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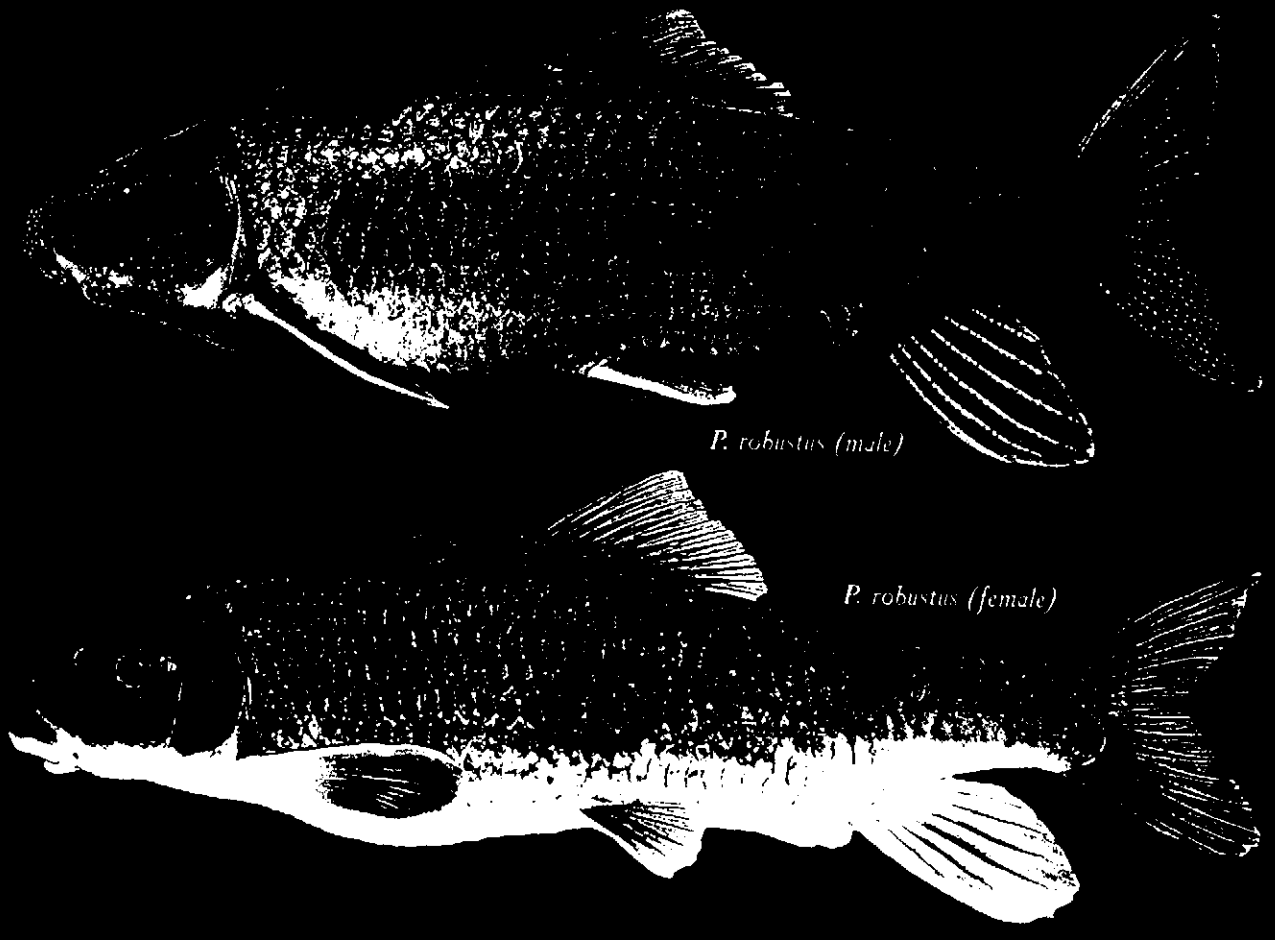
SOUTHERN SCIENCE

The Mystery Fish



Lost by Science For 122 Years, The Robust Redhorse, *Ptychostomus robustus* Has Been Rediscovered. Now Scientists Fight To Save It From Disappearing Forever.

By Richard T. Bryant, James W. Evans, Robert E. Jenkins & Byron J. Freeman

Hundreds of years ago, before the era of European colonization, forests covered much of North America in a virtually unbroken canopy which stretched from the Atlantic Ocean to the western prairies. The protective canopy of the great trees sheltered the soils from heavy rains, and extensive root systems held the soils in place. The rivers ran clear, even after the rains. The various peoples inhabiting the country at that time lived in one of the most productive and diverse regions on earth.

