This spiny river snail, lodged in inverted position, is shown here trying to right itself. It is being considered for endangered status.

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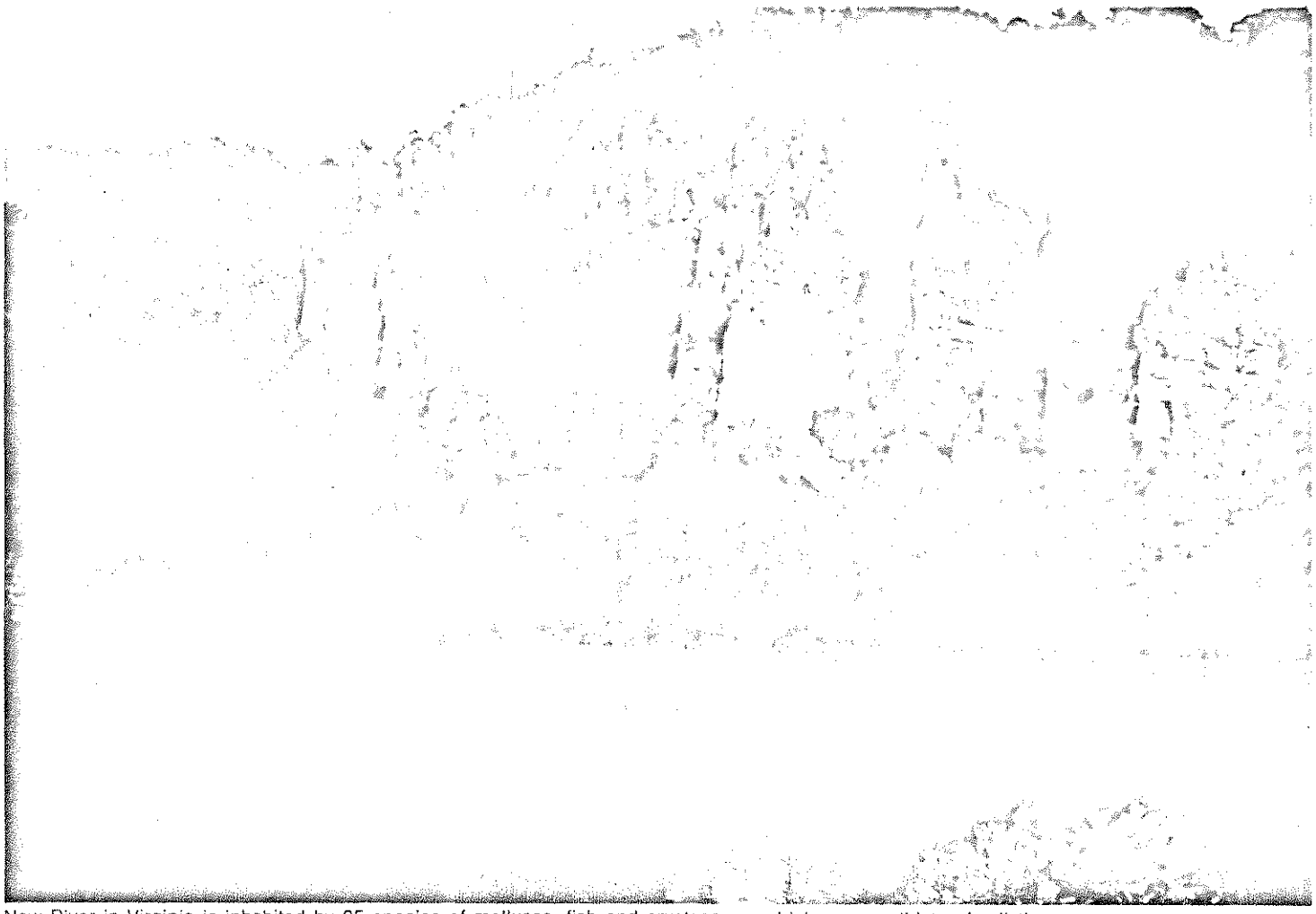
The clean gravel shoals beneath the swift, cool, clear waters that line a portion of the Little Tennessee River in Loudon County, Tennessee are unique. This 17-mile stretch is the first area in the United States to be officially determined a "critical" habitat, for it is the only known home of a tiny fish called the snail darter. This same locale is slated to be covered by impounded river waters when the Tellico Dam is completed.

The Tennessee Valley Authority, which is building the dam, is being sued by private citizens who want to halt the dam's construction. They claim that impoundment of water behind the structure poses a threat to the existence of the darter. A Federal court has ruled in favor of continuing construction on grounds that a large amount of capital has been invested in the project and the fact that the darter was not discovered until after construction started. The case is under appeal and construction is proceeding. However, the agency is enjoined from filling the dam's reservoir until the legal issues are resolved.

