clean rivers, because many of the fish hosts are visual predators.

Freshwater snails also have an interesting biology and allow them to adapt to all types of aquatic environments. Some species breathe air from the surface through a primitive lung, while most extract air from the water with a single gill. Some species are separately sexed, and others are hermaphroditic. Most species lay their eggs on the margins of stream and river channels, and fully formed juvenile snails hatch several weeks later. However, some species can hold their eggs internally, allowing them to hatch and feed on mucus in a special pouch inside the mother's body before release. Many snails live only a year while other species can live as many as 15 years. Because freshwater snails show a terrific ability to adapt their biology to local environmental variation, their widespread disappearance from rivers and streams directly reflects the severity of water quality and habitat destruction already wrought on the rivers and streams of the Southeast.

Conservation Strategies

In the last few years, the Tennessee Valley Authority has embarked on a multi-million-dollar effort to improve water quality conditions in several of its hydroelectric dam tailwaters. The Reservoir Release Program is restoring natural conditions to tailwaters by improving dissolved oxygen levels and water temperature regimes. These efforts by the water authority have vastly improved water temperature and dissolved oxygen conditions in the tailwaters, which allows for the restoration of many aquatic species. Additionally, Alabama Power has made major release improvements at Jordan Dam on the Coosa River. Minimal release schedules at Jordan Dam, begun 10 years ago, have improved mollusk populations and habitat conditions below the dam dramatically, and additional improvements at other dams on the Coosa River are under consideration. These improvements make ongoing restoration efforts of rare fish and mollusks possible in the mainstem of the Tennessee and Coosa Rivers.



These four highly endemic freshwater mollusks are native to southeastern river systems, including the Conasauga, Coosa, Duck, and Oostanaula Rivers.

In the few remaining tributary systems where the fauna is intact, the species have become the focus of recovery efforts by the U.S. Fish and Wildlife Service and The Nature Conservancy. The conservancy's Freshwater Initiative Program develops citizen-based watershed alliances in important tributary basins throughout the southeast. These alliances take a "front lines" approach by directly working with citizens, politicians, farmers, and business leaders in each community to improve conditions within each basin. The alliances are organized as not-for-profit agencies, and a citizen board oversees the specific activities of each alliance. To date, The Nature Conservancy has organized river alliances for the Altamaha, Cahaba, Clinch, Chattahoochee, Conasauga, Duck, Etowah, Green, Hatchie, Paint Rock, and the Wolf River basins in Alabama, Kentucky, Tennessee, and Georgia. The Nature Conservancy also has worked closely with biologists in the Southeast, determining the last remaining diversity hotspots, in order to select which basins are important enough to target for future restoration efforts.

Other private conservation agencies also are assisting with North America's most serious animal biodiversity problem. The World Wildlife Fund recently completed an assessment of freshwater ecoregions of North America, which has shown riverine fauna of the southeast to be of the highest global importance for conservation.[5] Conservation efforts by American Rivers, although mostly directed towards the rivers of the Pacific Northwest, now include southeastern

attention, especially in working to participate in the Federal Energy Regulatory Commission hydroelectric dam re-licensing efforts in the region. Additionally, new conservation science organizations, such as the Freshwater Mollusk Conservation Society, are advancing mollusk recovery efforts by developing national conservation strategies and sponsoring national symposia and workshops dedicated to mollusk recovery efforts.[6] Many of these private conservation agencies now work cooperatively with each other to improve the conditions of river ecosystems and the animals that inhabit them.

Several federal, state, and private agencies are working cooperatively to directly recover rare species of mollusks and fish. The U.S. Fish and Wildlife Service recently the developed an "experimental population designation" rule for aquatic threatened and endangered species. The rule allows conservation scientists to return an extirpated species to an area of its former range. State conservation agencies have oversight in deciding where experimental populations can be established; to date, state conservation agencies in Alabama, Georgia, Tennessee, and Virginia are participating in these recovery programs. Research scientists from the U.S. Geological Survey Cooperative Extension units at Virginia Polytechnic Institute and Tennessee Technological University, the Virginia Department of Game and Inland Fisheries, the Tennessee Aquarium Research Institute, and Conservation Fisheries Inc. are providing the labor and technical expertise to breed in captivity many of these rare fish and mollusks. These captive-bred mollusks and fish are then used to establish new experimental populations or, more often, augment existing ones.

With so many riverine species in the southeastern United States in need of conservation attention, current levels of effort and support for restoration programs make it unrealistic that all can be saved. Indeed, some very hard choices regarding the aquatic natural heritage of the Southeast are directly at hand. However, important steps could be taken toward improving recovery efforts for aquatic species and insuring that at least some of these remarkable species have a future. First, non-game species restoration would greatly benefit from the passage of the full Conservation Assessment and Reinvestment Act. The bill that passed last year provided funding for 2001 only, whereas passage of the full act would ensure annual recovery funds. Because aquatic fauna recovery efforts are long-term projects, they require a steady and reliable source of funding.

Secondly, aquatic non-game species would benefit from the proper assignment of dollar values on species for recovery efforts. Dollar values help states generate cost estimates in assessing punitive fines and in recovering a portion of the natural resource value lost when a large pollution spill kills thousands of animals. Currently, only the loss (take) of federally listed species and the illegal sale or transport of commercial mussel species are the only avenue for the assessment of fines. The assignment of value to non-commercial and non-listed mussel species would give state resource agencies another avenue to pursue recovery dollars to replace some of the resource lost from these catastrophic spills. Because some recent spills have killed large numbers of freshwater mussels in several river systems across the country, the Freshwater Mollusk Conservation Society is moving forward with the development of dollar values for non-listed freshwater mussels.

Another step would be for the conservation community to adopt a new strategy beyond litigation as a means to increase federal funding for threatened and endangered species. While lawsuits by environmental groups against the U.S. Fish and Wildlife Service theoretically lead to Congress appropriating more funds for listing, recovery, and habitat needs, on the whole, these lawsuits appear to have diminished the service's ability to carry out recovery efforts, because the services personnel time and resources are increasingly directed toward addressing lawsuits, rather than recovery issues. Efforts by conservationist might be better spent in lobbying Congress for more Fish and Wildlife Service funding.

Stronger regulation and enforcement of existing nonpoint source emission regulations. The primary threats to freshwater fauna in the Southeast today are impacts from nonpoint sources. The effects of heavy sedimentation, herbicide/pesticide runoff, complete removal of riparian buffers, and the physical alteration of natural watersheds are combining with disastrous effects on our riverine species. Current restoration efforts must address each of these habitat issues simultaneously before long-term species restoration efforts are effective. Stronger regulation and enforcement of current regulations would not only improve habitat for riverine species, but would have the added benefit of improving water quality for everyone. ■

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