After the mild winters had given way to spring, during the months of April and May, a great migration occurred in many of the rivers flowing into the Atlantic Ocean from the area occupied by the present states of Georgia and the Carolinas — a migration which has all but ceased today. Vast numbers of large fish, led by unerring instinct, would migrate to shallow gravel bars and face into the swift current. The males would arrive first, each attempting to stake out a dominant position by sparring with rival males. The females, swollen with eggs, would follow onto the gravel shoals, some so shallow that their broad, bronze-colored backs were exposed. Each female would be flanked by a male on each side, the males caressing the females, swimming, dancing alongside, stimulating her to release her eggs in a frenzied, splashing spasm of instincts, enough to mix the eggs and sperm and bury them into the soft sandy gravel shoal, where they would develop into the young of the next generation.

Acres of these spawn-crazed fish, completely oblivious to their own safety, paying attention to nothing but their instinct to pass on their own kind, must have been very easy prey for a hunter with a sharp stick. They were large fish, up to 17 pounds with delicious white flesh, and it is little wonder that archaeological sites from middle Georgia to northern North Carolina contain their remains. The thankful Native Americans who witnessed these great spawning migrations must have stood on the river banks in awe. The fish were as much a part of the rhythm of the seasons as the blooming of flowers and the migration of birds, annual events that added to the certainty that another spring would lead to another summer, and that all was as it should be. Today the great numbers of fish are gone, the rivers are cloudy with silt, the forests are broken, and the peoples which once lived here have been replaced by ones with entirely different views of nature.

And what happened to the great abundance of fish? What did they look like? Why did they disappear? This is a mystery story of sorts, and for the first clue we must travel back to the late 19th century.

In 1870 Edward Drinker Cope, one of the greatest natural historians of the century, published a very brief, two-paragraph description of a heavy-bodied fish, a "redhorse" he had collected in the Yadkin River of North Carolina. He called this "stout" redhorse *Ptychostomus robustus.*

"In *P. robustus* we have a species, stout in all its proportions, and with marked coloration ... Color smoky or clouded above, mingled with golden reflections; sides similar, below yellowish. Dorsal, caudal and anal fins dark crimson. Size large. I examined one of six pounds weight."

Unfortunately, this very short narrative did not contain nearly enough detail to describe the species well. In fact, it appears that Cope did not even examine the large, molar-like pharyngeal teeth in the throat area of the fish, such an important diagnostic feature that he used them in the very same article when referring to other redhorse species. Pharyngeal teeth are modified fifth gill arches in minnows and suckers, which are located just before the opening of the esophagus. If the teeth are molar-like, as in the robust redhorse, they are adapted for crushing mussel shells. The narrative description was also not illustrated with the customary line drawings.

Although lacking substantial detail, these few sentences represent the only published description of *P. robustus* since 1870. This was the same species that had spawned in such large numbers in the once pristine rivers of Georgia and the Carolinas, although no one would know this fish again for another 122 years.

To complete the story of *P. robustus*, we must return to the 1870s and follow the activities of Edward Cope and his fellow naturalists up to the present time. The mystery deepens when we learn that Cope's original preserved specimens of the robust redhorse have never been located. Apparently, he made arrangements to have his biological

Above left, a breeding male robust redhorse. Note the small white tubercles on the head, anal fin, and tail. Photo by Byron J. Freeman. Below left, a breeding female robust redhorse. Photo by Richard T. Bryant.

Photo by Richard T. Bryant

Greg Looney of the U.S. Fish and Wildlife Service strips the eggs from a robust redhorse on the banks of the Oconee River.

and mineral specimens shipped via railroad to Germantown Academy near Philadelphia, but a bureaucrat at the university said the freight bill was "heavy," and the specimens "worthless." They were never seen again. Undoubtedly, they are gone forever.

For unexplained reasons, specimens of a related species in the collection at the Academy of Natural Sciences of Philadelphia were mistakenly labeled *Ptychostomus robustus*. Then, in 1877, the name *Ptychostomus* was replaced with *Moxostoma*, and the masculine name *robustus* was changed to *robustum* to agree in gender with the neuter *Moxostoma*.

In 1956, Richard Robins and Edward Raney published a paper which misapplied the name *robustum* to a smaller species, the smallfin redhorse. If this wasn't confusing enough, the smallfin redhorse historically shared many of the same river systems with the real *robustum*. In short, Edward Cope's *P. robustus* lost its name to another fish species. Although the trail of errors has now been discovered, it has not been widely publicized and fish identification manuals continue to perpetuate the confusion.