In another recent case, the U.S. Supreme Court pro-

Photos by Hans Stuart, U.S. Fish & Wildlife Service



New River in Virginia is inhabited by 25 species of molluscs, fish and crustaceans which are candidates for listing.

tected the Mississippi sandhill crane by refusing to review an appeals court decision that permanently halted construction of an interstate highway through the birds' habitat.

The Tennessee-Tombigbee Waterway project of the Army Corps of Engineers also has landed in the courtroom. One of the claims in a railroad company's suit is that the project is violating environmental statutes. Among the aquatic residents of the affected Tennessee-Alabama-Mississippi area are five species of molluscs which the U.S. Fish and Wildlife Service believes are endangered by the navigation project.

Unfortunately, there often is no really satisfactory solution to this relatively new type of coexistence problem. Only in recent years has the extinction of species and subspecies been generally recognized as a biologically undesirable occurrence. Not until late in 1973 did the United States enact a strong law to protect endangered creatures and plants in their unequal competition with man for habitat and other resources.

One proposed solution to this coexistence problem is mitigation, which can mean transferring affected species to other, similar locations. But even in those rare cases where mitigation appears to be successful—and so far few of the transplanted darters are surviving—years must pass before biologists can be certain that transplanted species such as molluscs will be able to reproduce at a rate high enough to assure their survival.

Creating new habitat is similarly risky and also expensive. The level of technical expertise necessary for duplicating a watery molluscan habitat has not yet been achieved.

Molluscs—clams, snails, limpets, oysters, mussels, slugs, octopuses and squid—are affected by many human activities. The single most important threat to aquatic endangered species is the erosion of our topsoil with the consequent silting of our streams. Research is needed into land treatment of erosion to replace stream channelization, which is carried out by the Corps of Engineers and other agencies, because dredging and channelization of streams eradicates nearly all bottom life for a decade or more. Even where some bottom life

has returned, no instance is known where the diversity has reached even 50 percent of the original number.[1]

Another big problem that molluscs face is large dams. The principal difficulty with these structures is that they are usually constructed in rural areas likely to contain abundant wildlife. When the land is inundated, a large portion of our dwindling wildlife is destroyed.

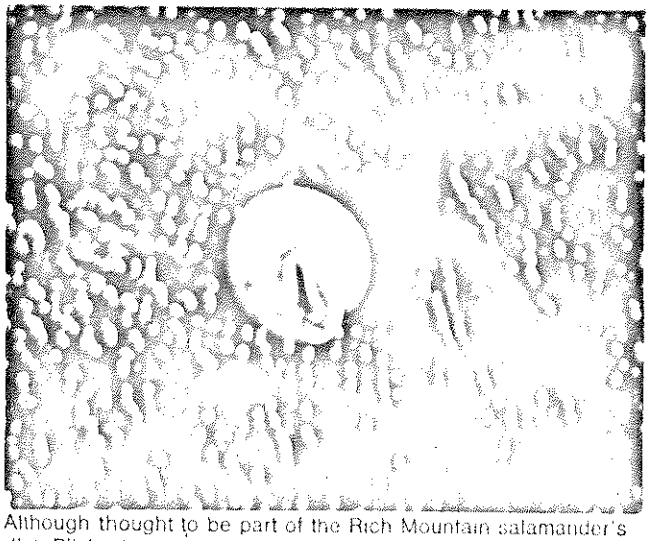
A third problem is pollution. Adding waste, treated or untreated, to unpolluted or slightly polluted streams causes a degree of degradation in water quality. On the other hand, using streams which are moderately or heavily polluted for the disposal of well-treated wastes may improve existing water quality. It is necessary to compare the effects of ozone treatment to chlorination of wastes, secondary to tertiary treatment, and compare all of these to land treatment.

In recent years there has been an unfortunate tendency to make enormous efforts to clean up streams that are already dead and, at the same time, to allow the water quality in slightly polluted streams to deteriorate to the point of species extinction. This leveling trend toward homogenization of the water quality and aquatic life in our rivers would be counteracted by carrying out the water pollution control efforts which are necessary to protect these aquatic endangered species.

Finally, the risk of hybridization generally corresponds to increasing disturbance of the habitat by pollution, channelization, dredging, deforestation and other such operations. Land snails, for example, have been found to hybridize, or produce offspring of mixed parentage, in disturbed areas.

