CENTER FOR BIOLOGICAL DIVERSITY

Protecting endangered species and wild places through science, policy, education, and environmental law.

Candidate Petition Project

MOLLUSKS

PETITIONS TO LIST AS FEDERALLY ENDANGERED SPECIES

The following document contains the individual petitions for the 28 mollusk species to be listed as federally endangered species under the federal Endangered Species Act.

Alabama clubshell	***Pleurobema troschelianum***
Painted clubshell	***Pleurobema chattanoogaense***
Georgia pigtoe	***Pleurobema hanleyanum***
Texas hornshell	***Popenaias popei***
Fluted kidneyshell	***Ptychobranchus subtentum***
Neosho mucket	***Lampsilis rafinesqueana***
Alabama pearlshell	***Margaritifera marrianae***
Slabside pearlymussel	***Lexingtonia dolabelloides***
Ogden Deseret mountainsnail	***Oreohelix peripherica wasatchensis***
Bonneville pondsnail	***Stagnicola bonnevillensis***
Georgia rocksnail	***Leptoxis downei***
Sisi	***Ostodes strigatus***
Diamond Y spring snail	***Tryonia adamantine***
Fragile tree snail	***Samoana fragilis***
Guam tree snail	***Partula radiolata***
Humped tree snail	***Partula gibba***
Lanai tree snail	***Partulina semicarinata***
Lanai tree snail	***Partulina variabilis***
Langford's tree snail	***Partula langfordi***
Phantom Lake cave snail	***Cochliopa texana***
Tutuila tree snail	***Eua zebrina***
Phantom springsnail	***Tryonia cheatumi***
Gonzales springsnail	***Tryonia circumstriata***
Huachuca springsnail	***Pyrgulopsis thompsoni***
Three Forks springsnail	***Pyrgulopsis trivialis***
Newcomb's tree snail	***Newcombia cummingi***
Altamaha spinymussel	***Elliptio spinosa***
Elongate mud meadows pyrg	***Pyrgulopsis notidicola***

Tucson • Phoenix • Idyllwild • San Diego • Oakland • Sitka • Portland • Silver City • Buxton

Main Office: PO Box 710 • Tucson, AZ • 85702-0710
PHONE: (520) 623-5252 • FAX: (520) 623-9797 • WEB: www.biologicaldiversity.org

PETITION TO LIST

Alabama clubshell
(*Pleurobema troschelianum*)
painted clubshell
(*Pleurobema chattanoogaense*)
Georgia pigtoe
(*Pleurobema hanleyianum*)

AS FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 10/25/99: C
CNOR 10/30/01: C
CNOR 6/13/02: C

TAXONOMY

The taxonomic status of the Alabama clubshell (*Pleurobema troschelianum*, Unionidae), the painted clubshell (*Pleurobema chattanoogaense*, Unionidae), and the Georgia pigtoe (*Pleurobema hanleyianum*, Unionidae) as valid species is uncontroversial (e.g., Williams et al. 1993; Turgeon et al. 1998). The specific epithet for the Georgia pigtoe was written "*hanleyanum*" in the U.S. Fish and Wildlife Service candidate species list (as well as in Williams et al. 1993), but according to Turgeon et al. (1998) the original description of this species used the specific epithet "*hanleyianum*" and this spelling is therefore the valid one.

NATURAL HISTORY

The Alabama clubshell, painted clubshell, and Georgia pigtoe are freshwater mussels that were historically widely distributed in the Coosa River and many of its tributaries in Alabama, Georgia, and Tennessee. All three species currently are known only from isolated populations surviving in localized portions of a short reach of the Conasauga River above Dalton in Whitfield and Murray Counties, Georgia. These species inhabited moderate to high gradient reefs, shoals, and riffles of small to large rivers throughout the drainage. Host fish and other aspects of the life history of these species are unknown.

POPULATION STATUS

The Alabama clubshell, painted clubshell, and Georgia pigtoe have been extirpated from throughout most of their historic ranges. The three species are currently known from recent collections of a few live and fresh dead shells of each species from localized portions of the upper Conasauga River in Murray and Whitfield counties, Georgia. The painted clubshell has also been identified from a short reach of the Coosa River in Cherokee County, Alabama (personal communication 2000 cited in U.S. Fish and Wildlife Service candidate assessment form). The decline of these species can be attributed to extensive impoundment of the Coosa River and its primary tributaries, and the effects of point and non-point source pollution on the surviving isolated populations.

In 1990, a status survey and review of the molluscan fauna of the Mobile River Basin included extensive surveys and collections from throughout the Coosa River drainage (M. Pierson, Field Records 1991 to1994, Calera, Alabama, *in litt* cited in U.S. Fish and Wildlife Service candidate assessment form; Fish and Wildlife Service Field Records, Jackson, Mississippi, 1991 to 1994 cited in U.S. Fish and Wildlife Service candidate assessment form). At all localities in the Coosa River drainage, the freshwater mussel fauna had declined from historical levels, and at all but a few localized areas, the fauna proved to be completely eliminated or severely reduced. Following a review of these efforts and observations, the U.S. Fish and Wildlife Service reported 14 species of mussels in the genus *Pleurobema*, including the Alabama clubshell, painted clubshell, and Georgia pigtoe, as presumed extinct in the Mobile River Basin, based on their absence from collection records, technical reports, or museum collections for a period of 20 years or more (U.S. Fish and Wildlife Service 1994).

Studies in the Coosa River drainage for mollusks (cited in U.S. Fish and Wildlife Service candidate assessment form: M. Pierson, Field Records, 1995 to 1998; M. Hughes, Field Records, Knoxville, Tennessee, 1997 to 1998; D. Shelton, Field Records 1997 to 1998, Mobile Alabama; Service Field Records 1995 to 1998; Williams and Hughes 1998, Johnson and Evans 2000) resulted in finding several fresh dead and live individuals of the painted clubshell, Georgia pigtoe, and Alabama clubshell. The species were collected during mussel surveys in the upper Conasauga River, Murray and Whitfield counties, Georgia (two 1998 personal communications cited in U.S. Fish and Wildlife Service candidate assessment form; Johnson and Evans 2000).

The Painted clubshell and the Georgia pigtoe are both considered critically endangered by the International Union for the Conservation of Nature (IUCN), and endangered by the American Fisheries Society.

The U.S. Fish and Wildlife Service classifies the Alabama clubshell, Painted clubshell, and Georgia pigtoe as candidates for Endangered Species Act protection with a listing priority number of 5.

LISTING CRITERIA

A. ***The present or threatened destruction, modification, or curtailment of its habitat or range.***

Historic range:	Alabama, Georgia, Tennessee. These three mussels historically occurred throughout the Coosa River drainage from the Conasauga River in Tennessee to the lower Coosa River in Alabama (Williams and Hughes 1998, Hurd 1974, van der Schalie 1981). In Tennessee, the painted clubshell was reported from the Conasauga River. In Georgia, the species was found in the Conasauga, Chattooga, Coosa, and Oostanaula Rivers and Armuchee Creek. In Alabama, it was recorded throughout the length of the Coosa River and in the lower portions of some of the larger tributaries. The Georgia pigtoe was historically reported from the Conasauga River in Tennessee and Georgia; the Coosawatee, Oostanaula, Coosa, and Etowah Rivers in Georgia; and the Coosa River and tributaries Big Wills, Terrapin, Big Canoe, Yellowleaf, Waxahatchee, Talledega, and Hatchet Creeks, in Alabama. The Alabama clubshell was historically known from the Conasauga River in Tennessee and Georgia; the Chattooga, Coosawatee and Oostanaula Rivers and Coahutta Creek in Georgia; and the middle Coosa River and Terrapin, Shoal, and Hatchet Creeks in Alabama.
Current range:	Georgia. All three species currently are known from isolated populations surviving in localized portions of a short reach of the Conasauga River above Dalton in Whitfield and Murray Counties, Georgia.
Land ownership:	All riparian lands are in corporate or private ownership.

The Alabama clubshell, painted clubshell, and Georgia pigtoe have been extirpated from well over 90 percent of their historic range. All three species currently are known from isolated populations surviving in localized portions of a short reach of the Conasauga River above Dalton, Georgia. The painted clubshell has also been identified from a short reach of the Coosa River in Cherokee County, Alabama.

Isolated populations are vulnerable to land surface runoff that affects water quality or the suitability of aquatic habitats within a watershed. Blocked from avenues of emigration to less affected watersheds, they gradually and quietly perish if changes in land use activities cause aquatic habitat conditions to deteriorate. Similarly, if positive land use changes improve previously degraded aquatic habitat conditions, barriers to immigration will, nevertheless, prevent natural recolonization of those areas.

While the detrimental effect of any one source or land use activity may be insignificant by itself, the combined effects of land use runoff within a watershed may result in gradual and cumulative adverse impacts to isolated populations and their habitats. For example, excessive sediments deposited on stream bottoms can smother and kill relatively immobile mussel species, or make their habitat unsuitable for feeding or reproduction (Waters 1995, Hartfield and Hartfield 1996). Suspended sediments can interfere with feeding or affect behavior and reproduction (Waters 1995, Haag et al. 1995). Sediment is probably the most abundant pollutant currently affecting these three species. Potential sediment sources within a particular watershed include virtually all activities that disturb the land surface. Highway construction, improper logging practices, agriculture, housing developments, pipeline crossings, or cattle grazing often result in physical disturbance of stream substrates or the riparian zone, and/or changes in water quality, temperature, or flow.

Excessive nutrient input from multiple sources (e.g, nitrogen and phosphorus from fertilizer, sewage waste, animal manure, etc.) into an aquatic system can also have cumulative effects. Land surface runoff contributes the majority of human-induced nutrients to water bodies throughout the country. Large amounts of nutrients in surface runoff can result in periodic low dissolved oxygen levels that are detrimental to aquatic species (Hynes 1970). They also promote excessive algal growth that can eliminate habitat for mussel conglutinates or juvenile mussels requiring clean rock or gravel substrate (e.g., Hartfield and Hartfield 1996). Excessive nutrients within a stream or river can also indicate the potential presence of pathogenic microorganisms. The human population is expanding within the Conasauga River watershed increasing the sediment and nutrient input to the system, and making the three mussel species vulnerable to progressive degradation from land surface runoff.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

These species are not commercially valuable nor is the Conasauga River subject to commercial mussel harvesting activities. The species have been taken for scientific and private collections in the past. Such activity may increase as the species continued existence becomes known. Although collecting is not considered a factor in the decline of this species, the localized distribution and small size of the known extant populations renders them vulnerable to overzealous recreational or scientific collecting.

C. ***Disease or predation.***

Diseases of freshwater mussels are poorly known. Juvenile and adult mussels are prey items for some invertebrate predators and parasites, and provide prey for a few vertebrate species. Although predation by naturally occurring predators is a normal aspect of the population dynamics of a healthy mussel population, predation may contribute to the further decline of this species due to the localized extent and low numbers of mussels associated with the extant populations.

D. ***The inadequacy of existing regulatory mechanisms.***

Although the negative effects of point source discharges on aquatic communities in the Conasauga River have been reduced over time by compliance with State and Federal regulations pertaining to water quality, there has been less success in dealing with non-point source pollution impacts. Such impacts result from individual private landowner activities (e.g., construction, grazing, agriculture, silviculture, etc.), and public construction works (e.g., bridge and highway construction and maintenance, etc.). Lacking State or Federal recognition, these mussels are not currently given any special consideration under other environmental laws when project impacts are reviewed.

Current Conservation Efforts: A refuge is being established in the upper Conasauga River. Watershed management outreach has been conducted. The Nature Conservancy has conducted a watershed impact analysis for the Conasauga River watershed. Surveys are ongoing, and genetic studies are in progress to clarify and confirm taxonomy of these species.

E. ***Other natural or manmade factors affecting its continued existence.***

The threats to the Alabama clubshell, painted clubshell, and Georgia pigtoe are compounded by their restricted range and low numbers. The three species are vulnerable to random catastrophic events (e.g., flood scour, drought, toxic spills, etc.). Limited range and low numbers also make the species vulnerable to land use changes within the Conasauga River watershed that would result in increases in non-point source pollution impacts. These species may also be adversely affected by the loss or reduction in numbers of the fish host(s) essential to their parasitic glochidial stages. The specific fish host(s) for the glochidia of these species are not known; therefore, impacts on this aspect of the mussels' life cycles cannot be evaluated.

REFERENCES

Haag, W.R., R.S. Butler, and P.D. Hartfield. 1995. An extraordinary reproductive strategy in freshwater bivalves: prey mimicry to facilitate larval dispersal. Freshwater Biology 34:471-476.

Hartfield P. and E. Hartfield. 1996. Observations on the conglutinates of *Ptychobranchus greeni* (Conrad, 1834) (Mollusca: Bivalvia: Unionoidea). American Midland Naturalist 135:370-375.

Hurd, J.C. 1974. Systematics and zoogeography of the unionacean mollusks of the Coosa River drainage of Alabama, Georgia, and Tennessee. Ph.D. Dissertation, Auburn University, Auburn, Alabama. 240 pp.

Hynes, H.B.N. 1970. The Ecology of Running Waters. University of Toronto Press, Toronto.

Johnson, P. D. and R.R. Evans. 2000. A contemporary and historical database of freshwater mollusks in the Conasauga River Basin. Report to USGS. SARI, Cohutta, GA.

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P.M. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G.

Thompson, M. Vecchione, and J.D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks, 2nd edition. American Fisheries Society, Special Publication 26, Bethesda, Maryland.

U.S. Fish and Wildlife Service. 1994. Status review of select mussel species in the Mobile River Basin. Status Report, U.S. Fish and Wildlife Service, Jackson, Mississippi. 3 pp.

van der Schalie, H. 1981. Mollusks in the Alabama River drainage, past and present. Sterkiana 71:24-40.

Waters, T.F. 1995. Sediment in streams: sources, biological effects, and control. American Fisheries Society Monograph 7. 251 pp.

Williams, J.D. and M.H. Hughes. 1998. Freshwater mussels of selected reaches of the main channel rivers in the Coosa drainage of Georgia. U.S. Geological Survey report to U.S. Army Corps of Engineers, Mobile District. 21 pp. and appendices.

Williams, J.D., M.L. Warren, Jr., K.S. Cummings, J.L. Harris, and R.J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18 (9): 6-22.

PETITION TO LIST

Texas hornshell
(*Popenaias popeii*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 1/6/89:	
CNOR 11/21/91:	
CNOR 11/15/94:	
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

The taxonomic status of the Texas hornshell, *Popenaias popeii* (Unionidae), as a valid species is uncontroversial (e.g., Williams et al. 1993; Turgeon et al. 1998). The specific epithet of this species is written "*popei*" in the U.S. Fish and Wildlife Service candidate species list, but according to Turgeon et al. (1998) the correct spelling is "*popeii*"

NATURAL HISTORY

Morphology

The shell of the Texas hornshell is subtrapezoidal and elongate, compressed, anteriorly rounded and narrow, posteriorly slightly truncated and wider, beaks (umbos) well-defined slightly above hinge line (often eroded), umbo cavity shallow with dorsal pits, periostracum (outer surface) dull brown, left valve with 2 small pseudocardinal teeth, right valve with a single small pseudocardinal tooth (Burch 1973, Howells et al. 1996). Ortman (1912) noted unique beak sculpturing that might represent a diagnostic criteria for the genus.

Behavior

Adult freshwater mussels are filter-feeders, siphoning phytoplankton, diatoms, and other microorganisms from the water column including zooplankton, algae, inorganic material, and organic detritus (James 1987, Pennak 1989). For their first several months juvenile mussels employ foot (pedal) feeding, and are thus suspension feeders that feed on algae and detritus. Mussels tend to grow relatively rapidly for the first few years, then slow appreciably at sexual maturity (when energy is being diverted from growth to reproductive activities). Mussel beds are extremely long-lived, living from a few decades to a maximum of approximately 200 years. Large, heavy-shelled riverine species, like Texas hornshell tend to have longer life spans but no age-specific information is available.

Reproduction in North American freshwater mussels is replete with highly variable inter- and intra-specific reproductive strategies and life histories. In dioecious (separate sexes) unionids, like Texas hornshell, ova are discharged, following gametogenesis, into the mantle chamber and are fertilized from sperm expelled by males suspended in the incurrent water flow. Developing zygotes are sequestered in brood pouches of the gills (marsupia), where development proceeds to a bivalved larval stage (glochidium). Gonads are active year-round with viable gametes present in February, and oviposition occurring April through August. Glochidial brooding periodicity within the marsupia varies depending on the mussel species from short-term (2-3 weeks) multiple brooders of summer to more long-term (6-12 months) winter brooders.

The Texas hornshell breeds over an extended period of time from late spring (April) through August, which implies that females and males are not tied to a restricted period of synchronous reproduction; rather an opportunistic reproductive strategy seems to prevail. Females either sequentially or alternately release ova into the gills while males are releasing sperm continuously over several months; such reproductive asynchronicity is not common in unionids. Contrary to previous reports (Ortmann 1912, Heard and Guckert 1970), The Texas hornshell is considered an asynchronous, short-term brooder with an extended period (late winter to mid-summer) of oviposition (Smith et al. 2000).

Glochidia of most North American mussels are obligate parasites typically requiring a fish host to metamorphose into juvenile mussels. Aquatic salamanders have also been reported as hosts (mudpuppy, *Necturus maculosas*; Howard 1915). The glochidial parasitic period typically lasts 2-3 weeks, and serves as a primary dispersal mechanism for mussels. Completely metamorphosed juveniles are recruited into the free-living benthic-dwelling community once excysted from the host fish (Gordon and Layzer 1989, Howells et al. 1996). Glochidia of Texas hornshell metamorphosed into juvenile mussels within 6-10 days post-inoculation on 25 of 28 species of fish representing 10 families and 6 orders, including several non-native fish species (personal communication cited in U.S. Fish and Wildlife Service candidate assessment form).

Habitat

The Texas hornshell typically occurs at the head and terminus of shallow, narrow run habitat over travertine bedrock where small-grained substrata (clays, silts, sands, and gravel) collect in undercut riverbanks, crevices, shelves, and at the base of large boulders. Within this macrohabitat type, Texas hornshell occur singly or aggregated in shallow water microhabitats that serve as flow refugia (Strayer 1999) where the mussels can likely secure a foot hold during large volume discharge periods associated with annual precipitation events (Howells and Lang 1999).

Distribution

The macrohabitat types are most common throughout the lower reach of the Black River from Black River Village downstream to the USGS gauging station where the river channel is less incised, the riverbanks are not as steep, and the floodway is not as narrow and confined compared to other reaches (Howells and Lang 1999).

In New Mexico, this species was common in the lower Pecos River from North Spring River, Roswell, Chaves County (Cockerell 1902) south to Texas, including the Black and Delaware rivers, Eddy County (Taylor 1983, NMGF files). Live specimens were taken from the lower Pecos River near Carlsbad, New Mexico, as late as 1937 (Metcalf 1982). Umbonal shell fragments of fossil Texas hornshell were collected from the Pecos River on the Salt Creek Wilderness, Bitter Lake National Wildlife Refuge (Chaves County), and the Delaware River, Eddy County in 1996 (Howells and Lang 1999). Since 1996, a live population of Texas hornshell has been confirmed in the Black River, New Mexico, from Black River Village downstream to the U.S. Highway 285 bridge crossing (Howells and Lang 1999).

Live specimens have been observed at 16 of 35 sites investigated in the lower portion of the Black River and were common at most sites. The lower Black River has permanency of flow, adequate water quality, and suitable substrates provide habitat conditions for the persistence of this relict population. Live Texas hornshell had not previously been reported in New Mexico since the 1930's (Metcalf 1982). Intensive searches by NMGF in other portions of the Black River and nearby locations in the Delaware River and Pecos River have not revealed evidence of any additional populations in this region (Howells and Lang 1999).

Other early records show the species in the Pecos River, Ward County, Texas (Strecker 1931) and near the Rio Grande confluence in Val Verde County, Texas (Metcalf 1982). Despite numerous collection efforts, no evidence of living freshwater mussels has been documented in recent times in these areas. Based on conchological characteristics of fresh valves, Metcalf (1982) postulated that Texas hornshell may still occur in the lower Pecos drainage of New Mexico. Unionid surveys were initiated in the lower Pecos River in 1995 and are ongoing, but to date have not located any shells of Texas hornshell.

In the Rio Grande in Texas, collections indicate the species historically occurred from San Francisco Creek in the Big Bend area, Brewster County, downstream to Brownsville, near the Gulf of Mexico (Howells et al. 1996). Collections were also made historically that confirmed presence of Texas hornshell in the Devils River and Las Moras Creek, tributaries to the Rio Grande in Texas (Howells et al. 1996). However, live specimens from these areas in Texas were last reported by Strecker (1931). In 1998, 32 sites along approximately 100 river-miles of the Rio Grande downstream of Big Bend National Park were surveyed by TPWD (Howells and Lang 1999). Although no live Texas hornshell were observed, 3 of 5 valves collected were of recently dead specimens. This would indicate there are likely relic populations extant in this reach of the Rio Grande. Extensive collections in the Rio Grande Basin in Texas and in the Rio Conchos Basin in Mexico by TPWD have provided no evidence of any other extant populations (Howells et al. 1997; Howells 1994-1999).