Other specimens of Cope's *P. robustus* were probably collected during the next 110 years by biologists, sportsmen, and commercial fisherman in Georgia and the Carolinas, but they were misidentified, unidentified, or not deposited in a museum. Since the species was apparently already declining in abundance when Cope wrote his short description in 1870, *P. robustus* seemed on the way to oblivion before its existence was ever officially recognized.

Then, in the 1980s, two rather mysterious fish came to the attention of scientists, the first collected from the Savannah River of Georgia/South Carolina and the second from the Pee Dee River in North Carolina. Ironically, the Savannah River fish was netted in 1980 by aquatic biologists from the Academy of Natural Sciences of Philadelphia, where Cope worked and his collections are deposited. It was thought to be the first record of a molar-toothed sucker from any Atlantic drainage river, and for confirmation, it was mailed to Dr. Robert Jenkins, the country's leading expert on redhorse suckers. With only one speci-

men, however, unique as it may have been, he couldn't tell at the time if it was a different species from the molar-toothed species found west of the Appalachians, the river redhorse, *Moxostoma carinatum*. Jenkins wrote to numerous biologists, pleading for more specimens, and he was rewarded.

The Pee Dee River specimen was collected in 1985 by biologists working for a consulting firm who thought enough of the fish to photograph it as it came out of the water, but not enough to carefully preserve it. After being wrapped in a plastic bag and neglected, the fish was bloated, partially eaten by rats, and infested with maggots — not the typical fish specimen a normal person would get too excited about. By the time the decision was made to send the fish to Jenkins, it had to be stuffed into a pants leg from an old pair of blue jeans to keep it from falling apart. Jenkins was thrilled.

Along with the Savannah River fish, the Pee Dee fish seemed to represent a totally new species, or was it? Given the state of deterioration in the specimen, it was difficult to determine with certainty. Its true identity would not be known for a few more years.

In 1991, fishery biologist Jimmy Evans and technician Wayne Clark of the Georgia Department of Natural Resources (GaDNR) collected five large redhorses in the Oconee River near Toomsboro. They were using an electrofishing boat to collect fish for studies associated with the Federal Energy Regulatory Commission (FERC) relicensing of Sinclair Dam, a Georgia Power Company facility. The fish were unlike any species known to occur in the Oconee River and were shipped to Dr. Byron (Bud) Freeman at the University of Georgia and Dr. Hank Bart at Auburn University for further study. Both ichthyologists recognized the potential significance of the specimens and thought there might be a connection between these fish and the mystery fish from the Savannah and Pee Dee rivers. After painstaking examination of the specimens and lengthy consultations with Dr. Jenkins at his lab in Roanoke College, Virginia, it was determined that the Oconee, Savannah, and Pee Dee specimens were one and the same species.

But could these fish actually represent a species completely new to science? It seemed difficult to believe. After all, this was 1991 and most biologists assumed that all large North American fish species had long ago been discovered. How could a fish this large escape detection? It seemed to reach a length of 30 inches and a weight of 17 pounds. This would make it almost twice as large as any other redhorse species on the Atlantic slope, and perhaps the largest animal species discovered in North America in 100 years.

Bob Jenkins, Bud Freeman, and Jimmy Evans now began the laborious process of meticulously describing every detail of the new fish, and as if things weren't already confusing enough, everyone seemed to have a different name for it. There seemed to be no doubt that it was a redhorse, but how about "bighead" redhorse. Yes, some of them had big heads, but they also had very large pharyngeal teeth — maybe "stumptooth" redhorse, but not very elegant some thought. It was also hefty — perhaps "broadback" or maybe "rotund" redhorse. And then it became obvious.