[1] *Ed. Note:* The Corps is currently researching dredging and disposal of dredged material at the Environmental Effects Laboratory at its Waterways Experiment Station at Vicksburg, Mississippi.

Upper Clinch River, Tennessee is sole home for many species of plants, fish and invertebrates, including this rough rabbit's foot pearly mussel.



Although thought to be part of the Rich Mountain salamander's diet, Pilsbry's narrow apertured land snail is extraordinarily modified for keeping out other predators.

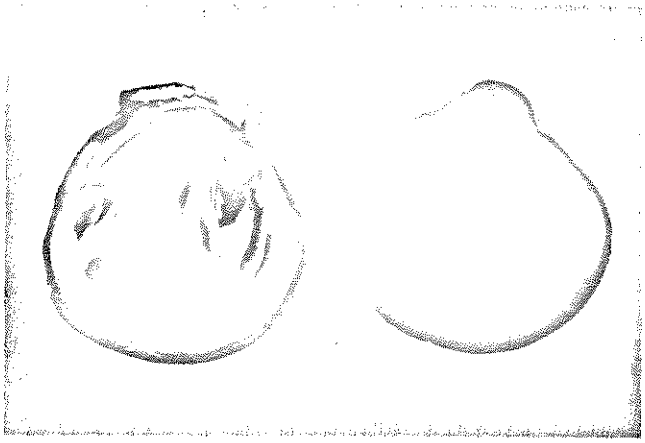
The importance of dam building, dredging, waste treatment or their alternatives (relocation of buildings, railroads or recycling) is easily understood. Many dams are designed to protect lives and property from flooding; dredging aids navigation and transportation, and waste treatment is certainly essential for our good health. Many persons, however, ask why seemingly insignificant molluscs are also important to man.

A diversity of species provides resilience, adaptability and stability to the web of life which covers our planet. Once a species becomes extinct, its genetic composition and all of its potential values as a natural resource are lost to mankind. For instance, molluscs rarely get cancer. One of its substances (mercenene) that has already been isolated prevents or delays two types of cancer in mice and has had no side effect when tested on human amnion cells. When potential values such as this are lost through extinction of a species or subspecies, the thin web of life on earth is forever diminished by just that much.

Already snails and mussels are serving man by acting as a gauge of the health of stream ecosystems. They are a valuable link in the food chain because they make up part of the diets of birds, mammals and other aquatic species.

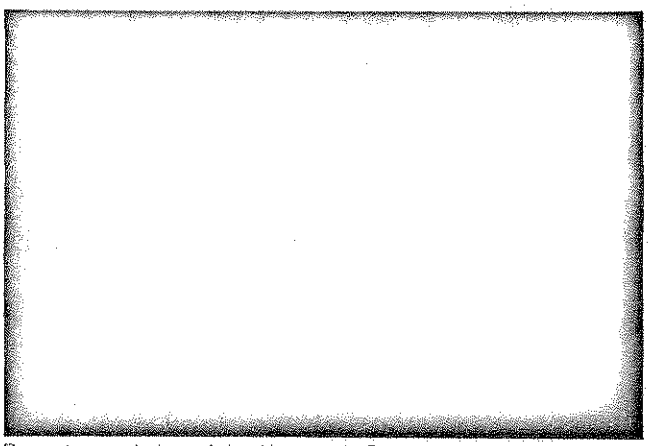
Molluscs constitute the second largest group of animal or plant life in the world. Comprised of some 120,000 species, they are exceeded only by the group containing insects.

They first appeared during the Paleozoic era of 500 to 600 million years ago. Molluscs are by and large a very successful stage between early stationary animals,



Unlisted but believed to be endangered, the golf stick pearly mussel lives in the Green River, near Mammoth Cave National Park in Kentucky.

Introducing the endangered Key Largo woodrat and doormouse to Lignumvitae Key, Florida jeopardized the existence of this local tree snail.



Recent completion of the Normandy Dam on Duck River, Tennessee has rendered the turgid riffle shell mussel effectively extinct. Of the 40 species of riffle shell mussels that once existed in the eastern United States, about half are now extinct.

sponges and coral for example, and more aggressive food seekers such as insects and crustaceans. While they belong to the external skeleton line of arthropods rather than the internal skeleton line of chordata, their great life style represents an alternative to either line because they possess both active and passive parts. Their slow but active animal parts, the foot and head, allow them movement while their passive vegetal[3] part stores food for months or years and protects them from dessication and predation.

Inadvertently, I once left a live-bearing freshwater snail, *Viviparus malleatus*, in a dry finger bowl over an entire summer. Within hours after this sealed shut, presumably dead animal was replaced in water, it was moving about actively.