There are unconfirmed reports of recent records of Texas hornshell in the Rio Grande near the confluence with the Río Conchos at Presidio, Texas (Ojinaga, MX); and from two tributaries of the Colorado River in central-west Texas (Llano River, Llano County and South Concho River, Tom Green County). Identity of these collections is in question and may represent errors in taxonomic identification (Howells and Lang 1999).

Historical collections in Mexico are from the Rio Salado (type locality), and were reported from two disjunct drainages, ríos Pánuco and Valles, San Luis Potosí, some 500 miles south of the Rio Grande Basin (Hinkley 1907, Ortmann 1912). Unfortunately scientific understanding of Mexican freshwater mussels is especially poor and aspects of classification, biology, and distribution remain confused. Therefore the status of the Texas hornshell in Mexico can not be fully determined.

POPULATION STATUS

The Texas hornshell represents the last remaining native mussel in New Mexico, as all other mussels (7 species) considered native in the State have been extirpated (Metcalf 1982, Lang and Melhop 1996). Williams et al. (1993) assigned Texas hornshell a designation of threatened. 1,000 - 3,000 individuals remain on about 2,000 - 10,000 acres, and 10 - 50 miles. Living specimens are known to occur in the Black River, New Mexico (Lang et al. 1998). Recently dead shells which had likely not been dead more than a few weeks found in the Rio Grande of Texas just downstream of Big Bend suggest a few stragglers probably persist there as well.

In over 20 years, this species has been known only from (1) a single recently dead specimen found in the Rio Grande, Brewester County, Texas, in January 1992 (Howells et al. 1997); 5 shells (three recently dead) found in the Rio Grande in Brewster and Terrell counties, Texas, in March 1998 (Texas Parks and Wildlife Department); and 35 living specimens in the Black River, New Mexico, 1997-1998 (Lang et al. 1998). None have been found in Mexican tributaries of the Rio Grande in recent years and none are known to survive in any Texas tributaries (NatureServe Explorer 2002).

The state of New Mexico has listed the Texas hornshell as an endangered species since 1983. The International Union for the Conservation of Nature(IUCN) considers the Texas hornshell as critically endangered. The American Fisheries Society considers the species' status as Threatened (NatureServe Explorer 2002).

The Natural Heritage Programs of both New Mexico and Texas rank the Texas hornshell as Critically Imperiled.

The U.S. Fish and Wildlife Service classifies the Texas hornshell as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. ***The present or threatened destruction, modification, or curtailment of its habitat or range.***

Historical range:	New Mexico; Texas; Mexico. Historically, Texas hornshell occurred in the lower Pecos River of New Mexico, downstream throughout the Lower Rio Grande (Brownsville, Texas) and major tributaries in Texas, southward to the Río Pánuco drainage of San Luis Potosí, México (Metcalf 1982, Taylor 1983, Neck and Metcalf 1988, Howells et al. 1996).
Current range:	New Mexico; Texas; Mexico. Texas hornshell has declined notably throughout its historic range and can only be confirmed as extant in the Black River of New Mexico and, possibly, the Big Bend reach of the Rio Grande in Texas.
Land ownership:	The Texas hornshell occurs within rivers, which are owned by the states. For the extant population in New Mexico, riparian land ownership along the Black River includes private, State, and Federal (BLM). In the Big Bend reach of the Rio Grande in Texas, where extant populations are presumed, riparian land ownership includes private, State (Park) and Federal (National Park Service).

Texas historically held an abundant and diverse assemblage of freshwater mussels, with 52 species (of the nearly 300 native taxa in the central U.S.) present in the State's waters (Howells et al. 1996, Howells et al. 1997). Dramatic declines have been documented during the past two decades, so dramatic that many rivers and streams no longer support any native mussel populations (Howells et al. 1997). Two other species of freshwater mussels native to the Rio Grande basin may already be extirpated from Texas, or even extinct. There has been no evidence of living populations of the Rio Grande monkeyface (*Quadrula couchiana*) and the Mexican fawnsfoot (*Truncilla cognata*) for more than 25 years, despite significant efforts to locate these species (Howells et al. 1997).

The decline in freshwater mussel populations in New Mexico and Texas can be directly attributable to human actions that modify physical conditions in streams. Direct changes in stream environments occur from impoundments and diversions for water storage, agricultural irrigation and flood control.

Major impoundments within the historic range of Texas hornshell include Brantley Dam in New Mexico and Red Bluff Dam in Texas on the Pecos River and Amistad and Falcon dams in Texas on the Rio Grande. Numerous other smaller impoundments and diversion dams exist within the historic range of the species. Impoundments result in the dramatic modification of riffle and shoal habitats and the resulting loss of mussel resources, especially in larger rivers.

Impoundment impacts are most profound in riffle and shoal areas, which harbor the largest assemblages of mussels. Dams interrupt most of a river's ecological processes by modifying flood pulses; controlling impounded water elevations; altering water flow, sediments, nutrients, energy inputs and outputs; increasing depth; decreasing habitat heterogeneity; and decreasing stability due to subsequent sedimentation (Collier et al. 1996, Williams et al. 1992). The reproductive process of riverine mussels is generally disrupted by impoundments making the Texas hornshell unable to successfully reproduce and recruit under reservoir conditions or in tailwater habitats below dams and diversions.

In addition, dams can also seriously alter downstream water quality and riverine habitat (Collier et al. 1996), and negatively impact tailwater mussel populations. These changes include thermal alterations immediately below dams; changes in channel characteristics, habitat availability, and flow regime; daily discharge fluctuations; increased silt loads; and altered host fish communities. Significant mussel populations were lost in the lower Pecos River canyon reaches and lower Devils River of Texas due to inundation by Amistad Reservoir, completed in1968 (Metcalf 1982, Howells et al. 1996). Falcon Reservoir on the Rio Grande is suspected to have decimated mussel habitat when it was built in 1953. Construction of McMillan Dam in the early 20th century, (replaced by Brantley Dam in 1988), may account for suspected extirpations from the Pecos River near the Seven Rivers confluence, Eddy County, New Mexico.

The release of pollutants into streams from point and non-point sources have immediate impacts on water quality conditions and may make environments unsuitable for habitation by mussels. Indirectly, losses in stream flows can result from regional groundwater depletion, and pollution can also arise from groundwater contaminants (Hennighausen 1969, Metcalf 1982, Quarles 1983, Taylor 1983, NMGF 1988, Williams et al. 1993, Neves et al. 1997). Much of the riverine habitat within the historic range of Texas hornshell has experienced tremendous increases in salinity levels as a result of agricultural returns to the rivers.

The channel morphology and flow regimes of the Rio Grande and Pecos River have been severely modified over the past century for flood control, water supply, and border maintenance, through channelization, levee construction, destruction of native riparian vegetation, dredging, and water diversion. The invasion of the exotic riparian tree salt cedar (*Tamarisk* sp.) have fortified, along with levees, the river banks. Flood control dams upstream have curtailed the annual peak flows and resulted in sediment rich, narrow river channels that no longer interact with the floodplain and do not provide natural riverine processes to support native biotic communities, including mussels (Layzer et al. 1993) such as the Texas hornshell.

Excessive human consumption of river water for agricultural irrigation and municipal use have also contributed to the degraded state of the aquatic ecosystems that no longer support populations of Texas hornshell. Flows have severely declined, often to the point of ceasing to flow, resulting in ecological changes that severely limit native fauna persistence. In the upper watershed of the Rio Grande, new municipal diversions threaten the already desiccated river. Santa Fe, Albuquerque, Las Cruces, and El Paso metropolitan areas are in the process of converting their municipal water consumption from diminishing groundwater supplies to depend on surface water from the Rio Grande. The result will likely be less water for instream flows in the Rio Grande below El Paso, within the range of Texas hornshell.

Oil and gas industry operations (exploration, transfer, storage, and refining) are ongoing in the Black River sub-basin and lower Pecos River valley of New Mexico and Texas. Such extractive activities are known to contaminate ground- and surface-waters (Jercinovic 1982, 1984, Longmire 1983, Boyer 1986, Rail 1989, Martinez et al. 1998), and represent a threat to extant Texas hornshell populations (Eisler 1987, Havlik and Marking 1987, Green and Trett 1989, Neves et al. 1997).

Contaminants contained in point and non-point discharges can degrade water and substrate quality and adversely impact mussel populations. The effects are especially profound on juvenile mussels, which can readily ingest contaminants, and glochidia, which appear to be very sensitive to certain toxicants. Mussels are very intolerant of heavy metals, and even at low levels, certain heavy metals may inhibit glochidial attachment to fish hosts. Cumulative impacts of insensitive land-use practices (e.g., removal of native vegetation, prolonged over-grazing, non-point source runoff pollution [sediments, toxic chemicals, hydrocarbons], etc.) within the watershed of the Black River have increased erosion and sedimentation in the river, exacerbated drainage basin entrenchment, increased pulse-discharge of pollutants into the system, and altered stream channel morphology and substrate composition. These environmental changes have profound effects on the long-term viability of mollusk populations, overall health of aquatic ecosystems, and stability of low flow refuge habitat typically colonized by Texas hornshell (Fuller 1974, Neves et al. 1997, Strayer 1999, NMGF files). Pulse discharge of large-volume storm flows in the Black River represent a primary cause of natural mortality of localized populations of Texas hornshell (NMGF files).

Siltation and general sedimentation runoff has been implicated in the decline of stream mussel populations across the United States. Scouring in upstream areas often results in excessive deposition of silt downstream, inundating larger substrates and eliminating mussel habitats. Sources of silt and sediment include overgrazing, which began in the mid-1800's; removal of terrestrial macrophytes and replacement with nonnative vegetation; complete clearing of riparian vegetation for agricultural, silvicultural, or other purposes; poorly designed and executed highways and bridges; and those construction, mining, and other practices that allow exposed earth to enter streams. Specific impacts on mussels from silt and sediments include clogged gills thus reducing their feeding and respiratory efficiency, impaired reproductive activity, disrupted metabolic processes, reduced growth rates, substrate instability, and the physical smothering of mussels under a blanket of silt (Houp 1993).

An example of the decline in mussel populations due to habitat loss is demonstrated at Fort Clark Springs, the headwaters of Las Moras Creek, in Bracketville, Kinney County, Texas. Before the turn of the century, the spring had an abundant and diverse community of mussels (over twenty species of mollusks reported), including Texas hornshell (Taylor 1967). Murray (1975) reported the extirpation of the species due to mechanical removal of vegetation, conversion of the spring to a swimming pool by paving the banks and chlorinating the water. Examination of the area by TPWD in 1995 found no evidence of any native mussel (Howells et al. 1997).

Although the status of the Texas hornshell in Mexico is unknown, the general deterioration of aquatic resources and especially stream habitats in Northern Mexico makes it unlikely that any remaining populations would not be significantly threatened (Contreras-B. and Lozano-V. 1994)

B. *Overutilization for commercial, recreational, scientific, or educational purposes.*

The Texas hornshell is not a commercially valuable species, but may be increasingly sought by collectors with its increasing rarity. Most stream reaches inhabited by this species are restricted, and its populations are small. Although scientific collecting is not thought to represent a significant threat, localized populations could become impacted and possibly extirpated by over collecting.

C. ***Disease or predation.***

The occurrence of disease in mussels is virtually unknown. Muskrats are known to prey upon live Texas hornshell, as evidenced by freshly fragmented valves strewn along vegetated riverbank margins (Howells and Lang 1999). Natural predation by other mammals (e.g., raccoons) is probable.

D. ***The inadequacy of existing regulatory mechanisms.***

The state of New Mexico has listed the Texas hornshell as an endangered species since 1983. Texas does not recognize any mussels as threatened or endangered. Texas only requires a fishing license for collection of mussels and a special permit for commercial collections. Texas has established 28 no-harvest mussel sanctuaries throughout the State (Howells et al. 1997). However, none occur within the Rio Grande or Pecos river basins. There are no state regulations in New Mexico or Texas that protect mussels from other threats, such as habitat destruction.

Current Conservation Efforts: Temporary lease of surface water rights per New Mexico Statutes Annotated, 72-5-28 (1995), may serve as a short-term measure to maintain discharge of Black River, thereby ensuring some form of minimum base flow for Texas hornshell for the one confirmed extant population in New Mexico. However, long-term conservation measures are needed that will require cooperative efforts between resource management agencies and private land owners, as extant populations of Texas hornshell in New Mexico exist primarily on private land along Black River. Development of Best Management Practices for the Black River watershed has been recommended by a proactive consortium of diverse land-use interests whose primary objective is to protect the long-term sustainability (i.e., ecology and economy) of the region.

Efforts have been made by TPWD to educate the staff at Big Bend National Park about the status of freshwater mussels in the Rio Grande and provide information to allow them to collect shells when found in the river (Howells 1998). In addition, TPWD has established a volunteer mussel watch program for interested individuals to report mussel citings and monitor some known populations in the State of Texas.

Status assessment of Texas hornshell throughout its historic range is ongoing with inventory efforts being coordinated between the NMGF, TPWD, the U.S Fish and Wildlife Service and private land stewards. Field research efforts are focusing on distribution and abundance, habitat quantification, reproductive biology, and population genetics.

E. ***Other natural or manmade factors affecting its continued existence.***

Introduction of exotic bivalves, namely the Asian clam (*Corbicula flumine*a), quagga mussel (*Dreissena bugensi*s) and zebra mussel (*D. polymorph*a), to surface waters of New Mexico and Texas threatens extant populations of Texas hornshell through potential competitive exclusive for space and resources (Williams et al. 1993, Neves et al. 1997). The Asian clam is already present in many locations within the historic range of Texas hornshell (Howells 1999). A critical component of the life history of freshwater mussels is the availability of fish hosts for developing glochidia. However, the fish communities of the rivers and streams within the historic range of Texas hornshell have been drastically altered, primarily by changes in habitat conditions (Edwards et al. 1991, Hubbs 1990, Miller et al. 1989, Smith and Miller 1986, Treviño-Robinson 1959). Over the last century, the decline of many native fishes, and even the extinction and extirpation of some species, could indirectly have affected mussel populations by the loss of necessary hosts to complete the reproductive cycle.

REFERENCES

Boyer, D. G. 1986. Differences in produced water contaminants from oil and gas operations in New Mexico - implications for regulatory action. Pp. 291-316, *In* Proceedings of the Conference on Southwestern Ground Water Issues (National Water Well Association, Publisher).

Burch, J. B. 1973. Freshwater Unionacean clams (Mollusca: Pelecypoda) of North America. Environmental Protection Agency, Biota of Freshwater Ecosystems Series, Identification Manual No. 11.

Cockerell, T. D. A. 1902. *Unio popei*, Lea, in New Mexico. The Nautilus 16:69-70.

Collier, M., R. Webb, and J. Schmidt. 1996. Dams and rivers: primer on the downstream effects of dams. U.S. Geological Survey Circular 1126. 94 pp.

Contreras-B., S. and M.L. Lozano-V. 1994. Water, endangered fishes, and development perspectives in arid lands of Mexico. Conservation Biology 8:379-387.

Edwards, R.J. and S. Contreras-Balderas. 1991. Historical Changes in the Ichthyofauna of the Lower Rio Grande (Río Bravo de Norte) Texas and México. Southwest Naturalist 36:201-212..10

Eisler, R. 1987. Polycyclic aromatic hydrocarbon hazards to fish, wildlife, and invertebrates: a syntopic review. U. S. Fish and Wildlife Service. Contaminant Hazard Reviews Report No. 11, Biological Report 85 (1.11).

Fuller, S.L.H. 1974. Clams and mussels (Mollusca: Bivalvia). Pages 215-273 in C.W. Hart and S.L.H. Fuller, eds. Pollution ecology of freshwater invertebrates. Academic Press, New York.

Gordon, M. E., and J. B. Layzer. 1989. Mussels (Bivalvia: Unionidae) of the Cumberland River: review of life histories and ecological relationships. U. S. Fish and Wildlife Service, Biological Report 89(15). Gordon, M. E., B. K. Lang, C. S. Altenbach. In Review. The Southwest Naturalist.

Green, J. and M. W. Trett. 1989. The fate and effects of oil in freshwater. Elsevier Science Publishing Co., Inc., New York.

Havlik, M. E. and L. L. Marking. 1987. Effects of contaminants on naiad mollusks (Unionidae): a review. U. S. Fish and Wildlife Service, Resource Publication 164.

Heard, W. H. and R. H. Guckert. 1970. A re-evaluation of the Recent Unionacea (Pelecypoda) of North America. Malacologia 10:333-355.

Hennighausen, F. H. 1969. Meters and their effects in the Roswell Artesian Basin in Chaves and Eddy counties, New Mexico. Pp. 29-33, *In* 14th Annual New Mexico Water Conference (Water Resources Institute).

Hinkley, A.A. 1907. Shells collected in northeastern New Mexico. The Nautilus 21:68-72, 76-80.

Houp, R. E. 1993. Observations on long-term effects of sedimentation on freshwater mussels (Mollusca: Unionidae) in the North Fork Red River, Kentucky. Transactions of the Kentucky Academy of Science 54(3-4):93-97.

Howard, A. D. 1915. Some experimental cases of breeding among the Unionidae. Nautilus 29:4-11.

Howells, R.G. 1994. Distributional surveys of freshwater bivalves in Texas. Progress report for 1992. Texas Parks and Wildlife Department, Management Data Series 105. Austin, Texas.

Howells, R.G. 1996a. Distributional surveys of freshwater bivalves in Texas. Progress report for 1994. Texas Parks and Wildlife Department, Management Data Series 120. Austin, Texas.

Howells, R.G. 1996b. Distributional surveys of freshwater bivalves in Texas. Progress report for 1995. Texas Parks and Wildlife Department, Management Data Series 125. Austin, Texas..11

Howells, R.G. 1997. Distributional surveys of freshwater bivalves in Texas. Progress report for 1996. Texas Parks and Wildlife Department, Management Data Series 144. Austin, Texas.

Howells, R.G.. 1998. Freshwater mussels of the Rio Grande with special emphasis on the Big

Bend Region. Report for Big Bend National Park, Texas. 19 pp.

Howells, R.G. 1999. Distributional surveys of freshwater bivalves in Texas: progress report for 1998. Texas Parks and Wildlife Department, Management Data Series No. 161. 28 pp.

Howells, R.G. and B.K. Lang. 1999. Status of the Texas hornshell and native freshwater mussels (Unionoidea) in the Rio Grande and Pecos River of New Mexico and Texas. Performance report as required by the Endangered Species Program Texas Grant No. E-1-10. Endangered and threatened species conservation. Project No. 90. November 30, 1999.

Howells, R.G., R.W. Neck, and H.D. Murray. 1996. Freshwater Mussels of Texas. Texas Parks and Wildlife Department, Austin, Texas.

Howells, R.G., C.M. Mather, and J.A.M. Bergmann. 1997. Conservation status of selected freshwater mussels in Texas. Pages 117-127 *in* K.S. Cummings, A.C. Buchanan, C.A. Mayer, and T.J. Naimo, eds. Conservation and management of freshwater mussels II: initiatives for the future. Proceedings of a UMRCC symposium, 16-18 October 1995, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Hubbs, C. 1990. Declining fishes of the Chihuahuan Desert. Third Symposium on Resources of the Chihuhuan Desert Region, U.S. and Mexico, 10-12 November 1988. Chihuahuan Desert Research Institute, Alpine, Texas.

James, M. R. 1987. Ecology of the freshwater mussel *Hyridella menziesi* (Gray) in a small oligotrophic lake. Archives of Hydrobiology 108:337-348.

Jercinovic, D. E. 1982. Assessment of refined petroleum-product contamination problems in surface and ground waters of New Mexico. Water Pollution Control Bureau, New Mexico Environmental Improvement Division, EID/WPC-82/5.

Jercinovic, D. E. 1984. Petroleum-product contamination of soil and water in New Mexico. New Mexico Environmental Improvement Division, EID/GWH84/2.

Lang, B.K., M.E. Gordon, and R.G. Howells. 1998. Distribution of Texas hornshell mussel, *Popenaias popei* (Bivalvia: Unionidae), of the Rio Grande Basin of New Mexico and Texas. Abstract of a presentation at the United States and Mexico Borders Conference, June 1998.

Lang, B.K. and P. Mehlohop. 1996. Distribution of freshwater mussels (Unionidae) of the Canadian River drainage: New Mexico and Texas. Segment I: Survey of freshwater bivalve mollusks of the Canadian River, New Mexico. National Biological Service, State Partnership Program, Final Report, 39 pp.

Layzer, J.B., M.E. Gordon, and R.M. Anderson. 1993. Mussels: the forgotten fauna of regulated rivers. A case study of the Caney Fork River. Regulated Rivers: Research and

Management 8:63-71..12

Longmire, P. A. 1983. Petroleum-product contamination of ground and surface water: a literature review. Ground Water Section, Water Pollution Control Bureau, New Mexico Environmental Improvement Division. EID/WPC-83/7.