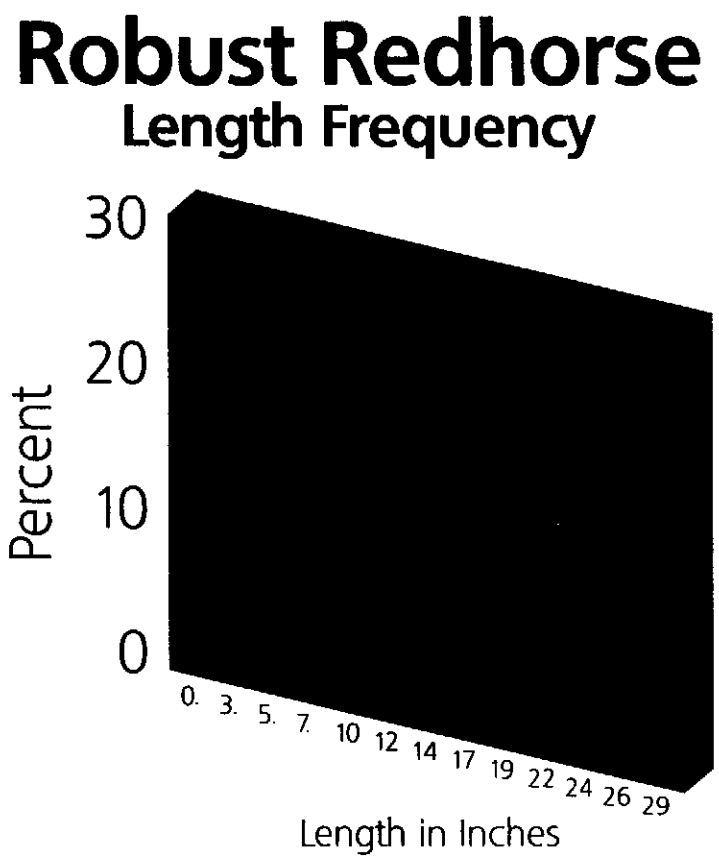
One evening Bob Jenkins was reviewing his research on the redhorses, when he reread (for the twentieth time) Edward Cope's long-misunderstood description of a fish which everybody believed was the smallfin redhorse. These few sentences, written in 1870, seemed an uncannily accurate (though skimpy) description of the mystery fish recently collected from the Oconee, Savannah, and Pee Dee rivers. Then, Jenkins discerned errors in labeling the specimens that had wrongly been given the name *robustum* in 1956; they were impostors! It was now clear that Cope's *Ptychostomus robustus* had been rediscovered, and after a lapse of over a century!

It was also now clear what the rediscovered species should be called; there was no choice but to transfer Cope's original name, as befitted such a robust fish. Unfortunately, as you recall, the name *robustum* had erroneously been given to the impostor species. Confusing enough? A manuscript is currently being prepared which will formally transfer Cope's original name to the robust redhorse as *Moxostoma robustum*. The species which presently possesses that scientific name, the smallfin redhorse, is actually a new undescribed species! It will be renamed the brassy jumprock and placed in a separate genus. Then some of ichthyological history's past mistakes will finally be corrected.

The present conservation status of the robust redhorse can best be described as perilous. Five years of diligent searching in the Oconee, Ogeechee, Savannah, and Pee Dee river systems since 1991 has produced not a single specimen outside the Oconee River. Anecdotal reports of

large redhorses from other rivers persist, but investigations have failed to verify any of them. Although some hope remains that other remnant populations will be located, most authorities agree that the 50 river mile section of the Oconee River between Milledgeville and Dublin, Georgia probably contains the only remaining viable population.

The GaDNR has been systematically investigating the status of the Oconee River robust redhorse population since 1992. Recaptures of fish marked with small plastic streamer tags have yielded a population estimate of between 1,000 and 3,000 adults. Even more troubling than the small population size is the advanced age of the great majority of individuals. The average age of adults is 17 years, with more than 90 percent of the adults between the ages of 15 and 25, much older than most fish species ever attain. A very few individuals, now averaging about 20 inches in length, were spawned in the wild and successfully reared about six to eight years ago. Over 90 percent of the population is between 24 and 27 inches in length and the smallest ever seen was 17 inches (see above graph). It is like the age distribution inside a nursing home with hundreds of extremely old individuals and a handful of young attendants. Not the kind of age distribution you would want to entrust the future of your species to. A population with this age distribution cannot survive for many years without human intervention to artificially build up the strength of the younger age classes.



The graph above shows the terribly abnormal size distribution of robust redhorses. Note the virtual absence of any fish under 22 inches long.

What factors could have pushed to the edge of extinction a large, healthy population of fish which at one time ranged across the Piedmont and Upper Coastal Plain from at least the Yadkin River in North Carolina to the Altamaha River drainage of central Georgia? Although there are undoubtedly a number of contributing causes, four factors which are probably central to the decline of the robust redhorse are overfishing, deforestation and sedimentation, the damming of virtually all rivers within the historical range, and the introduction of exotic, large, predatory fish species.