Furthermore, the watery nature of molluscs' soft tissue makes all sorts of wonderful metabolic and excretory activities possible. For instance, their watery tissue enables them to isolate and store an inordinately high number of compounds, some of them substances which are extremely toxic to man. This capability also gives them a very effective waste metabolism so that some of the energy normally required for excretion is freed for other activities.

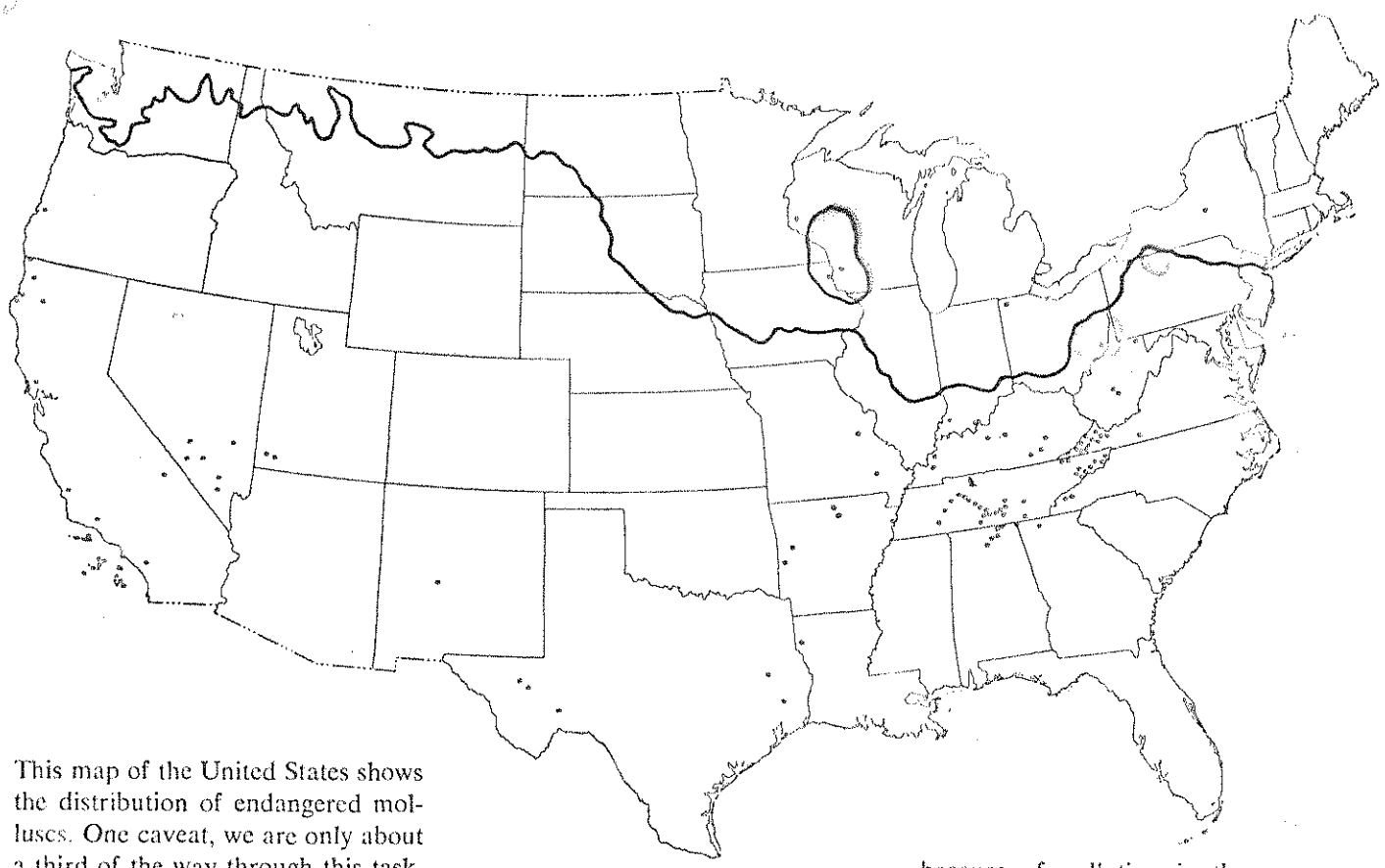
Freshwater mussels daily produce urine equivalent to 24 percent of their body weight, including shell. Their high water content then helps the mussel reabsorb from the excreted urine the sodium, chloride and calcium which so efficiently helps them maintain their osmotic balance.