Martinez, J. D., K. S. Johnson, and J. T. Neal. 1998. Sinkholes in evaporite rocks. American Scientist 86:38-51.

Metcalf, A. L. 1982. Fossil unionacean bivalves from three tributaries of the Rio Grande. Proceedings of the Symposium of Recent Benthological Investigations of Texas and Adjacent States, pp. 43-59.

Miller, R.R., J.D. Williams, and J.E. Williams. 1989. Extinctions of North American fishes during the past century. Fisheries 14(6):22-38.

Murray, H. D. and A. B. Leonard. 1962. Handbook of unionid mussel in Kansas. University of Kansas, Museum of Natural History, Miscellaneous Publication No. 28.

Murray, H.D. 1975. *Melanoides tuberculata* (Muller), Las Moras Creek, Bracketville, Texas. Bulletin of the American Malacological Union, Inc. 1975:43.

NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

Neck, R.W. and A.L. Metcalf. 1988. Freshwater bivalves of the lower Rio Grande, Texas. Texas Journal of Science 40: 259-268.

Neves, R.J. 1993. A state-of-the-unionids address. Pages 1-10 in K.S. Cummings, A.C. Buchanan, and L.M. Koch, editors. Conservation and management of freshwater mussels. Proceedings of a UMRCC symposium, 12-14 October 1992, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Neves, R. J., A. E. Bogan, J. D. Williams, S. A. Ahlstedt, and P. W. Hartfield. 1997. Status of aquatic mollusks in the southeastern United States: A downward spiral of diversity. Pp.43-85, *In* Aquatic Fauna in Peril (George W. Benz and David E. Collins, Eds.). Southeast Aquatic Research Institute Special Publication 1. Lenz Design & Communications, Decatur, Georgia.

New Mexico Statutes Annotated. 1995. Interstate Stream Commission Water Conservation Program: Pecos River Portion. NMSA Supplement 72-5-28.

New Mexico Department of Game and Fish. 1988. Handbook of species endangered in New Mexico. Account: A-310.

Ortmann, A. E. 1912. Notes upon the families and genera of the najades. Annals of the Carnegie Museum 8:222-365.

Pennak, R. W. 1989. Fresh-water invertebrates of the United States: Protozoa to Mollusca. John Wiley & Sons, Inc.

Quarles, J. 1983. Groundwater contamination in the United States. University of Pennsylvania Press, Philadelphia.

Rail, C. D. 1989. Groundwater contamination: sources, control, and preventative measures. Techonomic Publishing company, Inc. Lancaster, PA.

Smith, D. G., B. K. Lang, M. E. Gordon. 2000. Gametogenic cycle, reproductive anatomy, and larva morphology of *Popenaias popei* (Lea, 1857) (Unionoida) from the Black River, New Mexico. The Southwestern Naturalist.

Smith, M.L. and R.R. Miller. 1986. The evolution of the Rio Grande basin as inferred from its fish fauna. Chp. 13 in C.H. Hocutt and E.O. Wiley, eds. The zoogeography of North American freshwater fishes. John Wiley and Sons, New York.

Strayer, D. L. 1999. Use of flow refuges by unionid mussels in rivers. Journal of the North American Benthological Society 18(4):468-476.

Strecker, J. 1931. The distribution of naiades or pearly fresh-water mussels of Texas. Baylor University Museum Bulletin 2.

Taylor, D.W. 1967. Freshwater mollusks collected by the United States and Mexican Boundary Surveys. The Veliger 10(2):152-158.

Taylor, D. W. 1983. Endangered species: status investigation of mollusks of New Mexico. Professional Service Contract Nos. 519-69-01 and 519-69-01-A.

Treviño-Robinson, D., 1959. The Ichthyofauna of the Lower Rio Grande, Texas and Mexico. Copeia 3:253-256.

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P.M. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione, and J.D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks, 2nd edition. American Fisheries Society, Special Publication 26, Bethesda, Maryland.

United States Fish and Wildlife Service. 1996. Endangered and threatened wildlife and plants; Review of plant and animal taxa that are candidates for listing as endangered or threatened species. Federal Register 61(40):7596-7613.

Williams, J.D., S.L.H. Fuller, and R. Grace. 1992. Effects of impoundment on freshwater mussels (Mollusca: Bivalvia: Unionidae) in the main channel of the Black Warrior and Tombigbee rivers in western Alabama. Bull. Alabama Museum of Natural History 13:1-10.

Williams, J.D., M.L. Warren, Jr., K.S. Cummings, J.L. Harris, and R.J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18 (9): 6-22.

PETITION TO LIST

fluted kidneyshell
(*Ptychobranchus subtentum*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 10/25/99: C
CNOR 10/30/01: C
CNOR 6/13/02: C

TAXONOMY

The taxonomic status of the fluted kidneyshell, *Ptychobranchus subtentum* (Unionidae), as a valid species is uncontroversial (e.g., Williams et al. 1993; Turgeon et al. 1998).

NATURAL HISTORY

Morphology
The fluted kidneyshell is a relatively large mussel that reaches about 13 centimeters (5 inches) in length. The shape of the shell is roughly oval elongate, and the solid, relatively heavy valves are moderately inflated. A series of flutings (corrugations) characterizes the posterior slope of each valve. Shell texture is smooth and somewhat shiny in young specimens, becoming more dull with age. Shell color is greenish yellow, becoming brownish with age, with several broken, wide green rays. Internally, the pseudocardinal teeth are stumpy and triangular in shape. The lateral teeth are heavy. The color of the nacre (mother-of-pearl) is bluish white to dull white with a wash of salmon in the older part of the shell (beak cavity). Fluted kidneyshell conglutinates are shaped like insect larvae, and have an adhesive end that sticks to silt-free stones on the stream bottom (Parmalee and Bogan 1998).

Behavior
Adult freshwater mussels are filter-feeders, siphoning phytoplankton, diatoms, and other microorganisms from the water column. For their first several months juvenile mussels employ foot (pedal) feeding, and are thus suspension feeders that feed on algae and detritus. Mussels tend to grow relatively rapidly for the first few years, then slow appreciably at sexual maturity (when energy is being diverted from growth to reproductive activities). As a group, mussels are extremely long-lived, living from a few decades to a maximum of approximately 200 years.

Large, heavy-shelled riverine species tend to have longer life spans. No age specific information is available for the fluted kidneyshell. However, considering that it is a fairly large, heavy-shelled riverine species, it would seem probable that it is relatively long-lived (Parmalee and Bogan 1998).

Most mussels, including the fluted kidneyshell, have separate sexes. Males expel clouds of sperm into the water column, which are drawn in by females through their incurrent siphons. Fertilization takes place internally, and the resulting zygotes develop into specialized larvae termed glochidia inside the water tubes of her gills. The fluted kidneyshell, along with other members of its genus, is unique in that the marsupialized portion of a brooding female's outer gills are folded in a curtain-like fashion. The fluted kidneyshell is thought to have a late summer or early fall fertilization period with the glochidia incubating overwinter. The following spring or early summer, glochidia are released as conglutinates, which are analogous to cold capsules; gelatinous containers with scores of glochidia contained within. Glochidia must come into contact with a specific host fish(es) in order for their survival to be ensured. Without the proper host fish, the glochidia will perish.

Insect larvae are common food items of many stream fishes. The fluted kidneyshell's host fishes, which include the barcheek darter (*Etheostoma obeyense*); fantail darter (*Etheostoma flabellare*); rainbow darter (*Etheostoma caeruleum*); redline darter (*Etheostoma rufilineatum*); and banded sculpin (*Cottus carolinae*) are tricked into thinking that they have an easy meal when in fact they have infected themselves with mussel glochidia.

After a few weeks parisitizing the fishes' gill tissues, newly-metamorphosed juveniles drop off to begin a free-living existence on the stream bottom. Unless they drop off in suitable habitat, they will die. Thus, the complex life history of the fluted kidneyshell and other mussels has many weak links that may prevent successful reproduction and/or recruitment of juveniles to existing populations (Parmalee and Bogan 1998).

Habitat

The fluted kidneyshell is primarily a small river to large creek species, inhabiting sand and gravel substrates in relatively shallow riffles and shoals with moderate to swift current (Parmalee and Bogan 1998). This species requires flowing, well-oxygenated waters to thrive.

Distribution

The fluted kidneyshell is a Cumberlandian Region mussel, meaning it is restricted to the Cumberland (in Kentucky and Tennessee) and Tennessee (in Alabama, Tennessee, and Virginia) River systems. Historically, this species occurred in the Cumberland River main stem from below Cumberland Falls in southeastern Kentucky downstream through the Tennessee portion of the river to the vicinity of the Kentucky-Tennessee State line. In the Tennessee River main stem it occurred from eastern Tennessee to western Tennessee.

Records are known from approximately 16 Cumberland River tributaries. Working downstream, these streams included:

Horse Lick Creek, Middle Fork Rockcastle River, Rockcastle River, Buck Creek, Rock Creek, Kennedy Creek, Little South Fork, Big South Fork, Pitman Creek, Otter Creek, Wolf River, West Fork Obey River, Obey River, Caney Fork, South Harpeth River, and West Fork Red River. In addition, it is known from 21 Tennessee River system tributaries, including the South Fork Powell River, Powell River, Indian Creek, Little River, Clinch River, Copper Creek, Big Moccasin Creek, North Fork Holston River, Middle Fork Holston River, South Fork Holston River, Holston River, Nolichucky River, West Prong Little Pigeon River, Little Tennessee River, Hiwassee River, Flint River, Limestone Creek, Elk River, Shoal Creek, Duck River, and Buffalo River. Undocumented, but now lost, populations assuredly occurred in other Cumberlandian Region tributary systems.

During historical times, the fluted kidneyshell was fairly widespread and common in many Cumberlandian Region streams based on collections made in the early 1900s. However, its decline in certain streams may have begun before European colonization. The presence of the fluted kidneyshell in certain streams, particularly in the middle Tennessee River system, is known only by records from aboriginal “kitchen middens” (archeological records of mussels used as food from several hundred to several thousand years before present). The extirpation of this species from numerous streams within its historical range indicates that substantial population losses have occurred.

POPULATION STATUS

Populations of the fluted kidneyshell are generally considered extant if live or freshly dead specimens have been collected since 1980. The extant occurrences in the Cumberland River system represent six isolated populations, while four isolated populations remain in the Tennessee River system (two or more streams are considered to represent a single population if there are no absolute barriers, such as large impoundments, between them). Population size data gathered during the past 10 years indicates that the fluted kidneyshell is rare (experienced collectors may find four or fewer specimens per site of occurrence) in seven extant populations (10 streams). The species is only slightly more common in all but one of the remaining populations. The fluted kidneyshell is particularly imperiled in Kentucky. The vast reduction of the once sizable Little South Fork population since the late 1980s and the tenuous status of other populations puts the species at risk of total extirpation from the entire Cumberland River system.

Only in the Clinch River system is a population of the fluted kidneyshell known to be stable and viable, but in a relatively short reach of river primarily in the vicinity of the Tennessee-Virginia State line. Scores of adults and juveniles have recently been observed live in shoal habitats in the Clinch River, and many more fresh dead shells have been collected in muskrat middens along the shores in this vicinity.

The Kentucky Natural Heritage Program ranks the fluted kidneyshell as Critically Imperiled.

The Natural Heritage Programs of both Tennessee and Virginia rank the fluted kidneyshell as

Imperiled.

The U.S. Fish and Wildlife Service classifies the fluted kidneyshell as a candidate for Endangered Species Act protection with a listing priority number of 5.

LISTING CRITERIA

A. ***The present or threatened destruction, modification, or curtailment of its habitat or range.***

Historical range:	Alabama, Kentucky, Tennessee, Virginia. Historically, this species occurred in the Cumberland River main stem from below Cumberland Falls in southeastern Kentucky downstream through the Tennessee portion of the river to the vicinity of the Kentucky-Tennessee State line. In the Tennessee River main stem it occurred from eastern Tennessee to western Tennessee.
Current range:	Kentucky, Tennessee, Virginia. Currently, it is limited to nine streams in the Cumberland River system and seven streams in the Tennessee River system. Cumberland River system tributaries with extant populations include the Middle Fork Rockcastle River, Horse Lick Creek, Buck Creek, Rock Creek, Kennedy Creek, Little South Fork, Big South Fork, Wolf River, and West Fork Obey River. Presently, this species is also known in the Powell River, Indian Creek, Little River, Clinch River, Copper Creek, North Fork Holston River, and Middle Fork Holston River in the Tennessee River system. Extirpated from both the Cumberland and Tennessee River main stems, the fluted kidneyshell has also been eliminated from about three-fifths of the total number of streams from which it was historically known. The certainty that the fluted kidneyshell occurred in other streams within its historic range increases the estimated percentage of lost habitat and populations, thus making its present status that much more imperiled.
Land ownership:	The fluted kidneyshell occurs in streams that generally run through private lands. A small percentage (approximately 5 percent) of its current range occurs on Federal lands in the upper Cumberland River system. This includes U.S. Forest Service lands (i.e., Horse Lick Creek, Rock Creek, Little South Fork) in Kentucky and National Park Service lands (i.e., Big South Fork) in Kentucky and Tennessee.

The decline of the fluted kidneyshell in the Cumberlandian Region and other mussel species in the eastern United States is primarily the result of habitat loss and degradation. These losses have been well documented for over 130 years. Chief among the causes of decline are impoundments, stream channel alterations, water pollution, and sedimentation (Williams et al. 1992, Neves

1993, Neves et al. 1997). Specific information presented in this section on threats to the fluted kidneyshell and causes of its decline were gathered primarily from these published sources and other studies generally cited in their works, except where noted.

Impoundments result in the dramatic modification of riffle and shoal habitats and the resulting loss of mussel resources, especially in larger rivers. Impoundment impacts are most profound in riffle and shoal areas, which harbor the largest assemblages of mussel species, including the fluted kidneyshell. Dams interrupt most of a river's ecological processes by modifying flood pulses; controlling impounded water elevations; altering water flow, sediments, nutrients, energy inputs and outputs; increasing depth; decreasing habitat heterogeneity; and decreasing bottom stability due to subsequent sedimentation. The reproductive process of riverine mussels is generally disrupted by impoundments, making the fluted kidneyshell unable to successfully reproduce and recruit under reservoir conditions.

In addition, dams can also seriously alter downstream water quality and riverine habitat, and negatively impact tailwater mussel populations. These changes include thermal alterations immediately below dams; changes in channel characteristics, habitat availability, and flow regime; daily discharge fluctuations; increased silt loads; and altered host fish communities. Coldwater releases from large non-navigational dams and scouring of the river bed from highly fluctuating, turbulent tailwater flows have also been implicated in the demise of mussel faunas.

Population losses due to impoundments have probably contributed more to the decline of the fluted kidneyshell and other Cumberlandian Region mussels than has any other single factor. The majority of the Tennessee and Cumberland River main stems and many of their largest tributaries are now impounded. For example, over 2,300 river miles (about 20 percent) of the Tennessee River and its tributaries with drainage areas of 25 square miles or greater were impounded by the Tennessee Valley Authority (TVA) by 1971 (Tennessee Valley Authority 1971).

The subsequent completion of additional major impoundments on tributary streams (e.g., Duck River in 1976, Little Tennessee River in 1979) significantly increases the total miles impounded behind the 36 major dams in the Tennessee River system. Approximately 90 percent of the 562-mile length of the Cumberland River downstream of Cumberland Falls is either impounded (three locks and dams and Wolf Creek Dam), or otherwise adversely impacted by coldwater discharges from Wolf Creek Dam. Other major U.S. Army Corps of Engineers (Corps) impoundments on Cumberland River tributaries (e.g., Obey River, Caney Fork) have inundated over 100 miles of riverine habitat for the fluted kidneyshell.

Instream gravel mining has been implicated in the destruction of mussel populations. Negative impacts associated with gravel mining include stream channel modifications (e.g., altered habitat, disrupted flow patterns, sediment transport), water quality modifications (e.g., increased turbidity, reduced light penetration, increased temperature), macroinvertebrate population changes (e.g., elimination, habitat disruption, increased sedimentation), and changes in fish populations (e.g., impacts to spawning and nursery habitat, food web disruptions) (Kanehl and Lyons 1992). Gravel mining activities threaten the fluted kidneyshell population in Buck Creek, one of the few remaining populations of this species in the entire Cumberland River system. Heavy-metal rich drainage from coal mining and associated sedimentation have adversely impacted upper Cumberland River system streams with diverse historical mussel faunas. Strip mining continues to threaten mussels in coal field drainages of the Cumberland Plateau, including streams harboring small fluted kidneyshell populations (e.g., Horse Lick Creek, Little and Big South Forks). The low pH commonly associated with mine runoff can reduce glochidial encystment rates. Acid mine runoff, thus, may be having local impacts on recruitment of the fluted kidneyshell.

Mine discharge from the 1996 blowout of a large tailings pond on the upper Powell River in Virginia resulted in a major fish kill (personal communication 1996 cited in U.S. Fish and Wildlife Service candidate assessment form). Powell River mussel populations were inversely correlated with coal fines in the substrate; when coal fines were present, decreased filtration times and increased movements were noted in laboratory-held mussels (Kitchel et al. 1981). In a quantitative study in the Powell River, a decline of federally listed mussels and the long-term decrease in overall species composition since about 1980 was attributed to general stream degradation due primarily to coal mining activities in the headwaters (Ahlstedt and Tuberville 1997).

Contaminants contained in point and non-point discharges can degrade water and substrate quality and adversely impact mussel populations. The effects are especially profound on juvenile mussels, which can readily ingest contaminants, and glochidia, which appear to be very sensitive to certain toxicants. Mussels are very intolerant of heavy metals, and even at low levels, certain heavy metals may inhibit glochidial attachment to fish hosts.

Sediment from the upper Clinch River, where the largest population of the fluted kidneyshell remains, was found to be toxic to juvenile mussels (Ahlstedt and Tuberville 1997). It was speculated that the presence of toxins in the Clinch River may explain the decline and lack of mussel recruitment at some sites in the Virginia portion of that stream. Numerous streams have experienced mussel kills from toxic chemical spills and other causes, particularly in the upper Tennessee River system in Virginia (Neves 1986).

Siltation and general sedimentation runoff has been implicated in the decline of stream mussel populations. Sources of silt and sediment include poorly designed and executed timber harvesting operations and associated activities; complete clearing of riparian vegetation for agricultural, silvicultural, or other purposes; and those construction, mining, and other practices that allow exposed earth to enter streams. Specific impacts on mussels from silt and sediments include clogged gills thus reducing their feeding and respiratory efficiency, impaired reproductive activity, disrupted metabolic processes, reduced growth rates, substrate instability, and the physical smothering of mussels under a blanket of silt. Even a relatively thin layer of silt may preclude adhesive fluted kidneyshell conglutinates from attaching to stones (as suggested for another species of *Ptychobranchus*; see Hartfield and Hartfield 1996). Thus, a critical stage in its life cycle is potentially disrupted if contact with a proper host fish is not made.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

The fluted kidneyshell is not a commercially valuable species, but may be increasingly sought by collectors with its increasing rarity. Most stream reaches inhabited by this species are restricted and its populations are small. Although scientific collecting is not thought to represent a significant threat, localized populations could become impacted and possibly extirpated by overcollecting, particularly if this activity is unregulated.

C. ***Disease or predation.***

The occurrence of disease in mussels is virtually unknown. Several mussel dieoffs have been documented during the past 20 years (Neves 1986). Although the ultimate cause is unknown, some researchers believe that disease may be a factor. The recent decline in the once abundant fluted kidneyshell population in the Little South Fork in Kentucky showed signs that it may have been at least partially attributed to disease (personal communication 1998 cited in U.S. Fish and Wildlife Service candidate assessment form), but no definitive cause has been determined.

Predation on the fluted kidneyshell by muskrats represents a localized threat, as determined by Neves and Odum (1989) in the upper North Fork Holston River in Virginia. They concluded that muskrat predation could limit the recovery potential of endangered mussel species or contribute to the local extirpation of already depleted mussel populations. Although other mammals (e.g., raccoon, mink) occasionally feed on mussels, the threat is not significant.

D. ***The inadequacy of existing regulatory mechanisms.***

The States of Alabama, Kentucky, Tennessee, and Virginia prohibit the taking of mussels for scientific purposes without a State collecting permit. However, enforcement of this permit requirement is difficult. Furthermore, State regulations do not generally protect mussels from other threats. Existing authorities available to protect riverine ecosystems, such as the Clean Water Act (CWA), administered by the Environmental Protection Agency (EPA) and the Corps, may not have been fully utilized. This may have contributed to the general habitat degradation apparent in riverine ecosystems and loss of populations of aquatic species in the Southeast. Although the fluted kidneyshell coexists with federally listed mussels and fishes throughout most of its range, listing under the Endangered Species Act (Act) would provide additional protection. Federal permits would be required to take the species, and Federal agencies would be required to consult with the Service when activities they fund, authorize, or carry out may adversely affect the species.