Although Native Americans certainly used the robust redhorse as a food source, probably concentrating the harvest in the spring when spawning aggregations were vulnerable, it is unlikely they ever harvested enough fish to threaten the population of any river system. Harvest undoubtedly became more efficient with the introduction of new technologies by European settlers (better nets, guns, explosives), but it is unlikely that the Native Americans or early settlers had a dramatic effect on the species throughout its range. At least into the early 1800s, redhorse populations in many locations were quite robust. For example, Cope's 1870 description of the robust redhorse from the Yadkin River contains this passage, which presumably deals mainly with the robust redhorse, but probably with other redhorse species as well:

"It is highly valued for the table by the people living near the river ... These [spring] nets are attached by four corners and suspended to the extremity of a lever whose fulcrum, as high as a man's head, is on the river bank. Bait is thrown on it, and when the fishes congregate, the land end of the lever being suddenly depressed, the suckers do not escape. If fishing were confined to this mode, and the

autumn weirs not made too tight, an abundant supply of food from the rivers might be promised the State of North Carolina for future time. But unfortunately, too many of the people with the improvidence characteristic of ignorance, erect traps, for the purpose of taking the fishes as they ascend the rivers in the spring to deposit their spawn. Cart loads have thus often been caught at once, so that the supply is at the present time [1869] reduced one half in many of the principal rivers of the State. The repopulation of a river is a very different matter from its preservation, and involves much time, attention and expense. It would be far cheaper for the State of North Carolina to enact laws preservative of this important product of her waters, similar to those in force in many of our older states. The execution of such laws is, however, the important point, and the destruction by officers, of the spring traps and weirs in the Neuse, Cape Fear, Yadkin and Catawba Rivers, every spring, at the time of running of the fishes, would allow for the escape of immense numbers of them, before the traps could be repaired."

This is clear evidence that the need for enlightened fisheries management did not begin with the 20th century—Cope was ahead of his time. However, many species have been heavily exploited and it has proven difficult to drive species to extinction through overharvest alone. We must look at other causes to fully understand the historical decline of the robust redhorse.

There is increasing evidence that stream sedimentation is one of the major causes of the decline and extinction of fish and mussel species in the southeastern United States. The deforestation and row crop agricultural practices which accompanied human colonization of the southeastern United States throughout the last century resulted in extensive erosion and sediment deposition in rivers.

This pervasive sedimentation may have seriously harmed species such as the robust redhorse which require clean gravel for spawning. The fertilized eggs of this and related species fall into spaces between the gravel where they incubate and hatch, typically after a period of three to six days. The newly-hatched larvae have a large yolk sac, much like a chicken egg with the protective shell removed. They can't swim well and are very delicate. The gravel shelters the larvae for eight to 11 days, until the yolk is absorbed and the young fish, now called fry, are able to swim out to face the world. If the eggs or the helpless larvae are smothered by a layer of silt, they will almost certainly die.

Mussels are also harmed by unnatural amounts of sedimentation because as filter feeders they live most of their lives buried in a stream bottom, filtering food from the current. It is not hard to see how a choking cloud of mud would disrupt feeding, destroy habitat, and generally make life difficult for most mussel species. Since adult robust redhorse depend almost entirely on mussels as a food source and require clean gravel for spawning, sedimentation may have had a double-barreled impact, affecting both food supply and reproduction.

The following historical narrative is a telling illustration of the impact of human colonization, deforestation, and sedimentation on the character of Georgia's once pristine rivers. The observations are by one of the greatest geologists of the 19th century, Sir Charles Lyell, who embarked on a canoe trip down the Altamaha in December 1845:

"As our canoe was scudding through the clear waters of the Altamaha, Mr. Couper mentioned a fact which shows the effect of herbage, shrubs, and trees in protecting the soil from the wasting action of rain and torrents. Formerly, even during floods, the Altamaha was transparent, or only stained of a darker color by decayed vegetable matter, like some streams in Europe which flow out of peat mosses. So late as 1841, a resident here could distinguish on which of the two branches of the Altamaha, the Oconee or Ocmulgee, a freshet had occurred, for the lands in the upper country [Piedmont Plateau], drained by one of these (the Oconee) had already been partially cleared and cultivated so that that tributary sent down a copious supply of red mud, while the other (the Ocmulgee) remained clear, though swollen. But no sooner had the Indians been driven out, and the woods of their old hunting ground begun to give way before the ax of the new settler, than the Ocmulgee also became turbid."