Historically, the normal rate of molluscan extinction has ranged from 10 to 20 percent every million years. For example, a study of freshwater and land molluscs of the Blancan period of 2 to 5 million years ago shows that 11 of 50 molluscs from a Kansas rock formation, 21 of 31 molluscs from a California formation, and 4 of 20 from a Florida formation have become extinct worldwide.

The natural mean time span of individual snail species is reported to be 5 million years under stable conditions. Generally speaking, the natural extinction rate has been equal to the replacement rate over the long run. In the 50 United States, however, the extinction rate now equals 20 percent in 1,100 years for 56 documented molluscan extinctions have occurred since 1876. Today, this man-caused extinction rate has accelerated and 15 percent of living molluscs are expected to vanish in the next 5 to 15 years. Similar extinction rates have been found among almost all groups studied all over the world: mammals, birds, fish, crustaceans and plants. In short, 15 percent of living diversity is endangered.

Such worldwide mass extinctions have occurred only a few times in the history of the earth. Perhaps 40 per-

[3] Having or showing plantlike life or growth.



This map of the United States shows the distribution of endangered molluscs. One caveat, we are only about a third of the way through this task. In red are officially listed and proposed species. In blue are other endangered or threatened molluscs. The heavy black line denotes the southern extremity of the Wisconsin ice sheets of some 10,000 years ago. Earlier ice ages penetrated even deeper. Virtually all of the endangered molluscs are found south of the heavy black line. Northern species were pushed south or extirpated (wiped out).

Notice the importance of the unglaciated areas of French Creek in New York and Pennsylvania, the Muskingum River in Ohio, and the Kickapoo-Driftless area in Wisconsin (see shaded areas). They are northern refuges for many northern species. The northern tips of Greenland and Central Alaska may also be important for the same reason.

Some of the species that were pushed south later migrated back north, including, perhaps, the northern riffle shell *(Epioblasma rangiana)* in Ohio, the Higgins' eye pearly mussel *(Lampsilis higginsi)* in Illinois, and the mudpuppy mussel *(Simpsonichoncha ambigua)*, in Ontario which are indicated by shaded areas.

During the last 10,000 years few new species have evolved and thus become vulnerable to endangerment. One of these few is the Chittenango ovate amber snail, *Succinea ovalis chittenangoensis*, of New York (see shaded area). It has evolved in the spray zone talus under the falls for which it is named and has declined because of pollution in the spray. Apparently, there are a number of such postglacial species among certain plant and insect groups. If true, this would substantiate the popular notion that it is in the nature of insects to speciate.

Increased temperature does not appear to play nearly the role in the distribution of molluscan species which are endangered that it does for reptiles or plants. Note that there are as many endangered molcuses in Idaho as in Arizona and in Tennessee as in Alabama.

cent of all species disappeared at the time of trilobite[4] extinction at the end of the Paleozoic era, about 230 million years ago; and 30 percent vanished at the time of the dinosaur extinctions at the end of the Mesozoic era, about 65 million years ago. Evidence indicates that during these periods the magnetic poles reversed so that there was little or no magnetic field for several thousand years. Great solar flares also occurred during these times. The ozone layers were depleted and radiation destroyed all but the well protected.

Growing appreciation for the potential value of all species coincided with their accelerating extinction rate and led to enactment of the Endangered Species Act of 1973. Administration of the Endangered Species Program is the responsibility of the Office of Endangered Species, a component of the U.S. Fish and Wildlife Service in the Department of the Interior.

This act is perhaps the most comprehensive environmental legislation to be passed by any country. It directs the government to use three direct methods to help prevent future extinctions: acquisition of endangered species' habitat, encouragement of conservation and habitat protection for listed species on Federally managed lands, and encouragement of individual States to enact and fund their own endangered species laws.