Current Conservation Efforts:. The CWA has greatly reduced point discharge pollutants into streams and provides ways and means of addressing non-point source pollution. Partnering with State and Federal agencies and the coal industry, The Nature Conservancy (TNC) is addressing the complex issue of abandoned mine lands, which may continue to impact fluted kidneyshell populations (see “factor A” above), by working on the Coal Re-mining Initiative.

Numerous stakeholders have realized that restoring and protecting riparian habitat improves water quality and is crucial for mussels. The U.S. Fish and Wildlife Department has partnered with other field offices and a legion of stakeholders to initiate several watershed-based riparian habitat restoration projects on streams having diverse aquatic faunas within the Cumberlandian Region. Streams that harbor extant populations of the fluted kidneyshell and are the focus of these riparian restoration efforts include Horse Lick Creek, Kentucky, and the upper Clinch River, Tennessee and Virginia. TNC has selected the upper Clinch River, which has more species at risk mussels and fishes than any other small watershed in North America (and the largest extant fluted kidneyshell population known), as one of eight critical watersheds nationwide for protecting aquatic biodiversity (Master et al. 1998).

TNC has designated the community-based projects on Horse Lick Creek and the Clinch River as bioreserves. By working closely with key partners (e.g., Resource Conservation and Development Councils, Natural Resources Conservation Service (NRCS), numerous other agencies and organizations), riparian habitat restoration activities conducted by the U.S. Fish and Wildlife Service and TNC are proceeding in high-biodiversity watersheds in the Cumberlandian Region.

On-the-ground efforts that have helped improve riverine habitat in Bioreserves and other watershed-based riparian restoration projects include reducing erosion by stabilizing streambanks and using no-till agricultural methods, controlling nutrient enrichment by carefully planning heavy livestock use areas, establishing buffer zones by erecting fencing and revegetating riparian areas, developing alternative water supplies for livestock, and implementing voluntary Best Management Practices to control run-off for a variety of agricultural and construction activities. Programs administered by NRCS are becoming an increasingly important tool used in addressing habitat concerns associated with impaired Cumberlandian Region streams.

Two new watershed-based habitat restoration projects with fluted kidneyshell records exist. These are located on Buck Creek, Kentucky, which has a current population of the fluted kidneyshell, and the Duck River, Tennessee, which historically had a population. The U.S. Fish and Wildlife Service has conducted a stress analysis on Buck Creek and a mussel survey (there are records for four federally listed mussels). The stress analysis determines the location, type, severity, and extent of non-point source impacts facing that stream. Designed to function as a foundation for a holistic riparian habitat restoration program, priority reaches of high-quality habitat can be restored once a stress analysis has been completed.

Water and stream habitat quality improvements have made it possible for mussel populations to expand in some river reaches and may lead to augmenting depleted or reintroducing extirpated mussel populations in other streams.

State and Federal agencies and the scientific community have cooperatively developed mussel propagation and reintroduction techniques and conducted associated research that has facilitated the reintroduction of mussels into historical habitats.

The fluted kidneyshell historically occurred in Cumberlandian Region streams that drain four states and two U.S. Fish and Wildlife Service regions: Region 4 (Alabama, Kentucky, and Tennessee) and Region 5 (Virginia).

Streams with riparian habitat restoration projects have played a major role in the recovery of listed aquatic organisms, including mussels. Habitat for the fluted kidneyshell will benefit by cooperating landowners in the habitat restoration projects on the Clinch River and Horse Lick Creek Bioreserves. If listed, the fluted kidneyshell should become more of a focus organism in project watersheds.

E. ***Other natural or manmade factors affecting its continued existence.***

The remaining populations of the fluted kidneyshell are generally small and geographically isolated. The patchy distribution pattern of populations in short river reaches makes them much more susceptible to extirpation from single catastrophic events, such as toxic chemical spills. Such a spill occurred in the upper Clinch River in 1998 killing at least 44 fluted kidneyshell specimens, as well as thousands of specimens of other mussel species, including three federally listed species (personal communication 1999 cited in U.S. Fish and Wildlife Service candidate assessment form). Furthermore, this level of isolation makes natural repopulation of any extirpated population impossible without human intervention.

Population isolation prohibits the natural interchange of genetic material between populations, and small population size reduces the reservoir of genetic diversity within populations, which can lead to inbreeding depression (Avise and Hamrick 1996). It is likely that some populations of the fluted kidneyshell are below the effective population size (Soulé 1980) required to maintain long-term genetic and population viability. The present distribution and status of the fluted kidneyshell in the upper Cumberland River system in Kentucky may provide an excellent example of the detrimental bottleneck effect resulting when the effective population size is not attained.

A once large population of this species occurred throughout the upper Cumberland River main stem below Cumberland Falls and in several larger tributary systems. In this region there were no absolute barriers to genetic interchange among its sub-populations that occurred in various streams. With the completion of Wolf Creek Dam in the late 1960s, the main stem population was soon extirpated, and the remaining populations isolated by the filling of Cumberland Reservoir.

Whereas small isolated tributary populations of imperiled short-lived species (e.g., most fishes) would have died out within a decade or so after impoundment, the long-lived fluted kidneyshell would potentially take decades to expire post-impoundment. Without the level of genetic interchange the species experienced historically (i.e., without the reservoir barrier), isolated populations that are now comprised predominantly of adult specimens may be slowly dying out. The smaller and more isolated populations of the fluted kidneyshell may be lost to the devastating consequences of below-threshold effective population size. In reality, degradation of these isolated stream reaches resulting in ever decreasing patches of suitable habitat is contributing to the decline of the fluted kidneyshell.

REFERENCES

Ahlstedt, S.A. and J.M. Tuberville. 1997. Quantitative reassessment of the freshwater mussel fauna in the Clinch and Powell Rivers, Tennessee and Virginia. Pp. 72-97 In: K.S.

Cummings, A.C. Buchanan, C.A. Mayer, and T.J. Naimo, eds. Conservation and management of freshwater mussels II: initiatives for the future. Proceedings of a UMRCC symposium, 16-18 October 1995, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Avise, J.C. and J.L. Hamrick, eds. 1996. Conservation genetics: case histories from nature. Chapman and Hall, New York.

Gordon, M.E. and J.B. Layzer. 1989. Mussels (Bivalvia: Unionoidea) of the Cumberland River: review of life histories and ecological relationships. U.S. Fish and Wildlife Service Biological Report 89(15). 99 pp.

Hartfield, P., and E. Hartfield. 1996. Observations on the conglutinates of *Ptychobranchus greeni* (Conrad, 1834) (Mollusca: Bivalvia: Unionidea). American Midland naturalist 135:370-375.

Kanehl, P. and J. Lyons. 1992. Impacts of in-stream sand and gravel mining on stream habitat and fish communities, including a survey on the Big Rib River, Marathon County, Wisconsin. Wisconsin Department of Natural Resources Research Report 155. 32 pp.

Kitchel, H.E., J.C. Widlak, and R.J. Neves. 1981. The impact of coal-mining waste on endangered mussel populations in the Powell River, Lee County, Virginia. Unpublished Report to the Virginia State Water Control Board, Richmond. 26 pp.

Master, L.L., S.R. Flack, and B.A. Stein, eds. 1998. Rivers of life: critical watersheds for protecting freshwater biodiversity. The Nature Conservancy, Arlington, Virginia. 71 pp.

Neves, R.J. 1986. Recent die-offs of freshwater mussels in the United States: an overview. Pp. 7-18 In: R.J. Neves, ed. Proceedings of the workshop on die-offs of freshwater mussels in the United States, 23-25 June 1986, Davenport, Iowa. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Neves, R.J. 1993. A state-of-the unionid address. Pp. 1-10 In: K.S. Cummings, A.C. Buchanan, and L.M. Koch, eds. Conservation and management of freshwater mussels. Proceedings of a UMRCC symposium, 12-14 October 1992, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Neves, R.J. and M.C. Odom. 1989. Muskrat predation on endangered freshwater mussels in Virginia. Journal of Wildlife Management 53(4):934-941.

Neves, R.J., A.E. Bogan, J.D. Williams, S.A. Ahlstedt, and P.W. Hartfield. 1997. Status of aquatic mollusks in the southeastern United States: a downward spiral of diversity. Pp. 43-85 In: G.W. Benz and D.E. Collins, eds. Aquatic fauna in peril: the southeastern perspective. Special Publication 1, Southern Aquatic Research Institute, Chattanooga, Tennessee.

Parmalee, P.W. and A.E. Bogan. 1998. The freshwater mussels of Tennessee. The University of Tennessee Press, Knoxville. 328 pp.

Shute, P.W., R.G. Biggins, and R.S. Butler. 1997. Management and conservation of rare aquatic resources: a historical perspective and recommendations for incorporating ecosystem management. Pp. 445-466 In: G.W. Benz and D.E. Collins, eds. Aquatic fauna in peril: the southeastern perspective. Special Publication 1, Southern Aquatic Research Institute, Chattanooga, Tennessee.

Soulé, M.E. 1980. Threshold for survival: maintaining fitness and evolutionary potential. Pp. 151-169 In: M.E. Soulé and B.A. Wilcox, eds. Conservation biology. Sinauer Associates, Inc., Sunderland, Massachusetts.

Stansbery, D.H. 1971. Rare and endangered molluscs in the eastern United States. Pp. 5-18 In: S.E. Jorgensen and R.W. Sharpe, eds. Proceedings of a Symposium on Rare and Endangered Mollusks (Naiads) of the United States. U.S. Fish and Wildlife Service, Twin Cities, Minnesota.

Tennessee Valley Authority. 1971. Stream length in the Tennessee River Basin. Unpublished Report. Tennessee Valley Authority, Knoxville, Tennessee. 25 pp.

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P.M. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione, and J.D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks, 2nd edition. American Fisheries Society, Special Publication 26, Bethesda, Maryland.

Williams, J.D., M.L. Warren, Jr., K.S. Cummings, J.L. Harris, and R.J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18 (9): 6-22.

Winston, M.R., and R.J. Neves. 1997. Survey of the freshwater mussel fauna of unsurveyed streams of the Tennessee River drainage, Virginia. Banisteria 10:3-8.

PETITION TO LIST

Neosho mucket
(*Lampsilis rafinesqueana*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 5/22/84:	
CNOR 1/6/89:	
CNOR 11/21/91:	
CNOR 11/15/94:	
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

The taxonomic status of the Neosho mucket, *Lampsilis rafinesqueana* (Unionidae), as a valid species is uncontroversial (e.g., Williams et al. 1993; Obermeyer et al. 1997; Turgeon et al. 1998).

NATURAL HISTORY

Most unionid mussels are obligate parasites on fishes as larvae (glochidia). Neosho mucket glochidia have been successfully transformed onto smallmouth and largemouth bass, implicating these species as possible glochidia hosts (Barnhart and Roberts 1997). Gravid female Neosho muckets have been collected in June, July, and August, and females displaying mantle lures have been observed in July, August, and September. Mantle lures mimic small fish (Obermeyer 1999). The Neosho mucket is associated with stable runs, shoals, and riffles with gravely bottoms and moderate currents (Oesch 1984, Obermeyer 1999). Beyond this limited information, the habitat requirements and ecology of the species are poorly known.

The Neosho mucket is known only from the Illinois, Neosho, and Verdigris River basins in Arkansas, Kansas, Missouri, and Oklahoma. These basins flow into the Arkansas River in Northeastern Oklahoma. The Neosho mucket has been historically reported from the Illinois River in Oklahoma and Arkansas; the Neosho River in Oklahoma and Kansas; Neosho River tributaries, including the Elk River in Missouri, Cottonwood River in Kansas, and the Spring River in Oklahoma, Kansas, and Missouri, and Spring River tributaries, North Fork Spring River and Indian Creek in Missouri, and Shoal and Center Creeks in Kansas and Missouri; the Verdigris River in Oklahoma and Kansas, and its tributaries, Caney River in Oklahoma and Kansas, and Fall River in Kansas (Harris and Gordon 1988, Obermeyer et al. 1997a, Mather 1990, Vaughn 1996).

A number of surveys have recently been conducted to determine the current range and status of the Neosho mucket. In Arkansas, the Neosho mucket was found at 19 of 22 survey sites in the Illinois River, Washington/Benton Counties. Although the Neosho mucket was the third most abundant species collected from the approximately 50-kilometer (km)(30-miles (mi)) surveyed reach of river, there was little evidence of recent recruitment (i.e., small, young mussels were seldom collected) (Harris 1998). The species has not been found in surveys of other tributaries of the Arkansas River in Arkansas (Harris and Gordon 1988).

In Oklahoma, living Neosho muckets were found to be locally common in about 92 km (55 mi) of the Illinois River from the Oklahoma/Arkansas State line, downstream to the headwaters of Tenkiller Lake, Cherokee County, Oklahoma (Mather 1990). The population within the survey reach was estimated at more than 1200 individuals. Population demographics were skewed toward older aged cohorts, and only 3 animals were encountered during the survey that could be considered juveniles (i.e., evidence of recent recruitment). Neosho muckets were not found within, or below Tenkiller Lake.

More recent surveys in northeastern Oklahoma (Vaughn 1995, 1996, 1997) found Neosho muckets locally common at 9 of 42 sites on the Illinois River. Vaughn (1997) estimated the population within the Oklahoma portion of the Illinois River (the same reach surveyed by Mather in 1990) at between 500 and 1,000 Neosho muckets. Although some evidence of reproduction was observed (i.e., gravid females displaying mantle lures), there was little evidence of recruitment into the population (i.e., very few small, young Neosho muckets were collected). Searches in other historically occupied drainages in Oklahoma found no live Neosho muckets at 10 sites on the Spring River, 17 sites on the Neosho River, 32 sites on the Verdigris River, and 29 sites on the Caney River, however, relic Neosho mucket shells confirmed the historic presence of the species at many of these sites, and fresh dead Neosho mucket shells were found at two sites on the Spring River. The results of these recent surveys suggest the Neosho mucket has been extirpated from the Caney, Verdigris, Neosho, and Spring Rivers in Oklahoma (Mather 1990; Vaughn 1995, 1996, 1997).

During recent mussel surveys of historically occupied streams in Kansas and Missouri, living Neosho muckets or fresh dead shells were found in the lower Fall River, Greenwood and Wilson Counties, Kansas; the Verdigris River between the Toronto Lake Dam and the confluence of the Elk River, Wilson and Montgomery Counties, Kansas; the Neosho River between the John Redmond Reservoir Dam and the Parsons City Dam in Coffey, Allen, and Neosho Counties, Kansas; and the Spring and North Fork Spring Rivers, and Center and Shoal Creeks in Cherokee County, Kansas, and Jasper County, Missouri (Obermeyer et al. 1997a, Obermeyer 1999).

Neosho muckets were relatively rare in the Fall, Verdigris, Neosho, and North Fork Spring Rivers, and Shoal Creek, representing from 0.2-1.7 percent of all live mussels collected, and were not found at all stations surveyed. Neosho muckets were most abundant in a short reach (~10 km (6 mi)) of the Spring River, between the Missouri/Kansas State Line and the confluence of Center Creek, where it was the most abundant species found at 11 collection sites. In Center Creek, Jasper County, Missouri, only a single fresh dead shell was found. At all sites where living Neosho muckets were found, there was little evidence of recruitment. Based upon Obermeyer et al. (1997a) and others (Cope 1979, Cope and Distler 1985, Metcalf 1980), the Neosho mucket has been extirpated from the Elk, Caney, Cottonwood, and South Fork of the Cottonwood Rivers, the Neosho River above John Redmond Reservoir, the Verdigris River above Toronto Lake, the Fall River above Fall River Lake, and the lower reaches of the Spring River, Shoal and Center Creeks in Kansas, and Indian Creek in Missouri.

POPULATION STATUS

3,000 - 10,000 individuals exist on 10,000 - 50,000 acres. The estimated 250 stream miles of occupied habitat mostly support small populations. Historically, one of the most common mussels in parts of its range, it is now rare and shows no signs of recruitment, and faces major threats (Busby and Vaughn in NatureServe Explorer 2002).

The Neosho mucket is protected under Kansas and Oklahoma State laws as an endangered species. The Illinois River in Oklahoma is a State-designated mussel sanctuary, and no mussel harvest is allowed. The species is not protected in Arkansas and Missouri, beyond general mussel harvest laws. The International Union for the Conservation of Nature(IUCN) classifies the species as endangered.

The Natural Heritage Programs of Arkansas, Kansas, and Oklahoma rank the Neosho mucket as Critically Imperiled.

The Missouri Natural Heritage Program ranks the Neosho mucket as Imperiled.

The U.S. Fish and Wildlife Service classifies the Neosho mucket as a candidate for Endangered Species Act protection with a listing priority number of 5.

LISTING CRITERIA

A. ***The present or threatened destruction, modification, or curtailment of its habitat or range.***

Historical range:	Arkansas, Kansas, Oklahoma, Missouri. The Neosho mucket has been historically reported from the Illinois River in Oklahoma and Arkansas; the Neosho River in Oklahoma and Kansas; Neosho River tributaries, including the Elk River in Missouri, Cottonwood River in Kansas, and the Spring River in Oklahoma, Kansas, and Missouri, and Spring River tributaries, North Fork Spring River and Indian Creek in Missouri, and

Shoal and Center Creeks in Kansas and Missouri; the Verdigris River in Oklahoma and Kansas, and its tributaries, Caney River in Oklahoma and Kansas, and Fall River in Kansas (Harris and Gordon 1988, Obermeyer et al. 1997a, Mather 1990, Vaughn 1996).

Current range: Arkansas, Kansas, Oklahoma, Missouri**.** In summary, the Neosho mucket has been extirpated from approximately 70 percent of its historic range. Most of this extirpation has occurred within the Oklahoma and Kansas portions of its range. Causes of the disappearance of the species from many areas have been attributed to impoundment, mining, and pollution (Mather 1990, Obermeyer et al. 1997b). The Neosho mucket survives in four river drainages, however, only two of these, the Spring and Illinois Rivers, currently support potentially viable populations of the species due to the presence of a relatively large number of individuals. However, recruitment is either very low or not occurring in all of the extant populations.

Land ownership: Over 90% of the lands draining the watersheds populated by Neosho muckets are privately owned. An extensive reach of the Illinois River in Arkansas flows through Ozark National Forest. With the exception of the Spring River, all river reaches currently supporting Neosho muckets in Kansas and Oklahoma are controlled or affected by U.S. Army Corps of Engineers Reservoirs. The Oklahoma Department of Wildlife Conservation manages a 565-acre primitive area on the Illinois River. The Nature Conservancy is acquiring 15,000 acres on the Illinois River. In addition, the Kansas Department of Wildlife and Parks owns a small parcel of land (representing less than one river mile of streambank) along the Spring River in Cherokee County, which includes a portion of the large remnant population of Neosho Muckets in this stretch of river.

The reduction of habitat and range of the Neosho mucket has been attributed to impoundment, sedimentation, agricultural pollutants (Mather 1990, Obermeyer et al. (1997b), and mining (Obermeyer et al. 1997b). At least 11 major dams have been constructed that have impounded significant portions of the historic range of the Neosho mucket, effectively resulting in fragmented Neosho mucket populations and habitats. The species does not tolerate lentic conditions and has not been collected from those portions of its historic habitat that have been impounded. In addition, it is believed that the operation of these dams will continue to negatively affect the Neosho mucket. For instance, Obermeyer et al. (1997b) noted extensive bank scouring in the Neosho River below John Redmond Dam and made observations that suggest channel instability as a primary factor in mussel distribution below this dam.

Several types of pollution are also thought to affect Neosho mucket populations. Sediment is probably the most abundant pollutant currently affecting the Neosho mucket (Obermeyer 1999). Excessive sedimentation is known to cause direct mortality of freshwater mussels by deposition and suffocation (Ellis 1936) and can eliminate or reduce the recruitment of juvenile mussels

(Negus 1966, Box and Mossa 1999). High suspended sediment levels can also interfere with feeding activity (Dennis 1984). Sediment sources within the current range of the Neosho mucket include cultivated fields, cattle grazing, and urban, suburban, and rural construction activities. Sediment levels within the range of the Neosho mucket are higher than historic levels and are likely to increase. For example, the Illinois River in Arkansas drains portions of the two fastest growing counties in Arkansas. Continued development and growth within this basin will likely result in increased sediment and nutrient impacts to this river and to the Neosho mucket population found there (personal communication cited in U.S. Fish and Wildlife Service candidate assessment form).

Eutrophication, caused by the introduction of excess nutrients to a water body, has been shown to result in periodic low dissolved oxygen levels that are detrimental to mussels (Sparks and Strayer 1998). Excess nutrients also promote heavy growth of blue-green and other algae that can eliminate habitat for juvenile mussels. Nutrients, usually phosphorus and nitrogen, can emanate from agricultural, urban, and suburban runoff, including cultivated fields and pastures, livestock feedlots, leaking septic tanks, residential lawns, etc., in levels that result in eutrophication and reduced oxygen levels. At least one example of this has been documented within the range of the Neosho mucket where extirpation of mussel species from the Cottonwood River during the 1960s was attributed to feedlot runoff (Obermeyer et al. 1997b).