It is unknown if the robust redhorse originally migrated great distances up and down the river systems that drain the Atlantic slope of Georgia and the Carolinas. Cope's original description of the species was from the upper Piedmont of North Carolina and the single preserved specimen from North Carolina was collected from within the Fall Zone. The only specimen from the Savannah River

was taken from the middle Coastal Plain and the entire Oconee River population is found in a 50 mile section of river beginning immediately below the Fall Line. Fish tagged by the GaDNR in the Oconee River have moved as far as 35 river miles, but since Sinclair Dam serves as a barrier to upstream migration, movement patterns are artificially restricted. The robust redhorse may have migrated significant distances, especially during spring spawning runs. Similar behavior has been observed in other closely related species.

Beginning in the late 1800s and continuing up until modern times, dams of various types have been built on virtually all of the rivers within the historical range of the robust redhorse. The most obvious impact of these dams is their potential to disrupt migrations and reduce access to spawning areas. In addition to disruptions of migration patterns, dams impact all aquatic life through alterations to the natural flows of rivers, both upstream and downstream, for many miles. Eggs, larvae, and young fry of robust redhorses are most severely impacted by these flow changes. Normally, the very delicate eggs and yolk-sac larvae are sheltered in the spaces between the pebbles of shallow gravel bars, with just enough current to oxygenate them and sweep them clear of silt. When the fry become free-swimming, they move downstream into shallow pools and backwaters, where they feed and grow, sheltered from predators and strong currents.

Most dams on southeastern rivers presently operate as hydropeaking projects, with water releases for power generation occurring once or twice a day. Current velocities and water depths in rivers below these dams fluctuate wildly in comparison to natural streams. During minimum flow releases, when the turbines are not operating, water temperatures may increase enough to harm or kill the eggs and larvae. Eggs and larvae lying in the shallow gravel could be completely out of the water during low flows or scoured out of the gravel by higher generation flows and then eaten by predators or simply dashed to pieces as they are swept downstream. The free-swimming young could likewise be swept out of backwater nurseries and into the swift current, much to the delight of waiting predators. Displaced from nursery areas by high flows once or twice daily, few of these young fish may survive the first year of life. Obviously, some species of fish are less vulnerable to the hardships of life below dams, and a number of species are remarkably tolerant of these conditions. The significance of man-made flow alterations to the historical decline of the robust redhorse is only speculation at this point, but studies conducted below several hydropeaking dams have shown low abundance of species closely related to the robust redhorse.

Flathead catfish began appearing in several of the Atlantic slope drainages in the southeastern United States in the 1960s and 1970s. They were apparently introduced primarily by sport or commercial fishermen, although governmental agencies stocked some rivers. Flathead catfish now inhabit virtually every river throughout the previous range of the robust redhorse. They appeared in the Altamaha River system in the mid-1970s and are now abundant throughout most of the system, including the Oconee River up to Sinclair Dam.

Native to the Mississippi River and several adjacent drainages, flathead catfish are voracious predators and adapt easily to new environments. Soon after flathead catfish appeared in the Atlantic slope rivers, several native fish species began to decline, most notably bullhead catfish, some species of sunfish, and in a few cases some of the redhorse species. No longer constrained by whatever ecological balances held them in check in their native streams, flathead catfish are wreaking havoc among the more vulnerable fish found in their newly acquired homes. Flathead catfish appeared well after the robust redhorse had succumbed to other disturbances and had vanished from most of its former range. These predators are merely assuring that the few that remain will face another powerful enemy in the struggle for survival. Although very little can be done about the flathead catfish menace to the last known robust redhorse population, we can learn from past mistakes and work to prevent other introductions of exotic species into places where they do not belong.

Dr. Bud Freeman of the University of Georgia says of the fish: "The plight of the robust redhorse is indicative of how we have managed our landscape and aquatic systems for the past 250 years. Streams and lakes reflect all too well the damage done to any of the land within their watershed. The ultimate fate of the robust redhorse and many other aquatic species rests entirely with us."

It is little wonder that vulnerable

Photo by Byron J. Freeman

A female robust redhorse spawning with males on either side of her. The male on her left is turning to butt heads with an intruding male.

species like the robust redhorse are facing a struggle for survival, having to contend with overfishing, deforestation and river sedimentation, the damming of rivers, exotic predators, not to mention the unceasing encroachment of human development along river corridors and the inevitable pollution it brings. We should not be surprised when other species follow it to the brink. We had a bit of luck with the robust redhorse; it was discovered and its plight recognized before it vanished forever. The past history of Edward Cope's *P. robustus* is now known. But what of its future? That is the second part of our story.

Fortunately, fishery science has progressed to the point where techniques are available not only to assess the status of fish populations, but also hopefully to recover those that are in danger of extinction. To successfully recover any threatened fish species requires a massive effort involving both state and federal agencies, conservation groups, and often the private sector as well.