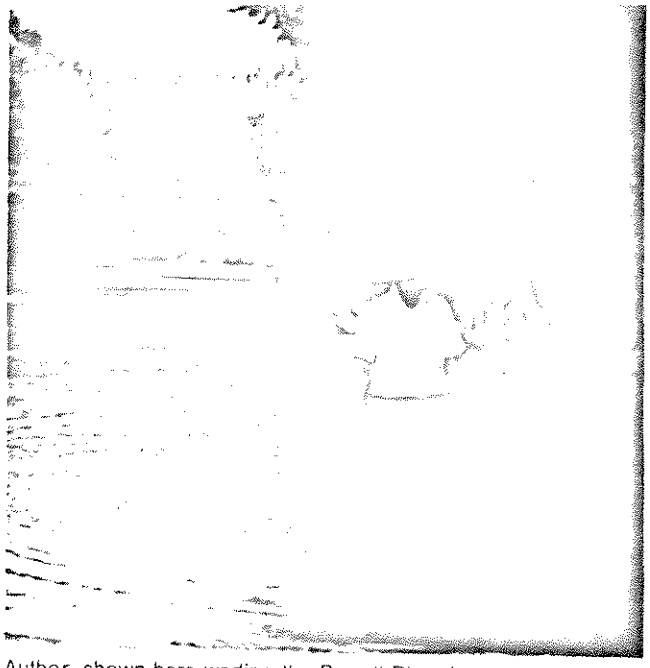
Section 4 of the act requires the Department of the Interior to publish lists of endangered and threatened species of creatures and plants. The lists differ essentially in priority. Those proposed as endangered are restricted to a very small area or occur in such small numbers as to be in imminent danger of extinction. The threatened list is for species that have a wider range or have sufficient numbers so that they face a less grave problem of survival but are likely to become endangered within the foreseeable future. Since the law was signed in December, 1973, 25 molluscs have been listed as endangered and 58 others have been proposed.

[4] A large class of marine anthropods whose bodies were divided by two furrows into three parts.

BOX SCORE OF WORLDWIDE SPECIES LISTINGS

Species	Endangered			Threatened		
	U.S.	Foreign	Total	U.S.	Foreign	Total
Mammals	36	215	251	1	3	4
Birds	65	144	209	1		1
Reptiles	8	46	54			
Amphibians	4	9	13			
Fishes	30	10	40	4		4
Snails		1	1			
Clams	22	2	24			
Crustaceans						
Insects	6		6	2		2
Plants						
Totals	171	427	598	8	3	11

Numbers of species currently proposed: 115 animals; approximately 1,850 plants



Author, shown here wading the Powell River in southwestern Virginia, was part of a group searching for endangered molluscs and fish.

All classifications of all plants and animals in the world are eligible for listing, including species, subspecies and isolated disjunct (disconnected) populations. Listing, delisting and reclassifying of endangered or threatened species may begin with a petition or a request from individuals or organizations or by initiative of the Service. Individuals and organizations must include supporting evidence with their requests. Before final listing, proposed endangered and threatened species are published in the *Federal Register*.

All Federal departments and agencies are required by section 7 of the act to insure that actions authorized, funded or carried out by them do not jeopardize the continued existence of listed species or result in the destruction or modification of their critical habitat.

The U.S. Fish and Wildlife Service has only some 180 law enforcement officers in the field, along with a few hundred field biologists. The 55 State and Territorial conservation agencies, by contrast, have well over 5,000 experienced conservation officers and several thousand professional wildlife biologists who are trained in the management of wild flora and fauna.

In June 1976, 11 States signed cooperative agreements with the Service, bringing a great many more specialists into the Endangered Species Program. Participating States are eligible to share about $2 million in Federal funds authorized to help them achieve their common conservation goals.

We have begun the task established by the legislation—development of methods to conserve the ecosystems on which endangered and threatened species depend. Much research lies ahead, however, because

the more we learn about our subject, the more complex it becomes.

Research has shown us, for example, that fire is necessary to the survival of certain land snails. When managed areas are kept free of fire for longer than the normal periods, the vegetation changes in character and the dependent land snail starves. During the fires, most of the snails survive by burrowing as deep as 5 feet beneath the forest floor. Alternatively, the snails living in areas adjacent to the burned lands eventually move in to eat the young vegetation which springs up.

Further research is needed before we will have the precise information needed to apply the finding that some molluscs need periodic fires to survive. Frequency and intensity of the fire and current humidity are all variables which have to be considered for each case. Apparently, this controlled fire is desirable in only 2 to 10 percent of our forested areas where the land snails depend on the type of vegetation which has evolved partially through the occurrence of natural fire.

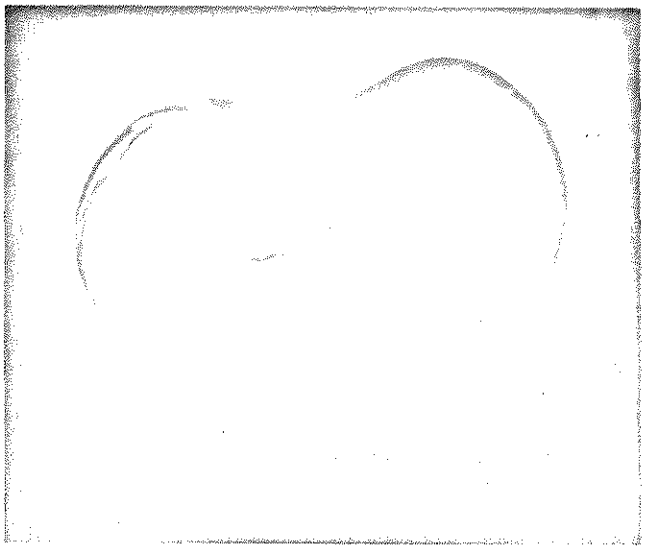
A disturbance threshold determination is needed for forestry practices and other environment-altering activities which threaten species with starvation, hybridization and domination by introduced exotics (foreigners). We do not yet know what degree of selective harvesting is satisfactory for the survival of endangered land snails in forest cover.