Pesticide residues from agricultural, residential, or silvicultural activities may also impact Neosho mucket populations, however, there is currently no available information on the sensitivity of this species to common pesticides. Nonetheless, chemical run-off or spills have resulted in mussel mortalities in various regions of the country, and there is no reason to believe that the Neosho mucket would be any less susceptible to pesticide residues than other mussel species. In fact, toxic contamination, including oil and saltwater spills, and heavy metals from mine tailings, have resulted in mussel mortality in the Cottonwood and Spring Rivers in the past (see Obermeyer 1999), but it is not known whether or not any of these mortalities were Neosho muckets. Also, pesticides and high fecal coliform counts have been reported for the Verdigris River downstream of Independence, Kansas, (Kansas Department of Health and Environment 1994) which are likely to affect the quality of Neosho mucket habitat.

In-stream and floodplain sand and gravel mining has been shown to cause channel degradation and is associated with mussel declines and extirpations in a number of river basins (Box and Mossa 1999, Hartfield 1993, Kanehl and Lyons 1992). An unknown number of mining operations are known to exist within the historic range of the species, and it is likely that other operations will be initiated in the future as the demand for gravel for roads and construction-related activities increases. Since Neosho muckets inhabit gravel/sand stream beds that are vulnerable to mining activities, it is expected that this particular threat to Neosho mucket habitat will increase. Pollution from mineral mining has already been implicated in the extirpation of all mussel species, including the Neosho mucket, from the lower Spring River in Kansas (*in litt.* 2000 cited in U.S. Fish and Wildlife Service candidate assessment form).

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

The Neosho mucket was once valuable in the pearl button industry, and historic episodes of over-harvest in the Neosho River may have contributed to its decline (Obermeyer et al. 1997b). Commercial harvest of the species is now prohibited in Kansas and Oklahoma. Arkansas currently permits commercial harvest of Neosho muckets at sizes of four inches or greater in length, and Missouri prohibits commercial mussel harvest but allows up to five Neosho muckets per person per day to be collected for private purposes (e.g., bait, shell collection, etc.). It is not known what effect the legal harvest of Neosho muckets is having on the populations of the species in these two states, but harvest for the cultured pearl nuclei trade is either prohibited or restricted to some degree in those states. Overall, the Neosho mucket's limited distribution and small population sizes makes it vulnerable to illegal commercial harvest.

C. ***Disease or predation.***

Diseases of freshwater mussels are poorly known, and are unknown as a factor in the decline of the Neosho mucket. Juvenile and adult mussels are prey items for some invertebrate predators and parasites (e.g., flatworms, trematodes, mites, etc.), and provide prey for a few vertebrate species (e.g., racoons, muskrats, minks, freshwater drum, etc.). Predation by naturally occurring predators is a normal aspect of the population dynamics of a healthy mussel population. However, predation may contribute to the further decline of localized mussel populations with low numbers of individuals and limited recruitment.

Escape of the non-native black carp, a molluscivore currently grown and used for mollusk control in fish farm operations, could present a threat of increased predation to native mollusks, including the Neosho mucket, but it is not known whether or not this species is being utilized by fish farmers within the range of the Neosho mucket. There is one record of an accidental release of black carp in Missouri (personal communication cited in U.S. Fish and Wildlife Service candidate assessment form). In April 1994, 30 or more black carp were released from an aquaculture facility near Lake of the Ozarks/Bagnell Dam when the fish were washed into the Osage River during a flood event. To date, none of these fish have been recaptured. The fish were reported to be triploid (non-reproductive). The Missouri Department of Conservation also recently made a decision to propagate certified triploid black carp for use in aquaculture facilities to control the yellow grub, a pest of aquaculture facilities throughout the Midwest and Gulf Coast states. Even if these fish are non-reproductive, accidental releases into streams could still impact native mussels, including Neosho mucket, as a result of increased predation.

D. ***The inadequacy of existing regulatory mechanisms.***

Although the negative effects of point source discharges on aquatic communities within the range of the Neosho mucket have been reduced over time by compliance with State and Federal regulations pertaining to water quality, there has been less success in dealing with non-point source pollution. Such impacts result from individual private landowner activities (e.g., construction, grazing, agriculture, silviculture, etc.), and public construction works (e.g., bridge and highway construction and maintenance, etc.).

Each state within the range of the Neosho mucket has a variety of laws and guidelines (e.g., forestry best management practices) which are intended to minimize non-point sources, however, the efficiency at which these regulations work can vary depending on the strength of the regulation, enforcement capabilities, and other factors. Often the inadequacy of these regulations or their enforcement can lead to stream impacts which may affect the Neosho mucket. The Neosho mucket is protected under Kansas and Oklahoma State laws as an endangered species. The Illinois River in Oklahoma is a State-designated mussel sanctuary, and no mussel harvest is allowed. The species is not protected in Arkansas and Missouri, beyond general mussel harvest laws. There is currently no requirement within the scope of Federal environmental laws to specifically consider the Neosho mucket during Federal activities, or to ensure that Federal projects will not jeopardize its continued existence.

Current Conservation Efforts: The Missouri Department of Conservation is working to artificially propagate Neosho muckets for population augmentation and reintroduction. The Kansas Department of Wildlife and Parks has developed a State recovery plan for the Neosho mucket and three other rare mussel species.

E. *Other natural or manmade factors affecting its continued existence.*

The Neosho mucket is now limited to four drainage populations: the Neosho, Verdigris, Illinois, and Spring River drainages. Each is isolated from the others by one or more major impoundments and by extended reaches of degraded river habitat. Isolation renders the four extant drainage populations vulnerable to random catastrophic events (e.g., flood scour, drought, toxic spills, etc.). During the 2000 drought, the Fall River population of Neosho mucket was severely stressed and threatened by low flow conditions and low dissolved oxygen concentrations (*in litt*. 2000 cited in U.S. Fish and Wildlife Service candidate assessment form). Limited range also makes these isolated populations vulnerable to land use changes that would result in increases in non-point source pollution impacts within occupied watersheds. Isolation also prevents emigration or immigration between populations in response to adverse or positive environmental changes, and increases the deleterious effects of inbreeding.

Recent collections indicate that Neosho mucket recruitment is limited (Mather 1990, Harris 1998, Obermeyer et al. 1997a; Vaughn 1995, 1996, 1997). All extant populations of the Neosho mucket are currently dominated by older aged cohorts, and juvenile muckets are rare. It is currently unknown if recruitment rates offset mortality rates in any population.

REFERENCES

Barnhart, M.C., and A. Roberts. 1997. Reproduction and fish hosts of unionids from the Ozark uplifts. Pp. 15-20 In: K.S. Cummings, A.C. Buchanan, C.S. Mayer, and T.J. Naimo (eds.) Conservation and Management of Freshwater Mussels II. Upper Mississippi River Conservation Committee, Rock Island, IL.

Box, J.B. and J. Mossa. 1999. Sediment, land use, and freshwater mussels: prospects and problems. J. N. Am. Benthol. Soc. 18(1):99-117.

Busby; W.H. and C. Vaughn in NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

Cope, C.H. 1979. Survey of the Unionidae considered for conservation status in Kansas. Kansas Game and Fish Commission, Pratt. 39 pp.

Cope, C.H. and D.A. Distler. 1985. Assessment of unionid mussel beds in the Spring River Basin. Project Completion Report, Contract No. 40. Kansas Department of Wildlife and Parks. 96 pp.

Dennis, S.D. 1984. Distributional analysis of the freshwater mussels of the Tennessee River system, with special reference to possible limiting effects of siltation. Ph.D. Dissertation, VPI & SU, Blacksburg, Virginia, 171 pp.

Ellis, M.M. 1936. Erosion silt as a factor in aquatic environments. Ecology 17:29-42.

Harris, J.L. 1998. Status survey of *Lampsilis rafinesqueana* Frierson, the Neosho Mucket, in Arkansas. Revised Draft Final Report. Little Rock, AR.

Harris, J.L., and M.E. Gordon. Distribution and status of rare and endangered mussels (Mollusca: Margaritiferidae, Unionidae) in Arkansas. Proceedings Arkansas Academy of Science 41:49-56.

Hartfield, P. 1993. Headcuts and their effect on freshwater mussels. Pp. 131-141 In: K.S. Cummings, A.C. Buchanan, and L.M. Koch (eds.) Conservation and Management of Freshwater Mussels. Upper Mississippi River Conservation Committee, Rock Island, IL.

Kanehl, P. and J. Lyons. 1992. Impacts of in-stream sand and gravel mining on stream habitat and fish communities, including a survey on the Big Rib River, Marathon County, Wisconsin. Research Report 155. Wisconsin Department of Natural Resources. Madison, WS.

Kansas Department of Health and Environment. 1994. Surface water and groundwater quality summaries for major river basins in Kansas, 1990-93. Kansas Department of Health and Environment. Topeka, Kansas. 24 pp

Mather, C.M. 1990. Status survey of the western fanshell and the Neosho mucket in Oklahoma. Final Report to Oklahoma Department of Wildlife Conservation, Oklahoma City, OK, Project E-7, 22 pp.

Metcalf, A.L. 1980. Unionacean mussels, past and present, from six streams in Kansas and

Oklahoma. Transactions of the Kansas Academy of Science 83:1-19.

Negus, C.L. 1966. A quantitative study of growth and production of unionid mussels in the River Thames at Reading. J. Animal Ecol. 35:513-532.

Obermeyer, B.K. 1999. Draft Recovery Plan for four freshwater mussels in southeast Kansas: Neosho mucket, Ouachita kidneyshell, rabbitsfoot, western fanshell. Kansas Department of Wildlife and Parks, Pratt, KS. 88 pp.

Obermeyer, B.K., D.R. Edds, C.W. Prophet, and E.J. Miller. 1997a. Freshwater mussels in the Verdigris, Neosho, and Spring River basins of Kansas and Missouri, with emphasis on species of concern. Amer. Malacological Bull. 14(1):41-45.

Obermeyer, B.K., D.R. Edds, E.J. Miller, and C.W. Prophet. 1997b. Range reductions of southeast Kansas unionids. Pages 108-116 In Conservation and Management of Freshwater Mussels II; Initiatives for the Future.

Oesch, R.D. 1984. Missouri naiades, a guide to the mussels of Missouri. Missouri Department of Conservation. 270 pp.

Sparks, B.L. and D.L. Strayer. 1998. Effects of low dissolved oxygen on juvenile Elliptio complanata (Bivalvia: Unionidae). J. N. Am. Benthol. Soc. 17(1):129-134.

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P.M. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione, and J.D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks, 2nd edition. American Fisheries Society, Special Publication 26, Bethesda, Maryland.

Vaughn, C.C. 1995. Determination of the status and habitat preference of the Neosho mucket in Oklahoma. Annual Performance Report submitted to Oklahoma Department of Wildlife Conservation, Oklahoma City, OK. 7 pp.+ app.

Vaughn, C.C. 1996. Determination of the status and habitat preference of the Neosho mucket in Oklahoma. Annual Performance Report submitted to Oklahoma Department of Wildlife Conservation, Oklahoma City, OK. 7 pp.

Vaughn, C.C. 1997. Determination of the status and habitat preference of the Neosho mucket in Oklahoma. Annual Performance Report submitted to Oklahoma Department of Wildlife Conservation, Oklahoma City, OK.

Williams, J.D., M.L. Warren, Jr., K.S. Cummings, J.L. Harris, and R.J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18 (9): 6-22.

PETITION TO LIST

Alabama pearlshell
(*Margaritifera marrianae*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 05/22/84:	
CNOR 01/06/89:	
CNOR 11/21/91:	
CNOR 11/15/94:	
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 06/13/02:	C

TAXONOMY

The taxonomic status of the Alabama pearlshell, *Margaritifera marrianae* (Margaritiferidae), as a valid species is uncontroversial (e.g., Williams et al. 1993; Turgeon et al. 1998). Known only from certain tributaries of the Alabama and Escambia River drainages of south-central Alabama, this mussel was recognized as a distinct species by Johnson (1983). It had previously been included with the Louisiana pearlshell, *Margaritifera hembeli* (Conrad 1838), a species now considered endemic to central Louisiana.

NATURAL HISTORY

Morphology
The Alabama pearlshell is a medium-sized mussel, up to 95 millimeters (mm) (3.8 inches (in)) in length, and oblong in outline. The shell exterior is colored a dark olivaceous or blackish-brown and is marked by small irregular ridges on the posterior slope of the shell. The nacre is bluish-white and moderately iridescent (see Johnson 1983 for a more detailed description).

Habitat
Frierson (1927) listed it from soft water streams from the pine barrens of southeastern Alabama. Substrates in this region tend to be sandy and high accumulations of detritus (in conjunction with the poor buffering quality) result in water stained brown by elevated concentrations of tanins. Water temperatures tend to be moderated by the influx of springs. Shelton (1997) reports the

habitat for the species to be headwater streams of slow to moderate current velocities with substrates consisting of sand, sandy mud, gravel, or a sand gravel mixture with an average depth of less than 0.5 meters.

Distribution

The historic and present distribution of the Alabama pearlshell is confined to south-central Alabama (Ortmann 1912, Simpson 1914, Clench and Turner 1956, Stansbery 1976; Shelton 1995, 1996, *in litt*. 1998 cited in U.S. Fish and Wildlife Service candidate assessment form). In the Escambia River drainage the species has been reported from tributaries of the Conecuh River, including Sandy Creek; Murder Creek and its tributaries Jordan, Autrey, Gin, Hunter, Otter, Beaver Creeks, and Little Cedar Creek, in Conecuh County; Bottle Creek, Conecuh County; Burnt Corn Creek, Conecuh/Monroe Counties; and Horse Creek, Crenshaw County. The species has also been reported from three streams in the Alabama River drainage: Limestone Creek and its tributary Brushy Creek, and Big Flat Creek, Monroe County, Alabama.

Knowledge of the current status and distribution of the Alabama pearlshell is based on recent surveys of more than 80 historic and potential localities of the Alabama pearlshell in the Brushy, Burnt Corn, and Patsaliga Creek drainages, and the Conecuh and Sepulga River drainages in Monroe, Conecuh, Crenshaw, Escambia, Covington, and Butler Counties, Alabama. These surveys were conducted between 1991 and 1998 by biologists from the National Fisheries Research Center (Gainesville, Florida), Douglas Shelton (Alabama Malacological Research Center, Mobile, Alabama), and U.S. Fish and Wildlife Service biologists (Jackson Field Office, Mississippi; Daphne Field Office, Alabama). More than 50 tributaries of the Alabama River have been recently surveyed for mollusks (*in litt.* 1993 cited in U.S. Fish and Wildlife Service candidate assessment form; McGregor et al. 1996). Only three live populations of Alabama pearlshells have been confirmed by recent survey efforts: Hunter, Jordan, and Little Cedar Creeks, Murder Creek drainage, Conecuh County, Alabama (NBS field records *in litt.* 1991, 1993 cited in U.S. Fish and Wildlife Service candidate assessment form; U.S. Fish and Wildlife Service field records in litt. 1991-1994, *in litt.* 1998 cited in U.S. Fish and Wildlife Service candidate assessment form).

Status of the Hunter Creek population is currently in doubt. Numbers of Alabama pearlshell were low in Hunter Creek in 1998 (8 individuals reported, *in litt.* cited in U.S. Fish and Wildlife Service candidate assessment form), and two 1999 visits to the stream found no evidence of the species (*in litt.* 1999 cited in U.S. Fish and Wildlife Service candidate assessment form). Increased sedimentation of Hunter Creek was observed. Jordan Creek supports the highest numbers of the species (63 individuals reported in 1998), and the presence of a few juvenile/subadult individuals indicates some level of recruitment in this population. Little Cedar Creek also contains good numbers of Alabama pearlshells (54 individuals reported in 1998) and shows the greatest variety of age classes of the three populations. Both Jordan and Little Cedar Creeks continued to sustain good populations with considerable evidence of recent recruitment in 1999 (*in litt.* 1999 cited in U.S. Fish and Wildlife Service candidate assessment form).

Evidence suggests that much of the decline of this species has occurred within the past few decades. The Alabama pearlshell was relatively common in localized portions of Limestone

Creek and its tributary Brushy Creek, Alabama River drainage, as recently as 1974 (personal communication 1993 cited in U.S. Fish and Wildlife Service candidate assessment form).

Searches of this creek drainage in recent years have located only a few shell fragments (*in litt.* 1994 cited in U.S. Fish and Wildlife Service candidate assessment form). Twelve specimens of the Alabama pearlshell were collected from Horse Creek, Conecuh River drainage, Crenshaw County, as recently as 1981 (University of Massachusetts collection record). Repeated searches of this stream drainage have failed to locate even shell fragments, and the species appears to be extirpated from this portion of its range. Records of occurrence exist for Autrey Creek from 1964 (Museum of Fluvatile Mollusks collection record). The most recent records from other historically occupied sites in Murder Creek proper, three of its tributaries, and Burnt Corn Creek, date from the early 1900's. The species has apparently been extirpated from these localities. The most recent surveys indicate that the distribution of the Alabama pearlshell continues to decline. The species was last reported in 1995 from Sandy Creek, Conecuh County, and Big Flat Creek, Monroe County, however, in 1998 surveys failed to relocate Alabama pearlshells at these sites (*in litt.* 1998 cited in U.S. Fish and Wildlife Service candidate assessment form).

POPULATION STATUS

Fewer than 1,000 individuals, fewer than 2,000 acres, and fewer than10 miles of stream length. Historically common within its range, it is now rare within most extant EOs with low density levels where found. Specific causes of the decline and disappearance of the Alabama pearlshell from historic stream localities are unknown, however they are probably related to past and present land use patterns. Many of the small streams historically inhabited by the Alabama pearlshell are impacted to various degrees by nonpoint source pollution. The existence of one of three limited extant populations in 1999 could not be confirmed, and surviving populations likely suffered drought stress in 2000.

The Alabama Natural Heritage Program ranks the Alabama pearlshell as Critically Imperiled.

The U.S. Fish and Wildlife Service classifies the Alabama pearlshell as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range: Alabama. The historic and present distribution of the Alabama pearlshell is confined to south-central Alabama (Ortmann 1912, Simpson 1914, Clench and Turner 1956, Stansbery 1976, in litt. 1994 cited in U.S. Fish and Wildlife Service candidate assessment form; Shelton 1995, 1996, *in litt.* 1998 cited in U.S. Fish and Wildlife Service candidate assessment form). In the Escambia River drainage the species has been reported from tributaries of the Conecuh River, including Sandy Creek; Murder Creek and its tributaries Jordan, Autrey, Gin, Hunter, Otter, Beaver Creeks, and Little Cedar Creek, in Conecuh County; Bottle Creek, Conecuh County; Burnt Corn Creek, Conecuh/Monroe Counties; and Horse Creek, Crenshaw County. The species has also been reported from three streams in the Alabama River drainage: Limestone Creek and its tributary Brushy Creek, and Big Flat Creek, Monroe County, Alabama.

Current range: Alabama. Only three live populations of Alabama pearlshells have been confirmed by recent survey efforts: Hunter, Jordan, and Little Cedar Creeks, Murder Creek drainage, Conecuh County, Alabama (NBS field records *in litt.* 1991, 1993; U.S. Fish and Wildlife Service field records *in litt.* 1991-1994 cited in U.S. Fish and Wildlife Service candidate assessment form, *in litt*. 1998 cited in U.S. Fish and Wildlife Service candidate assessment form).

Land ownership: All habitat is privately owned.

The Alabama pearlshell has disappeared from most of its historic range, including 13 stream systems in south Alabama. The species is now known to inhabit two small stream systems in Conecuh County, Alabama. The small stream habitats of the Alabama pearlshell are vulnerable to habitat modification, sedimentation, and water quality degradation from a number of activities associated with modern civilization. Highway construction, improper logging practices, agriculture, housing developments, pipeline crossings, or cattle grazing often result in physical disturbance of stream substrates or the riparian zone, and/or changes in water quality, temperature, or flow.

Sedimentation can cause direct mortality of freshwater mussels by deposition and suffocation (Ellis 1936, Box and Mossa 1999) and can eliminate or reduce the recruitment of juvenile mussels (Negus 1966, Box and Mossa 1999). Suspended sediment can also interfere with feeding activity (Dennis 1984). Many of the streams recently surveyed for the Alabama pearlshell were characterized by high sediment loads (NBS and U.S. Fish and Wildlife Service field observations, 1991-1994 cited in U.S. Fish and Wildlife Service candidate assessment form). Heavy sand bedloads in some of the streams have apparently rendered them unsuitable for any mussel species.

Current sources of sand and other sediment accumulation in south-central Alabama stream channels include cultivated fields, silviculture practices, cattle grazing, and unpaved road drainage. Certain silvicultural and agricultural activities cause erosion, riparian buffer degradation, and increased sedimentation of stream habitats. Strict adherence to Forestry Best Management Practices and maintaining buffers between cultivated fields and riparian areas minimizes these impacts. Uncontrolled access to small streams by cattle may result in destruction of riparian vegetation, bank degradation and erosion, and localized sedimentation of stream habitats. Alabama pearlshell habitat in Hunter Creek exhibited evidence of recent sedimentation during surveys in 1999 (*in litt.* 1999 cited in U.S. Fish and Wildlife Service candidate assessment form), presumably from construction of an upstream nature trail.