The Federal Endangered Species Act forms the legal framework and is the crucial cornerstone for all recovery efforts for threatened and endangered species. Although recovery plans for many imperiled plants and animals have been implemented, no federally listed fish species has been restored to the point that it could be removed from the list. This is because habitat degradation, in its various forms, is the primary cause of the decline of sensitive fish species, and habitat is typically both extremely difficult and expensive to recover after degradation has occurred. The rediscovery of Cope's long-forgotten fish is both a delight and an obvious challenge to those of us working in the field of fishery science within the former range of the species.

Recovery efforts for the robust redhorse were initiated in the spring of 1992, once it became apparent that the Oconee River between Sinclair Dam and Dublin, Georgia probably contained the only significant remnant population. A Memorandum of Understanding (MOU) establishing the Robust Redhorse Conservation Committee (RRCC) was signed in 1995 by state and federal agencies, power companies, and conservation groups throughout the species' former range. The primary responsibility of the RRCC is to analyze the factors leading to the decline of the fish, and attempt to restore the population to a sustainable level throughout its former range. Authorization for the MOU is provided under the provisions of the Federal Endangered Species Act.

Present signatories to the agreement are the Georgia Department of Natural Resources, South Carolina Department of Natural Resources, North Carolina Wildlife Resources Commission, U. S. Fish and Wildlife Service, National Biological Service, U. S. Forest Service, Georgia Power Company, Carolina Power and Light, and Duke Power and one conservation organization, the Georgia Wildlife Federation.

Jerry McCollum, President of the Georgia Wildlife Federation, says, "We should not miss this unique opportunity to preserve and recover a species like the robust redhorse. This fish could provide us with valuable information about low density survival and give us an opportunity to study a species of wildlife that is on the absolute brink of extinction."

A major goal of these efforts is recovery of the species without the need for federal listing, often referred to as a prelisting recovery approach. The entire recovery process has been accelerated by the ongoing relicensing of Sinclair Dam by the Federal Energy Regulatory Commission (FERC). The FERC is required by federal law to give equal consideration to environmental issues and power generation in the relicensing negotiations.

There are a number of advantages to a prelisting recovery approach. First, the recovery team can mobilize resources more quickly and with greater flexibility if the red tape associated with administrative requirements of the Federal Endangered Species Act can be avoided.

Second, a greater variety of funding sources are available to the recovery team if, in addition to the usual state and federal government agencies, private conservation groups, utilities, and other businesses are encouraged to contribute to the effort. As we are seeing in other arenas of public life, it is probably a mistake to rely entirely on the government to tackle the full array of environmental problems facing us.

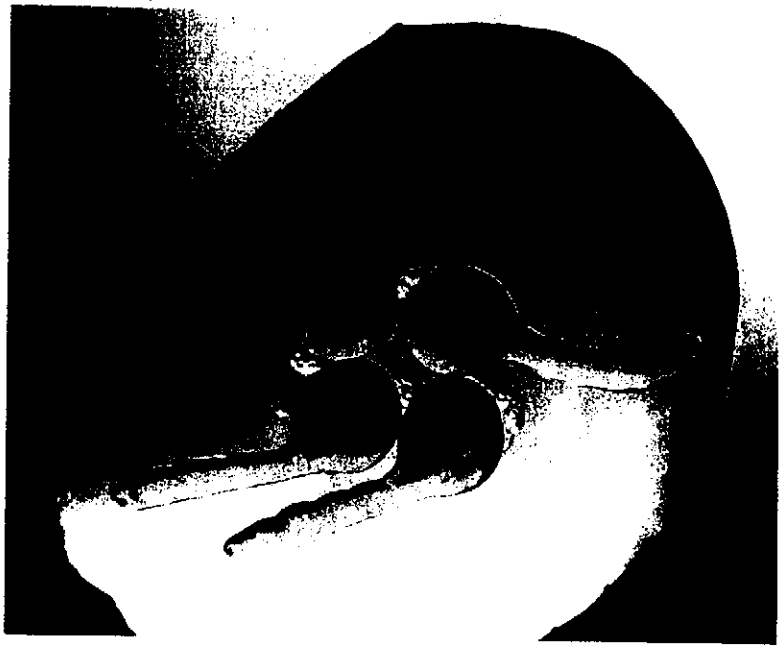
Third, the prelisting approach to recovery fosters an atmosphere of cooperation, rather than confrontation, between affected interest groups. Consensus for action is difficult to reach when regulatory agencies, utilities, developers, and private conservation groups sit on opposite sides of the table, mistrustful of each other, jealously guarding their own interests. Examples of this are easily found in the counterproductive waste of time and money that resulted from the snail darter/Tellico Dam controversy in the 1970s or the more recent battles over the spotted owl.