For example, Pilsbry's narrow apertured land snail is restricted to the north side of Rich Mountain, Arkansas and Oklahoma, where it lives under heavy forest cover and in damp ravines. It can survive selective harvesting, but any major lumbering could destroy local populations and clear cutting would create major problems. On the other hand, the painted snake coiled forest snail, *Auguispira picta,* of Buck Creek Cove, Tennessee lives in an area where the more accessible portions are subject to periodic lumbering but the interior is so far undisturbed. It is not found in selectively lumbered habitats and thus cannot survive any lumbering.

Species such as the painted snake coiled forest snail are a good index of virgin conditions. Certain areas in the East have been abandoned for hundreds of years after clearing, farming and depletion of soil. Such areas may appear virgin to the unknowing eye but do not contain such species as the painted snake coiled forest snail.

Another of the activities needing a disturbance threshold determination is pollution. Biologists in Louisiana, Alabama and North and South Carolina, for instance, have found that not polluting may be our best defense against domination of the benthos[5] by the introduced exotic Asian clam, *Corbicula.*

[5] All life found at the bottom of a body of water.



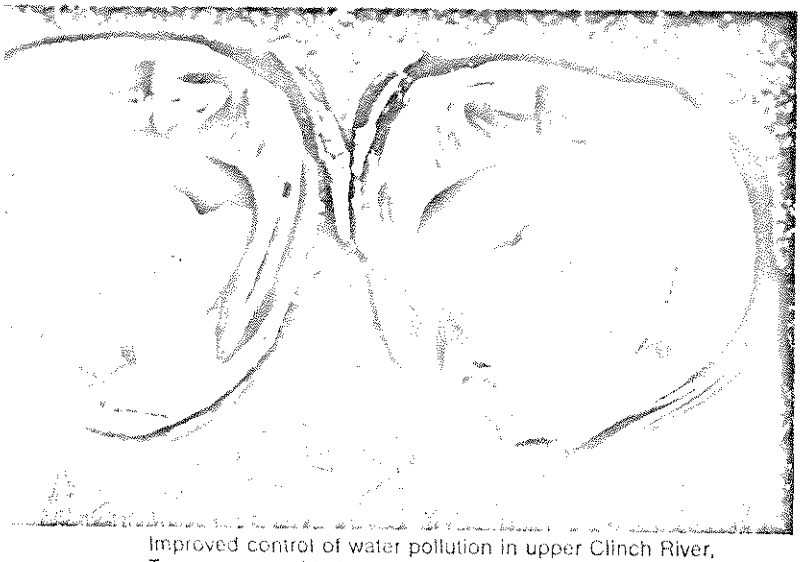
The North Carolina magnificent snail became extinct when lake shores were cleared of vegetation and ducks got them all.

Our experience to date clearly mandates an ecosystem approach to endangered species restoration. Pilsbry's narrow apertured land snail and the Rich Mountain salamander are both restricted to Rich Mountain. It is thought that the Rich Mountain salamander is especially adapted to capturing this snail. However, the snail's exceptionally narrow aperture is, in turn, extraordinarily modified for keeping out beetles and other snail predators.