Several streams surveyed for the presence of the Alabama pearlshell showed signs of eutrophication, such as heavy growth of blue-green and other algae (*in litt*. 1994 cited in U.S. Fish and Wildlife Service candidate assessment form, U.S. Fish and Wildlife Service field observations 1994 cited in U.S. Fish and Wildlife Service candidate assessment form). Nutrients, usually phosphorus and nitrogen, may emanate from agricultural fields, residential lawns, livestock feedlots, poultry houses, and leaking septic tanks in levels that result in eutrophication and reduced oxygen levels in small streams.

Pesticide residues from agricultural, residential, or silvicultural activities may also impact Alabama pearlshell populations. There is no information on the sensitivity of this species to common pesticides. The Alabama pearlshell may be more susceptible to pesticide residues than test organisms currently used in bioassays, therefore, pesticide label restrictions may be inadequate to protect them. Agricultural crops locally grown within the range of the Alabama pearlshell that are associated with high pesticide use include cotton, peanuts, and soybeans.

The confirmed extant populations of the Alabama pearlshell are in the vicinity of highway crossings. The primary habitat and highest abundance of the Hunter Creek population is immediately downstream of a heavily used U.S. Highway. Highway and bridge construction and widening could eliminate this population unless appropriate precautions are implemented to protect the species.

B. *Overutilization for commercial, recreational, scientific, or educational purposes.*

The Alabama pearlshell is not a commercially valuable species nor are the small streams it inhabits subject to harvesting activities for commercial mussel species. The species has been taken for scientific and private collections in the past. Such activity may increase as the species rarity becomes known. Although collecting is not considered a factor in the decline of this species, the localized distribution and small size of the known extant populations renders them vulnerable to overzealous recreational or scientific collecting.

C. *Disease or predation.*

Diseases of freshwater mussels are poorly known. Juvenile and adult mussels are prey items for some invertebrate predators and parasites (nematodes, mites, etc.), and provide prey for a few vertebrate species (racoons, muskrats, otter, etc.). Although predation by naturally occurring predators is a normal aspect of the population dynamics of a healthy mussel population, predation may contribute to the further decline of this species due to the localized extent and low numbers of mussels associated with the extant populations.

D. *The inadequacy of existing regulatory mechanisms.*

Although the negative effects of point source discharges on aquatic communities in Alabama have been reduced over time by compliance with State and Federal regulations pertaining to water quality, there has been less success in dealing with non point source pollution impacts to small stream drainages. Such impacts result from individual private landowner activities (e.g., construction, grazing, agriculture, silviculture, etc.), and public construction works (e.g., bridge and highway construction and maintenance, etc.). The effects of such activities can be, and often are reduced by employing Best Management Practices. There is currently no requirement within the scope of Federal environmental laws to specifically consider the Alabama pearlshell during Federal activities, or to ensure that Federal projects will not jeopardize its continued existence.

Current Conservation Efforts: Conservation activities have been limited to working with private landowners in southern Alabama to encourage the use of Best Management Practices to reduce the effects of agriculture and silviculture.

E. ***Other natural or manmade factors affecting its continued existence.***

The threats to the Alabama pearlshell are compounded by its limited range and low numbers. The three known populations are vulnerable to random catastrophic events (e.g., flood scour, drought, toxic spills, etc.). The effects of the 2000 drought on Alabama pearlshell are currently unknown, however, the small stream habitat of the species is susceptible to dewatering from droughts. Limited range and low numbers also makes the species vulnerable to land use changes within the three occupied watersheds that would result in increases in nonpoint source pollution impacts.

The Alabama pearlshell would be adversely affected by the loss or reduction in numbers of the fish host essential to its parasitic glochidial stage. The specific fish host for larval Alabama pearlshells is not known, therefore, impacts on this aspect of the mussel's life cycle cannot be evaluated.

REFERENCES

Box, J.B. and J. Mossa. 1999. Sediment, land use, and freshwater mussels: prospects and problems. J. N. Am. Benthol. Soc. 18(1):99-117.

Clench, W.J. and R.D. Turner. 1956. Fresh-water mollusks of Alabama, Georgia, and Florida from the Escambia to the Suwannee River. Bulletin of the Florida State Museum 1:97-239.

Conrad, T.A. 1838. Monography of the family Unionidae, or naiades of Lamarck, (Fresh water bivalve shells) of North America. Philidelphia, Pennsylvania, pp. 93-94, plate 51.

Dennis, S.D. 1984. Distributional analysis of the freshwater mussels of the Tennessee River system, with special reference to possible limiting effects of siltation. Ph.D. Dissertation, VPI & SU, Blacksburg, Virginia, 171 pp.

Ellis, M.M. 1936. Erosion silt as a factor in aquatic environments. Ecology 17:29-42.

Frierson, L.S. 1927. A classified and annotated checklist of the North American niades. Baylor University Press, Waco, Texas.

Johnson, R.I. 1983. Margaritifera marrianae, a new species of *Unionacea* (Bivalvia:Margaritiferidae) from the Mobile-Alabama-Coosa and Escambia River systems, Alabama. Occ. Papers on Mollusks, Harvard Univ., Cambridge, Massachusetts.

McGregor, S.W., T.E. Shepard, T.D. Richardson, and J.F. Fitzpatrick, Jr. 1996. A survey of the primary tributaries of the Alabama and lower Tombigbee Rivers for listed and candidate species of freshwater mussels, snails and crayfish, 1994-1996. Geological Survey of Alabama, Tuscaloosa, AL. 34 pp

NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

Negus, C.L. 1966. A quantitative study of growth and production of unionid mussels in the River Thames at Reading. J. Animal Ecol. 35:513-532.

Ortmann, A.E. 1912. Notes upon the families and genera of the najades. Annals of the Carnegie Museum 8(2):222-365.

Shelton, D.N. 1995. A status survey for the Alabama Pearl Shell, *Margaritifera marrianae* R.I. Johnson, 1983. Barry A. Vittor and Associates, Inc., Mobile, AL. 11 pp.

Shelton, D.N. 1996. The distribution, abundance, and life history of the Alabama pearlshell, *Margaritifera marrianae* R.I. Johnson, 1983. Alabama Malacological Research Center. Mobile, AL. 12 pp.

Shelton, D.N. 1997. Observations on the life history of the Alabama pearlshell, *Margaritifera marrianae*, R.I. Johnson, 1983. A file report of the Alabama Malacological Research Center, submitted to the U.S. Fish and Wildlife Service, Jackson, Mississippi. [cited in NatureServe Explorer, http://www.natureserve.org/explorer]

Simpson, C.T. 1914. A descriptive catalogue of the naiades or pearly freshwater mussels. Detroit, Michigan, Parts 1-3,pp. 523-524.

Stansbery, D.H. 1976. Naiad mollusks. In: H. Boschung (ed.). Endangered and threatened plants and animals of Alabama. Alabama Museum of Natural History Bulletin (2):44.

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P.M. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione, and J.D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks, 2nd edition. American Fisheries Society, Special Publication 26, Bethesda, Maryland.

Williams, J.D., M.L. Warren, Jr., K.S. Cummings, J.L. Harris, and R.J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18 (9): 6-22.

PETITION TO LIST

slabside pearlymussel
(*Lexingtonia dolabelloides*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 5/22/84:	
CNOR 1/6/89:	
CNOR 11/21/91:	
CNOR 11/15/94:	
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

The taxonomic status of the slabside pearlymussel, *Lexingtonia dolabelloides* (Unionidae), as a valid species is uncontroversial (e.g., Williams et al. 1993; Turgeon et al. 1998).

NATURAL HISTORY

Most information in this section is taken from Parmalee and Bogan (1998) and references therein.

Morphology
The slabside pearlymussel is a moderately-sized mussel that reaches about 9 centimeters (3.5 inches) in length. The shape of the shell is subtriangular, and the very solid, heavy valves are moderately inflated. Shell texture is smooth and somewhat shiny in young specimens, becoming more dull with age. Shell color is greenish yellow, becoming brownish with age, with a few broken green rays or blotches, particularly in young individuals. Internally, the pseudocardinal teeth are triangular or blade-like in shape. There is a single lateral tooth. The color of the nacre (mother-of-pearl) is white, or rarely straw-colored.

Behavior
Adult freshwater mussels are filter-feeders, siphoning phytoplankton, diatoms, and other microorganisms from the water column. For their first several months juvenile mussels employ

foot (pedal) feeding, and are thus suspension feeders that feed on algae and detritus. Mussels tend to grow relatively rapidly for the first few years, then slow appreciably at sexual maturity (when energy is being diverted from growth to reproductive activities). As a group, mussels are extremely long-lived, living from a few decades to a maximum of approximately 200 years. Large, heavy-shelled riverine species tend to have longer life spans. No age specific information is available for the slabside pearlymussel. However, considering that it is a moderately-sized, heavy-shelled riverine species, it seems probable that it is relatively long-lived.

Most mussels, including the slabside pearlymussel, have separate sexes. Males expel clouds of sperm into the water column, which are drawn in by females through their incurrent siphons. Fertilization takes place internally, and the resulting zygotes develop into specialized larvae termed glochidia inside the water tubes of her gills. The slabside pearlymussel utilizes all four gills as a marsupium for its glochidia. It is thought to have a spring or early summer fertilization period with the glochidia being released during the summer in the form of conglutinates, which are analogous to cold capsules (i.e., gelatinous containers) with scores of glochidia contained within. Glochidia must come into contact with a specific host fish(es) in order for their survival to be ensured. Without the proper host fish, the glochidia will perish.

Slabside pearlymussel conglutinates are undescribed, but they are probably shaped like some sort of common fish food item, such as insect larvae, similar to other mussels that expel conglutinates. The slabside pearlymussel's host fishes, which include six species of shiners (popeye shiner, *Notropis ariommus*; rosyface shiner, *Notropis rubellus*; saffron shiner, *Notropis rubricroceus*; silver shiner, *Notropis photogenis*; telescope shiner, *Notropis telescopus*; and Tennessee shiner, *Notropis leuciodus*), are tricked into thinking that they have an easy meal when in fact they have infected themselves with mussel glochidia.

After a few weeks parisitizing the fishes' gill tissues, newly-metamorphosed juveniles drop off to begin a free-living existence on the stream bottom. Unless they drop off in suitable habitat, they will die. Thus, the complex life history of the slabside pearlymussel and other mussels has many weak links that may prevent successful reproduction and/or recruitment of juveniles to existing populations.

Habitat
The slabside pearlymussel is primarily a large creek to moderately-sized river species, inhabiting sand, fine gravel, and cobble substrates in relatively shallow riffles and shoals with moderate current. This species requires flowing, well-oxygenated waters to thrive.

Distribution
Most studies of the distribution and population status on the slabside pearlymussel were conducted in the first quarter of this century and since the early 1960s. Gordon and Layzer (1989), Winston and Neves (1997), and Parmalee and Bogan (1998) give most of the references for survey work in regional streams. Current, unpublished distribution and status information is taken from State Heritage Programs, agency biologists, and other knowledgeable individuals. The slabside pearlymussel is a Cumberlandian Region mussel, meaning it is restricted to the Cumberland (in Kentucky and Tennessee) and Tennessee (in Alabama, Tennessee, and Virginia)

River systems.

Historically, this species occurred in the lower Cumberland River main stem from about Caney Fork downstream to the vicinity of the Kentucky State line, and in the Tennessee River main stem from eastern Tennessee to western Tennessee. Records are known from two Cumberland River tributaries, Caney Fork and Red River. In addition, it is known from nearly 30 Tennessee River system tributaries, including the South Fork Powell River, Powell River, Puckell Creek, Clinch River, North Fork Holston River, Big Moccasin Creek, Middle Fork Holston River, South Fork Holston River, Holston River, French Broad River, West Prong Little Pigeon River, Tellico River, Little Tennessee River, Hiwassee River, Sequatchie River, Paint Rock River, Larkin Fork, Estill Fork, Hurricane Creek, Flint River, Limestone Creek, Elk River, Sugar Creek, Bear Creek, Duck River, North Fork Creek, Big Rock Creek, and Buffalo River. Undocumented, but now lost, populations assuredly occurred in other Cumberlandian Region tributary systems.

Populations of the slabside pearlymussel are generally considered extant (current) if live or fresh dead specimens have been collected since 1980. Currently, it is limited to nine streams in the Tennessee River system, having been extirpated (eliminated) from the Cumberland River system and from the Tennessee River main stem. This species is still known from the Powell River, Clinch River, North Fork Holston River, Big Moccasin Creek, Middle Fork Holston River, Hiwassee River, Paint Rock River, Larkin Fork, Estill Fork, Hurricane Creek, Elk River, Bear Creek, and Duck River. The slabside pearlymussel has been eliminated from about three-fifths of the total number of streams from which it was historically known. The certainty that the slabside pearlymussel occurred in other streams within its historic range increases the percentage of lost habitat and populations, thus making its present status that much more imperiled.

During historical times, the slabside pearlymussel was fairly widespread and common in many Cumberlandian Region streams based on collections made in the early 1900s. However, its decline in certain streams may have begun before European colonization. The presence of the slabside pearlymussel in several streams, particularly those in the middle Tennessee River system, is known only by records from aboriginal “kitchen middens” (archeological records of mussels used as food from several hundred to several thousand years before present). The slabside pearlymussel was considered rare by mussel experts as early as 1970 (Stansbery 1971), which represents the first attempt to compile such a list. The extirpation of this species from numerous streams within its historical range indicates that substantial population losses have occurred.

The extant occurrences in the Tennessee River system represent nine isolated populations (two or more streams are considered to represent a single population if there are no absolute barriers, such as large impoundments, separating them). Population size data gathered during the past 10 years indicates that the slabside pearlymussel is rare (experienced collectors may find 4 or fewer specimens per site of occurrence) in about half of its extant populations. Although the species is more common in other populations, it is relatively abundant in only two or three streams. Populations of the slabside pearlymussel are declining rangewide, with the possible exception of the largest populations, which may represent the only viable populations remaining.

POPULATION STATUS

There are thought to exist between 3,000 - 10,000 individuals on 10,000 - 50,000 acres (Gordon and Morrison in NatureServe Explorer 2001). According to the U.S. Fish and Wildlife Service (1999), population size data gathered during the past ten years indicates it is rare in approximately half of its extant populations. Also see Ahlstedt and Tuberville (1997). There are thought to be nine isolated populations and only abundant in two or three streams (U.S. Fish and Wildlife Service 1999).

The Alabama Natural Heritage Program ranks the slabside pearlymussel as Critically Imperiled.

The Natural Heritage Programs of both Tennessee and Virginia rank the slabside pearlymussel as Imperiled.

The U.S. Fish and Wildlife Service classifies the slabside pearlymussel as a candidate for Endangered Species Act protection with a listing priority number of 5

LISTING CRITERIA

A. ***The present or threatened destruction, modification, or curtailment of its habitat or range.***

Historical range:	Alabama, Kentucky, Tennessee, Virginia. Historically, this species occurred in the lower Cumberland River main stem from about Caney Fork downstream to the vicinity of the Kentucky State line, and in the Tennessee River main stem from eastern Tennessee to western Tennessee. Records are known from two Cumberland River tributaries, Caney Fork and Red River. In addition, it is known from nearly 30 Tennessee River system tributaries, including the South Fork Powell River, Powell River, Puckell Creek, Clinch River, North Fork Holston River, Big Moccasin Creek, Middle Fork Holston River, South Fork Holston River, Holston River, French Broad River, West Prong Little Pigeon River, Tellico River, Little Tennessee River, Hiwassee River, Sequatchie River, Paint Rock River, Larkin Fork, Estill Fork, Hurricane Creek, Flint River, Limestone Creek, Elk River, Sugar Creek, Bear Creek, Duck River, North Fork Creek, Big Rock Creek, and Buffalo River. Undocumented, but now lost, populations assuredly occurred in other Cumberlandian Region tributary systems.
Current range:	Alabama, Tennessee, Virginia. Currently, it is limited to nine streams in the Tennessee River system, having been extirpated (eliminated) from the Cumberland River system and from the Tennessee River main stem. This species is still known from the Powell River, Clinch River, North Fork Holston River, Big Moccasin Creek, Middle Fork Holston River,

Hiwassee River, Paint Rock River, Larkin Fork, Estill Fork, Hurricane Creek, Elk River, Bear Creek, and Duck River. The slabside pearlymussel has been eliminated from about three-fifths of the total number of streams from which it was historically known. The certainty that the slabside pearlymussel occurred in other streams within its historic range increases the percentage of lost habitat and populations, thus making its present status that much more imperiled.

Land ownership: The slabside pearlymussel occurs in streams that run exclusively through private lands.

The decline of the slabside pearlymussel in the Cumberlandian Region and other mussel species in the eastern United States is primarily the result of habitat loss and degradation. These losses have been well documented for over 130 years. Chief among the causes of decline are impoundments, stream channel alterations, water pollution, and sedimentation (Williams et al. 1992, Neves 1993, Neves et al. 1997). Specific information presented in this section on threats to the slabside pearlymussel and causes of its decline were gathered primarily from these published sources and other studies generally cited in their works, except where noted.

Impoundments result in the dramatic modification of riffle and shoal habitats and the resulting loss of mussel resources, especially in larger rivers. Impoundment impacts are most profound in riffle and shoal areas, which harbor the largest assemblages of mussel species, including the slabside pearlymussel. Dams interrupt most of a river's ecological processes by modifying flood pulses; controlling impounded water elevations; altering water flow, sediments, nutrients, energy inputs and outputs; increasing depth; decreasing habitat heterogeneity; and decreasing stability due to subsequent sedimentation. The reproductive process of riverine mussels is generally disrupted by impoundments making the slabside pearlymussel unable to successfully reproduce and recruit under reservoir conditions.

In addition, dams can also seriously alter downstream water quality and riverine habitat, and negatively impact tailwater mussel populations. These changes include thermal alterations immediately below dams; changes in channel characteristics, habitat availability, and flow regime; daily discharge fluctuations; increased silt loads; and altered host fish communities. Coldwater releases from large non-navigational dams and scouring of the river bed from highly fluctuating, turbulent tailwater flows have also been implicated in the demise of mussel faunas.

Population losses due to impoundments have probably contributed more to the decline of the slabside pearlymussel and other Cumberlandian Region mussels than any other single factor. The majority of the Tennessee and Cumberland River main stems and many of their largest tributaries are now impounded. For example, over 2,300 river miles (about 20 percent) of the Tennessee River and its tributaries with drainage areas of 25 square miles or greater were impounded by the Tennessee Valley Authority (TVA) by 1971 (Tennessee Valley Authority 1971). The subsequent completion of additional major impoundments on tributary streams (e.g., Duck River in 1976, Little Tennessee River in 1979) significantly increases the total miles impounded behind the 36 major dams in the Tennessee River system. Approximately 90 percent of the 562-mile length of the Cumberland River downstream of Cumberland Falls is either impounded (three locks and dams and Wolf Creek Dam), or otherwise adversely impacted by coldwater discharges from Wolf Creek Dam. Other major U.S. Army Corps of Engineers (Corps) impoundments on Cumberland River tributaries (e.g., Caney Fork) have inundated over 100 miles of potential riverine habitat for the slabside pearlymussel.

Instream gravel mining has been implicated in the destruction of mussel populations. Negative impacts associated with gravel mining include stream channel modifications (e.g., altered habitat, disrupted flow patterns, sediment transport), water quality modifications (e.g., increased turbidity, reduced light penetration, increased temperature), macroinvertebrate population changes (e.g., elimination, habitat disruption, increased sedimentation), and changes in fish populations (e.g., impacts to spawning and nursery habitat, food web disruptions) (Kanehl and Lyons 1992). Gravel mining activities threaten the slabside pearlymussel populations in the Powell and Elk Rivers in the Tennessee River system.

Heavy metal-rich drainage from coal mining and associated sedimentation has adversely impacted portions of the upper Tennessee River system in Virginia. The low pH commonly associated with mine runoff can reduce glochidial encystment rates. Acid mine runoff, thus, may be having local impacts on recruitment of the slabside pearlymussel. Mine discharge from the 1996 blowout of a large tailings pond on the upper Powell River resulted in a major fish kill (personal communication 1996 cited in U.S. Fish and Wildlife Service candidate assessment form). Powell River mussel populations were inversely correlated with coal fines in the substrate; when coal fines were present, decreased filtration times and increased movements were noted in laboratory-held mussels (Kitchel et al. 1981). In a quantitative study in the Powell River, a decline of federally listed mussels and the long-term decrease in overall species composition since about 1980 was attributed to general stream degradation due primarily to coal mining activities in the headwaters (Ahlstedt and Tuberville 1997).

Contaminants contained in point and non-point discharges can degrade water and substrate quality and adversely impact mussel populations. The effects are especially profound on juvenile mussels, which can readily ingest contaminants, and glochidia, which appear to be very sensitive to certain toxicants. Mussels are very intolerant of heavy metals, and even at low levels, certain heavy metals may inhibit glochidial attachment to fish hosts.