Finally, despite the problems and controversies associated with its application, the Federal Endangered Species Act is crucially important legislation to everyone interested in the health of the natural environment. This legislation is under attack, however, and its future is uncertain. Recovery efforts which utilize a prelisting approach may avoid the need for controversial federal listings, thereby reducing political pressures on the Act and hopefully contributing to its future survival. It is important to remember that without the Endangered Species Act, there would not be any incentive or mechanism to get the affected parties to the negotiating table in the first place.

If the RRCC and other organizations devoted to the conservation of the robust redhorse cannot document clear progress toward recovery within a reasonable time, the species will be listed under the Federal Endangered Species Act, with all the attendant legalistic and bureaucratic entanglements. Everyone, including the robust redhorse, would be better off if this can be avoided. It should be emphasized that the prelisting approach being attempted with this species will not be the most suitable recovery vehicle for all endangered species. Effective conservation of some species will require federal listing. Where applicable, however, it could serve as a useful model of an alterative approach to the management of imperiled species.

Short-term recovery goals for the robust redhorse include the establishment of what can be termed "refuge" populations outside of the Oconee River. These populations would assure the survival of the species in the event

Photo by Greg Looney, U.S. Fish & Wildlife Service



This photo, taken through a dissecting microscope, shows the large yolk sacs of the delicate, freshly-hatched robust redhorse.

that the Oconee River population continues to decline, or is exposed to a catastrophic event, such as a chemical spill. Refuge populations should be established in at least three other river systems, with each site containing a minimum of 1,000 adults from at least five different age classes. Refuge populations will also be established in ponds. A realistic long-term goal is the establishment of reproducing populations in a minimum of three river systems within the species' known historical range.

In order to maintain the genetic diversity of the only known population, hatchery-reared fingerlings will not be introduced into the Oconee River below Sinclair Dam, unless significant population declines are noted. It would be much more desirable if successful natural spawning could be induced by manipulating flows out of Sinclair Dam. This would result in many more crossings and much greater genetic diversity than could possibly be produced from the stocking of hatchery-reared fingerlings. Studies funded by Georgia Power Company through at least 1997 are aimed at determining if natural reproduction is occurring in the Oconee River, and at evaluating some possible ways to improve reproductive success.

The first attempt to artificially spawn the robust redhorse was made in 1992 at the Warm Springs Fish Technology Center, in Warm Springs, Georgia, operated by the U. S. Fish and Wildlife Service; it was unsuccessful. About 5,000 fry were produced at Warm Springs in 1993, and studies funded by Georgia Power Company in 1995 to evaluate the effectiveness of hormones, which induce rapid ovulation in brood fish, resulted in the production of about 72,000 fry. These are presently stocked in ten rearing ponds at two state hatcheries in Georgia and two federal hatcheries in Georgia and North Carolina. Hatcheries which rear robust redhorses must be located within the historical range of the species, in case a few escape into a nearby river.

Advanced eight to 10 inch fingerlings from the 1993 year class were first introduced into the wild in March 1995 at two locations on the Broad River in Georgia (Savannah River Drainage). Approximately 30,000 to 40,000 advanced fingerlings from the 1995 year class should be available for reintroduction in the fall of 1996. Primary sites will be several locations in the Broad River system, although other sites in the Oconee and Savannah River drainages are being evaluated as well. Reintroductions will be attempted only in drainages within the historical range of the fish.

The recovery effort for the robust redhorse has clearly developed into a huge endeavor, with nothing less than the survival of a species at stake. According to Jimmy Evans of the GaDNR and current chairman of the RRCC: "I don't think anything of this magnitude devoted to the recovery of a species has ever been attempted in the Southeast."

What happened to *Ptychostomus robustus*? We now have many of the answers. And what will be its future? It's too early to tell. It may dwindle into extinction, or with our help, it may survive for another 126 years. SW

Richard T. Bryant is a free-lance photographer, photographic editor of Southern Wildlife and has a background in aquatic biology. **James W. Evans** is a fisheries biologist with the GA Department of Natural Resources, and the discoverer of the robust redhorse in the Oconee River. **Dr. Robert E. Jenkins** is a professor at Roanoke College and the leading expert on the redhorse suckers. **Dr. Byron J. Freeman** is an ichthyologist at the University of Georgia, and the expert on the fishes of Georgia.