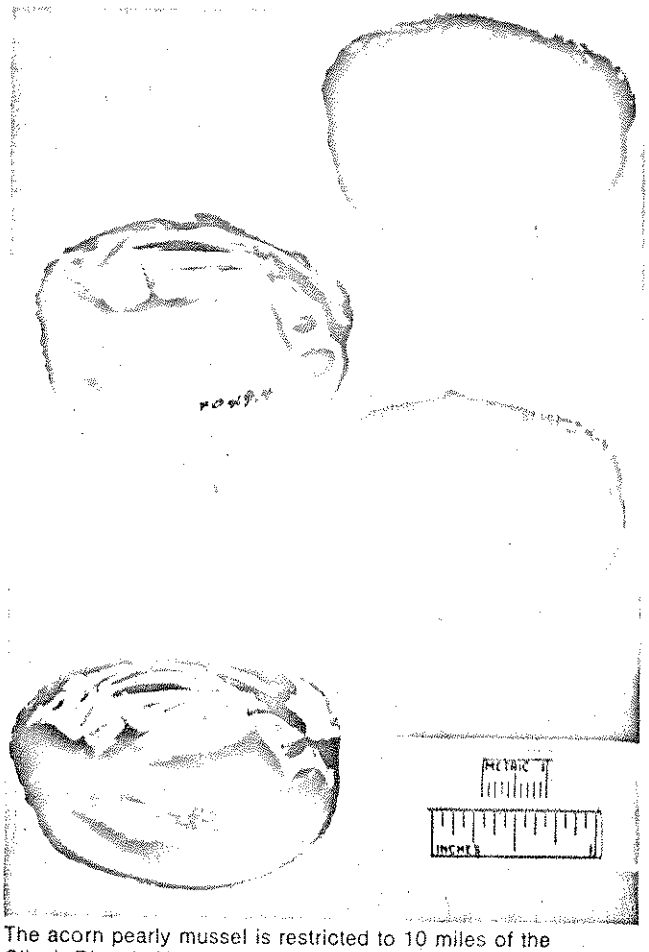
This type of interdependent relationship is working well in one small Texas ecosystem. The Diamond Y Pond snail, the Leon Creek pupfish and a small crustacean have been found living together there but nowhere else. Since species are interrelated and interdependent, introduction of one of these species elsewhere is unlikely to succeed.

Introduction is a bad word at the Office of Endangered Species but reintroduction is a good word since it involves rehabilitating the former range of a species. Preservation in aquaria, terraria and gardens, introduction outside of its native range and artificial mass production programs have proven chancy and subject to the whims of the budgetary process, especially during times of war or energy crises.

When species are transferred to new areas, their genetics change. Animals often grow bigger and some have been known to endanger other species of plants and animals. For instance, the introduction of the endangered Key Largo woodrat and Key Largo deermouse to Lignumvitae Key in Florida jeopardized *Liguus fasciatus lignumvitae,* a local tree snail.



Improved control of water pollution in upper Clinch River, Tennessee would also improve survival chances of resident species, including the pink pigtoe pearly mussel.



The acorn pearly mussel is restricted to 10 miles of the Clinch River in Virginia and is believed to be endangered by improperly treated municipal wastes. Already large beds of mussels have been wiped out.

Human beings and endangered species often compete for habitat and other resources. Depending on human uses and needs, measures to protect endangered species vary considerably in difficulty and cost. About one-third of the endangered species probably could be restored by relatively inexpensive means. Such measures might include modifying the boundaries of designated natural areas such as Mammoth Cave National Park in Kentucky or the proposed Channel Islands National Monument off the coast of California. Acquiring and protecting a number of caves or other small areas, each of which contains one or more endangered species, and additional management of parks and refuges are other options.

Another third of the endangered species are threatened principally by water pollution. Approximately 60 species of clams could be restored and protected by improved water pollution control efforts in five southern rivers: the Duck, Powell and Clinch Rivers in Virginia and Tennessee; the Green River in Kentucky; and the Altamaha River in Georgia.

The remaining third of these species would be considerably more difficult to protect. These are threatened by dams or other major projects. In most such cases, the conditions which have produced one unique species have also produced as many as a dozen or more endangered species such as bats, crayfish, plants and other distributionally limited species. Sometimes these concentrations of endangered species have simply evolved together as an adaption to a common unique habitat challenge such as an isolated cave system or the limestone talus that has built up under a waterfall. In other cases, they may belong to an isolated ecosystem left undisturbed by past glacial and volcanic activities. Others survive in the only remaining mature forest or unpolluted stream in a larger region. Such areas have numerous scenic or fish and wildlife values.

Almost all marine molluscs are not endangered at this time. These species are widely dispersed over areas of hundreds of miles, living in niches having common environments of temperature, salinity, nutrients and other characteristics. In the long run, perhaps 30 years from now, however, this pattern of dispersal will no longer protect marine molluscs. Pollution, plus other activities destructive to life, will have become so intense and pervasive in the oceans—which act as excellent carriers—that innumerable species will no longer be able to fend off these threats to their existence. They will go "all at once" so to speak. With them will go some of the strands in our web of life, leaving the rest of us more vulnerable by their passing. Failure to find the methods for keeping the web intact was described by the poet William Beebe in this way:

"The beauty and genius of a work of art may be reconceived, though its first material expression be destroyed; a vanished harmony may yet again inspire the composer; but when the last individual of a race of living things breathes no more, another heaven and another earth must pass before such a one can be again." □