Sediment from the upper Clinch River has been found to be toxic to juvenile mussels (Ahlstedt and Tuberville 1997). It was speculated that the presence of toxins in the Clinch River may explain the decline and lack of mussel recruitment at some sites in the Virginia portion of that stream. Numerous streams have experienced mussel and fish kills from toxic chemical spills and other causes, particularly in the upper Tennessee River system in Virginia (Neves 1986).

Siltation and general sedimentation runoff has been implicated in the decline of stream mussel populations. Sources of silt and sediment include poorly designed and executed timber harvesting operations and associated activities; complete clearing of riparian vegetation for agricultural, silvicultural, or other purposes; and those construction, mining, and other practices that allow exposed earth to enter streams. Specific impacts on mussels from silt and sediments include clogged gills thus reducing their feeding and respiratory efficiency, impaired reproductive activity, disrupted metabolic processes, reduced growth rates, substrate instability, and the physical smothering of mussels under a blanket of silt.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

The slabside pearlymussel is not a commercially valuable species, but may be increasingly sought by collectors with its increasing rarity. Most stream reaches inhabited by this species are restricted, and its populations are small. Although scientific collecting is not thought to represent a significant threat, localized populations could become impacted and possibly extirpated by overcollecting, particularly if this activity is unregulated.

C. ***Disease or predation.***

The occurrence of disease in mussels is virtually unknown. Several mussel dieoffs have been documented during the past 20 years (Neves 1986). Although the ultimate cause is unknown, some researchers believe that disease may be a factor. Predation on the slabside pearlymussel by muskrats represents a localized threat, as determined by Neves and Odum (1989) in the upper North Fork Holston River in Virginia. They concluded that muskrat predation could limit the recovery potential of endangered mussel species or contribute to the local extirpation of already depleted mussel populations. Although other mammals (e.g., raccoon, mink) occasionally feed on mussels, the threat is not significant.

D. ***The inadequacy of existing regulatory mechanisms.***

The States of Alabama, Kentucky, Tennessee, and Virginia prohibit the taking of mussels for scientific purposes without a State collecting permit. However, enforcement of this permit requirement is difficult. Furthermore, State regulations do not generally protect mussels from other threats. Existing authorities available to protect riverine ecosystems, such as the Clean Water Act (CWA), administered by the Environmental Protection Agency (EPA) and the Corps, may not have been fully utilized. This may have contributed to the general habitat degradation apparent in riverine ecosystems and loss of populations of aquatic species in the Southeast. Although the slabside pearlymussel coexists with federally listed mussels and fishes throughout most of its range, listing under the Endangered Species Act (Act) would provide additional protection. Federal permits would be required to take the species, and Federal agencies would be required to consult with the Service when activities they fund, authorize, or carry out may adversely affect the species.

Current Conservation Efforts: The CWA has greatly reduced point discharge pollutants into streams and provides ways and means of addressing non-point source pollution as well. Partnering with State and Federal agencies and the coal industry, The Nature Conservancy (TNC) is addressing the complex issue of abandoned mine lands, which may continue to impact slabside pearlymussel populations, by working on the Coal Re-mining Initiative.

Numerous stakeholders have realized that restoring and protecting riparian habitat improves water quality and is crucial for mussels. The Asheville U.S. Fish and Wildlife Service Field Office has worked with other FWS offices, TNC, and other stakeholders to initiate several watershed-based riparian habitat restoration projects on streams having diverse aquatic faunas within the Cumberlandian Region. Streams that harbor extant populations of the slabside pearlymussel and are the focus of these riparian restoration efforts include the upper Clinch River, Tennessee and Virginia, and the Paint Rock River, Alabama and Tennessee. TNC also has selected the upper Clinch River, which has more species at risk mussels and fishes than any other small watershed in North America, as one of eight critical watersheds nationwide for protecting aquatic biodiversity (Master et al. 1998).

TNC has designated the community-based project on the Clinch River a bioreserve. Local citizens with water quality concerns for that watershed, which has a fairly large, but declining, population of the slabside pearlymussel have established the Paint Rock River Initiative (PRRI). By working closely with key partners (e.g., Resource Conservation and Development Councils, Natural Resources Conservation Service (NRCS), etc.), riparian habitat restoration activities conducted by the U.S Fish and Wildlife Service and TNC are proceeding in high-biodiversity watersheds in the Cumberlandian Region.

On-the-ground efforts that have helped improve riverine habitat in Bioreserves and other watershed-based riparian restoration projects include reducing erosion by stabilizing streambanks and using no-till agricultural methods, controlling nutrient enrichment by carefully planning heavy livestock use areas, establishing buffer zones by erecting fencing and revegetating riparian areas, and developing alternative water supplies for livestock.

A new project on the Duck River (a Tennessee River tributary in Tennessee), which harbors a sizable, but localized population of the slabside pearlymussel, includes a stress analysis. Designed to function as a foundation for a holistic riparian habitat restoration program, priority reaches of high-quality habitat can be focused upon for restoration activities once a stress analysis has been completed and accompanying mussel survey information has been compiled.

Water and stream habitat quality improvements have made it possible for mussel populations to expand in some river reaches and may lead to augmenting depleted or reintroducing extirpated mussel populations in other streams.

State and Federal agencies and the scientific community have cooperatively developed mussel propagation and reintroduction techniques and conducted associated research that has facilitated the reintroduction of mussels into historical habitats. A proposed rule to reintroduce 16 federally listed mussel species and one aquatic snail to the remaining habitat of the site below Wilson Dam is currently under review. The slabside pearlymussel also historically occurred at this site. Certain Cumberlandian Region streams with records of the slabside pearlymussel receive a level of State protection from being designated outstanding resource waters.

Habitat for the slabside pearlymussel has benefitted from cooperating landowners in the habitat restoration projects on the Clinch River Bioreserve and the Paint Rock River. If listed, the slabside pearlymussel should become more of a focus organism in project watersheds.

E. ***Other natural or manmade factors affecting its continued existence.***

The remaining populations of the slabside pearlymussel are generally small and geographically isolated. The patchy distribution pattern of populations in short river reaches makes them much more susceptible to extirpation from single catastrophic events, such as toxic chemical spills. Such a spill that occurred in the upper Clinch River in 1998 killed thousands of mussel specimens of several species, including three federally listed species. Furthermore, this level of isolation makes natural repopulation of any extirpated population impossible without human intervention.

Population isolation prohibits the natural interchange of genetic material between populations, and small population size reduces the reservoir of genetic diversity within populations, which can lead to inbreeding depression (Avise and Hamrick 1996). It is likely that some populations of the slabside pearlymussel are below the effective population size (Soulé 1980) required to maintain long-term genetic and population viability.

The present distribution and status of the slabside pearlymussel in the Tennessee River system may be indicative of the detrimental bottleneck effect resulting when the effective population size is not attained. A once large population of this species occurred throughout much of the lower two-thirds of the Tennessee River main stem and in several larger tributary systems. In this region, there were no absolute barriers to genetic interchange among its tributary sub-populations and those of its host fishes that occurred in various streams. With the completion of numerous main stem Tennessee River dams during primarily the first half of this century, the main stem population was soon extirpated, and the remaining populations isolated. Whereas small isolated tributary populations of imperiled short-lived species (e.g., most fishes) would have theoretically died out within a decade or so after impoundment, the long-lived slabside pearlymussel would potentially take decades to expire post-impoundment.

Without the level of genetic interchange the species experienced historically (i.e., without the reservoir barrier), many small isolated populations that are now comprised predominantly of adult specimens may be slowly dying out. However, the degradation of these isolated stream reaches resulting in ever decreasing patches of suitable habitat is the major contributing factor to the decline of the slabside pearlymussel.

REFERENCES

Ahlstedt, S.A. and J.M. Tuberville. 1997. Quantitative reassessment of the freshwater musselfauna in the Clinch and Powell Rivers, Tennessee and Virginia. Pp. 72-97 In: K.S.

Cummings, A.C. Buchanan, C.A. Mayer, and T.J. Naimo, eds. Conservation and management of freshwater mussels II: initiatives for the future. Proceedings of a UMRCC symposium, 16-18 October 1995, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Avise, J.C. and J.L. Hamrick, eds. 1996. Conservation genetics: case histories from nature. Chapman and Hall, New York.

Gordon, M.E. and J.B. Layzer. 1989. Mussels (Bivalvia: Unionoidea) of the Cumberland River: review of life histories and ecological relationships. U.S. Fish and Wildlife Service Biological Report 89(15). 99 pp.

Gordon, M.E. and M. Morrison in NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

Kanehl, P. and J. Lyons. 1992. Impacts of in-stream sand and gravel mining on stream habitat and fish communities, including a survey on the Big Rib River, Marathon County, Wisconsin. Wisconsin Department of Natural Resources Research Report 155. 32 pp.

Kitchel, H.E., J.C. Widlak, and R.J. Neves. 1981. The impact of coal-mining waste on endangered mussel populations in the Powell River, Lee County, Virginia. Unpublished Report to the Virginia State Water Control Board, Richmond. 26 pp.

Master, L.L., S.R. Flack, and B.A. Stein, eds. 1998. Rivers of life: critical watersheds for protecting freshwater biodiversity. The Nature Conservancy, Arlington, Virginia. 71 pp.

Neves, R.J. 1986. Recent die-offs of freshwater mussels in the United States: an overview. Pp. 7-18 In: R.J. Neves, ed. Proceedings of the workshop on die-offs of freshwater mussels in the United States, 23-25 June 1986, Davenport, Iowa. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Neves, R.J. 1993. A state-of-the unionid address. Pp. 1-10 In: K.S. Cummings, A.C. Buchanan, and L.M. Koch, eds. Conservation and management of freshwater mussels. Proceedings of a UMRCC symposium, 12-14 October 1992, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois..slabside pearlymussel - *Lexingtonia dolabelloides* 2001 CNOR Page 12

Neves, R.J. and M.C. Odom. 1989. Muskrat predation on endangered freshwater mussels in Virginia. Journal of Wildlife Management 53(4):934-941.

Neves, R.J., A.E. Bogan, J.D. Williams, S.A. Ahlstedt, and P.W. Hartfield. 1997. Status of aquatic mollusks in the southeastern United States: a downward spiral of diversity. Pp. 43-85 In: G.W. Benz and D.E. Collins, eds. Aquatic fauna in peril: the southeastern perspective. Special Publication 1, Southern Aquatic Research Institute, Chattanooga, Tennessee.

Parmalee, P.W. and A.E. Bogan. 1998. The freshwater mussels of Tennessee. The University of Tennessee Press, Knoxville. 328 pp.

Shute, P.W., R.G. Biggins, and R.S. Butler. 1997. Management and conservation of rare aquatic resources: a historical perspective and recommendations for incorporating ecosystem management. Pp. 445-466 In: G.W. Benz and D.E. Collins, eds. Aquatic fauna in peril: the southeastern perspective. Special Publication 1, Southern Aquatic Research Institute, Chattanooga, Tennessee.

Soulé, M.E. 1980. Threshold for survival: maintaining fitness and evolutionary potential. Pp. 151-169 In: M.E. Soulé and B.A. Wilcox, eds. Conservation biology. Sinauer Associates, Inc., Sunderland, Massachusetts.

Stansbery, D.H. 1971. Rare and endangered molluscs in the eastern United States. Pp. 5-18 In: S.E. Jorgensen and R.W. Sharpe, eds. Proceedings of a Symposium on Rare and Endangered Mollusks (Naiads) of the United States. U.S. Fish and Wildlife Service, Twin Cities, Minnesota.

Tennessee Valley Authority. 1971. Stream length in the Tennessee River Basin. Unpublished Report. Tennessee Valley Authority, Knoxville, Tennessee. 25 pp.

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P.M. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione, and J.D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks, 2nd edition. American Fisheries Society, Special Publication 26, Bethesda, Maryland.

U.S. Fish and Wildlife Service (USFWS). 1999. Candidate and listing priority assignment forms.

Williams, J.D., M.L. Warren, Jr., K.S. Cummings, J.L. Harris, and R.J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18 (9): 6-22.

Winston, M.R. and R.J. Neves. 1997. Survey of the freshwater mussel fauna of unsurveyed streams of the Tennessee River drainage, Virginia. Banisteria 10:3-8

PETITION TO LIST

Ogden Deseret mountainsnail
(*Oreohelix peripherica wasatchensis*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 2/28/96:	C
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

The taxonomic status of the Ogden Deseret mountainsnail, *Oreohelix peripherica wasatchensis* (Oreohelicidae), as a valid subspecies is uncontroversial (e.g., NatureServe Explorer 2001).

NATURAL HISTORY

This snail is found in leaf litter within a small maple grove in a quartzite boulder area. It does not occur over limestone substrate at the periphery of its habitat, only among quartzite boulders. There is no record of the species occurring outside of its current habitat.

The Ogden Deseret mountainsnail is known from a single population near the mouth of Ogden Canyon adjacent to the City of Ogden, Weber County, Utah. The main habitat of this subspecies covers an area approximately 20 feet wide by 80 feet long.

POPULATION STATUS

The entire population of this snail is estimated at between 3,000 and 10,000 individuals.

The Utah Natural Heritage Program ranks the Ogden Deseret mountainsnail as Critically Imperiled.

The U.S. Fish and Wildlife Service classifies the Ogden Deseret mountainsnail as a candidate for endangered species protection with a listing priority number of 9.

LISTING CRITERIA:

A. ***The present or threatened destruction, modification, or curtailment of its habitat or range.***

Historical range:	Near the mouth of Ogden Canyon adjacent to the City of Ogden, Weber County, Utah.
Current range:	The Ogden Deseret mountainsnail is known from a single population near the mouth of Ogden Canyon adjacent to the City of Ogden, Weber County, Utah.
Land ownership:	This snail's habitat is part National Forest and part private land.

The colony is at the edge of a residential area. Fires occur with moderate frequency in forests close to residential areas, and a fire would probably destroy the colony. Electric power transmission and water lines are directly adjacent to the population. The area around this snail's habitat receives heavy recreational use.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

None known.

C. ***Disease or predation.***

None known.

D. ***The inadequacy of existing regulatory mechanisms.***

Invertebrates are not protected by any Utah State law or regulation. The habitat is on the boundary of the Wasatch-Cache National Forest. The portion of the population on the National Forest would receive administrative protection from the Forest Service.

Current Conservation Efforts: None.

E. ***Other natural or manmade factors affecting its continued existence.***

Because this snail has an extremely small and restricted population, it is vulnerable to any detrimental stochastic event which may destroy the its habitat or population, such as disease affecting either the species directly or the maple forest comprising its habitat.

REFERENCES:

Clarke, A. 1993. Final Report: Status Survey of Fifteen Species and Subspecies of Aquatic and Terrestrial Mollusks from Utah, Colorado, and Montana. U.S. Fish and Wildlife Service Contract No. 14-16-0006-91-046 (Revised).

NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Ecology and Life History 1997. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

PETITION TO LIST

fat-whorled pondsnail
(*Stagnicola bonnevillensis*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 11/15/94:	
CNOR 2/28/96:	C
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

The taxonomic status of the fat-whorled pondsnail, *Stagnicola bonnevillensis* (Lymnaeidae), as a valid species is uncontroversial (e.g., Turgeon et al. 1998). In its candidate species list, the U.S. Fish and Wildlife Service incorrectly spells the specific epithet for this species with just a single "l". This species is also known as the Bonneville pondsnail (this name is used in the U.S. Fish and Wildlife Service candidate species list), but Turgeon et al. (1998) list "fat-whorled pondsnail" as the accepted common name.

NATURAL HISTORY

This snail is found only in four pools north of the Great Salt Lake in Box Elder County, Utah. It is known historically from Utah Lake and springs adjacent to the lake. The four pools where this species lives are all spring-fed, occupy areas of between 0.25 and 1 acre, have diverse substrates (mud, gravel, and/or rocks), and are well-vegetated.

POPULATION STATUS

In the early 1990s, Clarke reported that populations appeared healthy. Population estimates based on average densities and area occupied were about one million snails at one site, and more than one million snails at two other sites.

The Utah Natural Heritage Program ranks the fat-whorled pondsnail as Critically Imperiled.

The U.S. Fish and Wildlife Service classifies the fat-whorled pondsnail as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA:

A. ***The present or threatened destruction, modification, or curtailment of its habitat or range.***

Historical range:	Utah. Four pools north of the Great Salt Lake in Box Elder County, Utah, as well as Utah Lake and springs adjacent to the lake.
Current range:	Utah. Four pools (three spring-pool systems) within a three mile area north of the Great Salt Lake in Box Elder County, Utah The species currently occupies less that 10 percent of its historical habitat near the Great Salt Lake.
Land ownership:	Owners of the pools include the.

The species is vulnerable to any modification of its aquatic habitat. In Utah's arid climate, water is precious and the owners of the springs may decide to divert the water for other uses. Two species from the same regional habitat, *Stagnicola utahensis* and *S. pilsbry*i, have become extinct presumably due to degradation of pond and lake habitats in northern and northwestern Utah. A third species, *Valvata utahensi*s, has been extirpated from similar habitat in Utah. *Stagnicola bonnevillensis* is subject to the same threats which caused the extinction or extirpation of the above species.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

None.

C. ***Disease or predation.***

It is possible that the ponds may be improved for fishing and the game fish introduced would probably cause the eradication of this species. Waterfowl are also very effective snail predators.

D. ***The inadequacy of existing regulatory mechanisms.***

Snails were recently included in the Utah Division of Wildlife Resources' (DWR) list of species of management responsibility. The Utah DWR has designated *Stagnicola bonnevillensis* as a sensitive species.

Current Conservation Efforts: Currently there are no management plans or conservation agreements for this species.

E. ***Other natural or manmade factors affecting its continued existence.***

The extremely restricted range of this species makes it highly vulnerable to any stochastic event which may destroy the current habitat or population.

REFERENCES:

Clarke, A. 1991. Final Report: Status Survey of Selected Land and Freshwater Gastropods in Utah. U.S. Fish & Wildlife Service contract No. 14-16-0006-89-021 (Revised).

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P.M. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione, and J.D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks, 2nd edition. American Fisheries Society, Special Publication 26, Bethesda, Maryland.

PETITION TO LIST

interrupted rocksnail
(*Leptoxis foremani = downiei*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 11/21/91:
CNOR 11/15/94:
CNOR 10/25/99: C
CNOR 10/30/01: C
CNOR 06/13/02: C

TAXONOMY

The U.S. Fish and Wildlife Service lists "*Leptoxis downei*" on its candidate species list. According to Burch (1989), the correct spelling of the specific epithet is actually "*downiei*", but in any case *L. downiei* is a synonym of *L. foremani* (Burch 1989), the valid name for this taxon (Turgeon et al. 1998). The candidate species list uses the common name "Georgia rocksnail", but Turgeon et al. (1998) list "interrupted rocksnail" as the accepted common name. This snail is in the family Pleuroceridae.

NATURAL HISTORY

The interrupted rocksnail is a small to medium sized freshwater snail. It lives attached to bedrock, boulders, cobble, and gravel, and tend to move little, except in response to changes in water level. It is believed to lay its adhesive eggs within the same habitat (Goodrich 1922).

Rocksnails live in shoals, riffles, and reefs of small to large rivers. Their habitats are generally subject to moderate currents during low flows and strong currents during high flows.

The interrupted rocksnail occurred historically in the upper Coosa River drainage of Alabama and Georgia. Numerous snail surveys have been recently conducted within the historical range of the Georgia rocksnail (Davis 1974; M. Pierson, Field Records 1991-1998, Calera, Alabama, *in litt.* cited in U.S. Fish and Wildlife Service candidate assessment form; Bogan and Pierson 1993; Williams and Hughes 1998; Jim Godwin, Alabama Natural Heritage Program *in litt*. 1998 cited in U.S. Fish and Wildlife Service candidate assessment form). These survey efforts resulted in the collection of only a single live specimen from the Oostanaula River, Floyd County, Georgia, during 1997 (Williams and Hughes 1998).

Intensive surveys of the Oostanaula, Coosa, and Conasauga Rivers in 1999 identified two small populations in a 5-mile reach of the Oostanaula River upstream of the Gordon/Floyd County line (Johnson and Evans 2000). Numbers within these populations have been measured at up to 129 snails per square meter (personal communication 2000 cited in U.S. Fish and Wildlife Service candidate assessment form).

POPULATION STATUS

The interrupted rocksnail has disappeared from virtually its entire historic range. This dramatic curtailment of range is primarily attributed to the construction of dams and to pollution.

The U.S. Fish and Wildlife Service classifies the interrupted rocksnail as a candidate for Endangered Species Act protection with a listing priority number of 5.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range:	Alabama, Georgia. The interrupted rocksnail was historically found in the Coosa River in Cherokee, Etowah, and St. Clair Counties, and in Terrapin Creek in Cherokee County, Alabama; Coosa and lower Etowah Rivers in Floyd County, Georgia; Oostanaula River in Floyd and Gordon counties, and the Conasauga River in Gordon, Whitfield, and Murray Counties, Georgia (Goodrich 1922). The snail was found in colonies on reefs and shoals.
Current range:	Georgia. Oostanaula River, Floyd County, Georgia.
Land ownership:	Watersheds flowing into the Oostanaula River are primarily privately owned.

About 50 percent (161 kilometers (100 miles)) of the interrupted rocksnail's historic habitat is affected by dams. Rivers impounded by dams have reduced water velocities, allowing sediments to accumulate on river channel habitats behind dams. Impounded waters also experience changes in water chemistry, which can affect survival or reproduction of riverine snails. For example, reservoirs in the Coosa River drainage currently experience some level of eutrophic (enrichment of a water body with nutrients) conditions (Alabama Department of Environmental Management (ADEM) 1994, 1996). The Georgia rocksnail requires highly oxygenated moving waters and clean rock bottoms to survive and reproduce. The physical and chemical changes to water and habitat resulting from impoundment affects feeding, respiration, and reproduction of the interrupted rocksnail.

Prior to the passage of the Clean Water Act and the adoption of State water quality criteria, water pollution may have been a significant factor in the disappearance of interrupted rocksnail populations from unimpounded portions of river channels. For example, Hurd (1974) noted the extirpation of freshwater mussel communities from the Conasauga River below Dalton, Georgia, apparently as a result of textile and carpet mill waste discharges. He also attributed the disappearance of the mussel fauna from the Etowah River and other tributaries of the Coosa River, to organic pollution and siltation. Short-term and long-term impacts of point and non-point source water and habitat degradation continue to be a primary concern for the survival of the interrupted rocksnail. Point source discharges and land surface runoff (non-point pollution) can cause nutrification, decreased dissolved oxygen concentration, increased acidity and conductivity, and other changes in water chemistry that are likely to seriously impact aquatic snails. Point sources of water quality degradation include municipal and industrial effluents.

Non-point source pollution from land surface runoff can originate from virtually all land use activities, and may include sediments, fertilizers, herbicides, pesticides, animal wastes, septic tank and gray water leakage, and oils and greases. During recent mollusk surveys of the upper Coosa River system, sediment deposition and other forms of pollution were identified as causes of habitat degradation (Williams and Hughes 1998).

Excessive sediments impact riverine snails requiring clean, hard shoal stream and river bottoms, by making the habitat unsuitable for feeding or reproduction. Similar impacts resulting from sediments have been noted for many other components of aquatic communities. For example, sediments have been shown to abrade and/or suffocate periphyton (organisms attached to underwater surfaces, upon which snails may feed); affect respiration, growth, reproductive success, and behavior of aquatic insects and mussels; and affect fish growth, survival, and reproduction (Waters 1995). Field observations indicate that the Coosa rocksnail is limited by fine sediment deposition in the shoals where it survives (personal communication 2000 cited in U.S. Fish and Wildlife Service candidate assessment form). Potential sediment sources within a watershed include virtually all activities that disturb the land surface. Portions of the Oostanaula River drainage are affected to varying degrees by sedimentation.

Land surface runoff also contributes the majority of human-induced nutrients to water bodies throughout the country. Excessive nutrient input (from fertilizers, sewage waste, animal manure, etc.) can result in periodic low dissolved oxygen levels that are detrimental to aquatic species (Hynes 1970). Nutrients also promote heavy algal growth that may cover and eliminate clean rock or gravel habitats of shoal dwelling snails. Nutrient and sediment pollution may have synergistic effects (a condition in which the toxic effect of two or more pollutants is much greater than the sum of the effects of the pollutants when operating individually) on freshwater snails and their habitats, as has been suggested for aquatic insects (Waters 1995).

B. *Overutilization for commercial, recreational, scientific, or educational purposes.*

The interrupted rocksnail has no commercial value, and overutilization has not been a problem. However, unregulated collecting by private and institutional collectors could pose a threat due to the species' rarity.

C. ***Disease or predation.***

Aquatic snails are consumed by various vertebrate predators, including fishes, mammals, and possibly birds. Predation by naturally occurring predators is a normal aspect of the population dynamics of a species and is not considered a threat to this species.

D. ***The inadequacy of existing regulatory mechanisms.***

There is currently no information on the sensitivity of the interrupted rocksnail to common industrial and municipal pollutants. Current State and Federal regulations regarding such discharges are assumed to be protective; however, this snail species may be more susceptible to some pollutants than test organisms currently used in bioassays. A lack of adequate research and data currently may prevent existing laws, such as the Clean Water Act, administered by the Environmental Protection Agency and the Army Corps of Engineers, from being fully utilized.

Lacking State or Federal recognition, the interrupted rocksnail is not currently given any special consideration under other environmental laws when project impacts are reviewed.

Current Conservation Efforts: Extensive survey activity for mollusks has occurred throughout the upper Coosa River drainage. Entities currently conducting studies (U.S. Geological Survey, Southeast Aquatic Research Institute (SARI), etc.) are aware of the rediscovery of the species and are actively searching for additional populations. SARI has established a captive colony for research and propagation. State and Federal regulatory agencies have been informally notified of the general location of their discovery.

E. ***Other natural or manmade factors affecting its continued existence.***

The species is known from a restricted reach of the Oostanaula River, making it vulnerable to random natural or manmade catastrophic events. Inbreeding and reduced genetic diversity may also be a problem.

REFERENCES

Alabama Department of Environmental Management (ADEM). 1996. Water quality report to Congress for calender years 1994 and 1995. Montgomery, Alabama. 144 pp.

Alabama Department of Environmental Management. 1994. Water quality report to Congress for calender years 1992 and 1993. Montgomery, Alabama. 111 pp.

Bogan, A.E. and J.M. Pierson. 1993. Survey of the aquatic gastropods of the Coosa River Basin, Alabama: 1992. Alabama Natural Heritage Program. Contract Number 1923.

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

Davis, G.M. 1974. Report on the rare and endangered status of a selected number of freshwater Gastropoda from southeastern U.S.A. Report to the U.S. Department of Interior, Fish and Wildlife Service, Washington, D.C. 51 pp. 25 maps.

Goodrich, C. 1922. The Anculosae of the Alabama River Drainage. Miscellaneous Publications, Museum of Zoology, University of Michigan (7):1-57.

Hurd, J.C. 1974. Systematics and zoogeography of the unionacean mollusks of the Coosa River drainage of Alabama, Georgia, and Tennessee. Ph.D. Dissertation, Auburn University, Auburn, AL. 240 pp.

Hynes, H.B.N. 1970. The Ecology of Running Waters. University of Toronto Press, Toronto.

Johnson, P. D. and R.R. Evans. 2000. A contemporary and historical database of freshwater mollusks in the Conasauga River Basin. Report to USGS. SARI, Cohutta, GA.

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P.M. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione, and J.D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks, 2nd edition. American Fisheries Society, Special Publication 26, Bethesda, Maryland.

Waters, T.F. 1995. Sediment in streams: sources, biological effects, and control. American Fisheries Society Monograph 7. 251 pp.

Williams, J.D. and M.H. Hughes. 1998. Freshwater mussels of selected reaches of the main channel rivers in the Coosa drainage of Georgia. U.S. Geological Survey report to U.S. Army Corps of Engineers, Mobile District. 21 pp. and appendices.

PETITION TO LIST

sisi
(*Ostodes strigatus*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 11/15/94:	
CNOR 2/28/96:	C
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

The taxonomic status of *Ostodes strigatus* (Neocyclotidae) as a valid species is uncontroversial (e.g., Bishop Museum 2001). The U.S. Fish and Wildlife Service lists this species in the family "Potaridae" in its candidate species list. However, this family name (which should actually be spelled "Poteriidae") is a junior synonym for Neocyclotidae (e.g., Bishop Museum 2001).

NATURAL HISTORY

There is nothing known about the life history or ecology of this species, but it can be assumed that this snail feeds on decaying leaf litter and fungus, and probably deposits eggs into leaf litter where they develop and hatch.

The snails are found to be highly scattered in the leaf litter on the forest floor under an intact canopy of 10-15 m above the ground.

Based on extensive material in the Bishop Museum that was collected mostly in the first half of the twentieth century, particularly during an expedition in 1926, it appears that this snail was at one time widespread and abundant on Tutuila. In 1975, it was still widespread and not considered threatened (Solem, 1975). Survey work in 1992 (Miller, 1993; Miller et al., 1993a, b) found live snails at only a single locality.

POPULATION STATUS

During a recent survey of snails in American Samoa (Miller 1993), fewer than 50 live snails were seen. Several live predatory snails, *Euglandina rosea* , were found in the same area, and the ground was littered with the shells of dead *Ostodes strigatus*. Shells of *Ostodes strigatus* were found at all of the survey sites visited on the island of Tutuila, American Samoa.

There is very little data that can be used to assess long-term temporal changes in the snail fauna of American Samoa. However, qualitative comparisons can be made between a 1993 survey (Miller 1993) and surveys conducted in 1975 (Solem 1975 and Christensen 1980). Of the 15 endemic species recorded alive in 1975, living individuals of five species and the shells of two additional species were seen in 1993. This qualitative comparison plus the more recent survey data indicate that the native snail fauna has declined dramatically and that *Ostodes strigatus* and several other terrestrial and arboreal species are on the verge of extinction. A current estimate of the number of *Ostodes strigatus* remaining on Tutuila is fewer than 200. The declines of the native snails in American Samoa have resulted from: (1) predation by introduced snails and rats; (2) loss of habitat to forestry and agriculture; and (3) loss of forest structure to hurricanes and alien weeds that establish after these storms. These threats may interact to greatly exacerbate the loss of populations and species. Currently, the introduced predatory snail *Euglandina rosea* and the loss of low and mid-elevation habitat to agriculture are thought to be the major causes of decline in *Ostodes strigatus.*

The U.S. Fish and Wildlife Service classifies the sisi as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range:	American Samoa (island of Tutuila). The historic range is confined to the island of Tutuila, in particular, the "western portion of island: center and south-east edge of central plateau, extreme southern coast, mountain slope near (just south of) Pago Pago" (Garardi, 1978).
Current range:	American Samoa (island of Tutuila). Maloata Valley (37-122 m elevation) on the western end of the island of Tutuila, American Samoa.
Land ownership:	Land ownership in American Samoa generally follows a historic village tradition. Large sections of land around each village is controlled by that village for the use of the village residence. The Maloata population of *Ostodes strigatus* is within the bounds of Maloata Village.

Loss of habitat to agriculture and to storms has greatly reduced the native habitat of Samoan snails. All live *Ostodes strigatus* found in a recent survey were in the leaf litter beneath remaining intact forest canopy. No snails were found in areas bordering agricultural plots or in forest areas that were severely damaged by three recent hurricanes (1987, 1990 and 1991). Under natural historic conditions, loss of forest canopy to storms did not pose a great threat to the long-term survival of these snails; enough intact forest with heathy populations of snails would support dispersal back into newly regrown canopy forest.

Several other species of snails native to American Samoa were either not seen or were seen in low numbers during the 1993 survey (Miller 1993). Several large arboreal snail species (*e.g.*: *Diastole schmeltziana* , *Trochomorpha apia, Eua zebrina, Samoana conica,* and *Samoana abbreviata*) and large terrestrial snails such as *Pythia scarabaeus* were also rare or absent throughout the island of Tutuila. Shells of many of these species were found in abundance at all of the surveyed locations on Tutuila, often accompanied by shells or live individuals of *Euglandina rosea* .

However, the presence of alien weeds such as mile-a-minute vine (*Mikania micrantha*) and weedy tree species such as *Funtumia elastica*, may reduce the likelihood that native forest will re-establish in areas damaged by the hurricanes (Whistler 1992). This loss of habitat to storms is greatly exacerbated by an expanding agriculture needed to support one on the world's highest human population growth rates (Craig et al. 1993). Agricultural plots have spread from low elevation up to middle and some high elevations on all the islands, greatly reducing the forest area and thus reducing the resilience of native forests and its populations of native snails. These reductions also increase the likelihood that future storms will lead to the extinction of populations or species that rely on the remaining canopy forest.

B. *Overutilization for commercial, recreational, scientific, or educational purposes.*

These snails are not currently subjected to use by humans.

C. *Disease or predation.*

The alien giant African snail, *Achatina fulica* , was introduced into American Samoa prior to 1977. This snail is a crop pest and an intermediate host of the rat lung worm, *Angiostrongylus cantonensis*, which can cause human eosinophilic meningoencephalitis (Alicata 1962 and Mead 1979). The most frequently recommended biological control agent of the giant African snail is the predatory snail *Euglandina rosea.* However, *E. rosea* is also a host to the rat lung worm (Wallace and Rosen 1969) and occupies a wider range of habitats than does the giant African snail (van der Schalie 1969 and Mead 1961), potentially spreading the rat lung worm through a wider area. It is not known if the parasite can be maintained in populations of native snails or if a parasite load would have negative effects on snail reproduction.

In an effort to eradicate the giant African snail, *Euglandina rosea* and another alien predatory snail, *Gonaxis kibweziensis* , were introduced in 1980 and 1977, respectively (Eldredge 1988). *Achatina fulica* and *E. rosea* have spread throughout the main island of Tutuila and have also spread to the island of Ta'u. By 1984, *E. rosea* was considered to be well established on Tutuila (Eldredge 1988). *Gonaxis kibweziensis* is present only Tutuila and seems to be in decline (Eldredge 1988).

After an initial increase lasting up to several years, populations of giant African snails typically go into decline (Mead 1961). Available data do not definitively show that.reductions in population size are due to predation by carnivorous snails (Mead 1961, Hadfield and Kay 1981, Christensen 1984, and Eldredge 1988). In fact, *Euglandina rosea* is probably not of great importance as a predator of giant African snails (Mead 1961), preferring instead to feed on small snails (Cook 1989 and Griffiths et al. 1993), which include most of the native snails on the Pacific islands to which it has been introduced.

The lack of evidence for predatory control of the giant African snail has unfortunately not stopped the intentional spread of snail predators like *E. rosea* into and throughout the Pacific basin, although numerous studies show that *E. rosea* feeds on endemic island snails and is a major agent in their declines and extinctions (van der Schalie 1969, Hart 1978, Howarth 1983, 1985,and 1991, Clarke et al. 1984, Pointier and Blanc 1984, Murray et al. 1988, Hadfield and Mountain 1981, Hadfield 1986, Hadfield et al. 1989, 1993, and Kinzie 1992). At present, the major threat to long-term survival of the native snail fauna in American Samoa is predation by *Euglandina rosea* .

D. ***The inadequacy of existing regulatory mechanisms.***

Currently, no formal or informal protection is given to *Ostodes strigatus* by the Federal or American Samoa governments or by private individuals or groups.

Current Conservation Efforts: None.

E. ***Other natural or manmade factors affecting its continued existence.***

Random environmental events can affect the continued existence of *Ostodes strigatus* due to the small numbers of populations and individuals that remain. Random environmental events such as hurricanes and droughts could remove some or all of the remaining populations.

REFERENCES

Alicata, J.E. 1962. *Angiostrongylus cantonensis* (Nematoda: Metastronglidae) as a causative agent of eosinophilic meningitis of man in Hawaii and in Tahiti. Can. J. Zool. 40:5-8.

Bishop Museum of Honolulu. Samoan Snails Searchable Database, revised June 19, 2001. http://www2.bishopmuseum.org/PBS/samoasnail/query.asp

Christensen, C.C. 1980. Preliminary summary of the terrestrial mollusks of Tutuila, American

Samoa. B.P. Bishop Museum, unpublished report.

Christensen, C.C. 1984. Are *Euglandina* and *Gonaxis* effective agents for biological control of the giant African snail in Hawaii? American Malacol. Bull. 2:98-99.

Clarke, B.C., J.J. Murray, and M.S. Johnson. 1984. The extinction of endemic species by a program of biological control. Pacific Science 38:97-104.

Cook, A. 1989. Factors affecting prey choice and feeding technique in the carnivorous snail *Euglandina rosea* Ferrusac. J. Molluscan Stud. 155: 469-477.

Craig, P., P. Trail, G. Grant, J. Craig, and d. Itano. 1993. American Samoa: Natural History and Conservation Topics. Volume 1. Biological Report Series, Report Number 42..Department of Marine and Wildlife Resouces, American Samoa Government.

Eldredge, L.G. 1988. Case studies of the impacts of introduced animal species on renewable resources in the U.S.-affiliated Pacific islands. In: B.D. Smith (ed), Topic reviews in insular resource development and management in the Pacific U.S.-affiliated islands. University of Guam Technical Report No. 88,118-146.

Garardi, E. L. 1978. The Samoan land snail genus *Ostodes* (Mollusca: Prosobranchia: Poteriidae). Veliger 20:191-250.

Griffiths, O., A. Cook, and S.M. Wells. 1993. The diet of the introduced carnivorous snail *Euglandina rosea* in Mauritius and its implications for threatened island gastropod faunas. Journal of Zoology, London 229:79-89.

Hadfield, M.G. 1986. Extinction in Hawaiian achatinelline snails. Malacologia 27:67-81.

Hadfield, M.G. and E.A. Kay. 1981. The multiple villainies of *Euglandina rosea* (or its human proponents). Hawaiian Shell News 29:5-6.

Hadfield, M.G., S.E. Miller and A.H. Carwile. 1989. Recovery plan for the O'ahu tree snails of the genus *Achatinella* . U.S. Fish and Wildlife Service, 300 Ala Moana Blvd., Honolulu, Hawaii 96850.

Hadfield, M.G., S.E. Miller and A.H. Carwile. 1993. The decimation of endemic Hawai'ian tree snails by alien predators. Am. Zool. in press.

Hadfield, M.G. and B.S. Mountain. 1981. A field study of a vanishing species, *Achatinella mustelina* (Gastropoda, Pulmonata) in the Wai'anae Mountains of O'ahu. Pacific Sci. 34:345-358.

Hart, A.D. 1978. The onslaught against Hawaii's tree snails. Natural History. December; 46-57.

Howarth, F.G. 1983. Classical biocontrol: Panacea or Pandora's box? Proc. Hawaiian entomol. Soc. 24:239-244..Howarth, F.G. 1985. Impacts of alien land arthropods and mollusks on native plants and animals in Hawaii. In: C.P. Stone and J.M. Scott, eds., Hawaii's terrestrial ecosystems: preservation and management. Cooperative National Park Research Studies Unit, Honolulu, Hawaii. 149-179.

Howarth, F.G. 1991. Environmental impacts of classical biological control. Ann. Rev. Entomol. 36:485-509.

Kinzie, R.A. 1992. Predation by the introduced carnivorous snail *Euglandina rosea* (Ferussac) on endemic aquatic lymnaeid snails in Hawaii. Biological Conservation 60:149-155.

Mead, A.R. 1961. The giant African snail: a problem in economic malacology. University of Chicago Press. 257 pp. Mead, A.R. 1979. Economic malacology with particular reference to *Achatina fulica* . In V. Fretter and J. Peake (eds.), The Pulmonates, Vol. 2B. Academic Press, N.Y.

Miller, S.E. 1993. Final report on surveys of the arboreal and terrestrial snail fauna of American Samoa. Unpublished report to the U.S. Fish and Wildlife Service, Pacific Islands Office, Honolulu, Hawaii. 30 pp.

Murray, J.J., M.S. Johnson and B.C. Clarke. 1982. Microhabitat differences among genetically similar species of *Partula* . Evolution 36:316-325.

Murray, J.J., E. Murray, M.S. Johnson, and B.C. Clarke. 1988. The extinction of *Partula* on Moorea. Pacific Science 42:150-153.

NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

Pointier, J.D. and C. Blanc. 1984. *Achatina fulica* en Polynesie Francaise. Situation en 1982-83 en Polynesie Francaise apres l'introduction des escargots geants en 1967. Centre de l'Environment, Moorea, Rapport RA13. 42 pp.

Solem, A. 1975. Final report, Office of Endangered Species. Contract No. 14-16-0008- 837.

Van der Schalie, H. 1969. Man meddles with nature - Hawaiian style. The Biologist 51:136-146..Wallace G.D. and L. Rosen. 1969. Studies on eosinophilic meningitis. V. Molluscan hosts of *Angiostrongylus cantonensis* on Pacific islands. Am. J. Trop. Med. & Hygiene 18:206-216.

Whistler, W.A. 1992. Vegetation of Samoa and Tonga. Pacific Science 46:159-178..

PETITION TO LIST

Diamond Y springsnail
(*Tryonia adamantina*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 1/6/89:	
CNOR 11/21/91:	
CNOR 11/15/94:	
CNOR 2/28/96:	C
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

The taxonomic status of the Diamond Y springsnail, *Tryonia adamantina* (Hydrobiidae), as a valid species is uncontroversial (e.g., Turgeon et al. 1998; Hershler et al. 1999).

NATURAL HISTORY

Morphology and ecology
The Diamond Y springsnail is a very small snail, measuring only 2.9 to 3.6 millimeters (0.11 to 0.14 inches) in length. The shell is narrowly conical, with an obtuse apex and broadly rounded anterior end (Taylor 1987). Whorls are 4.75 to 5.75 in larger females, regularly convex and swollen to weakly shouldered, and separated by a deeply incised suture (Taylor 1987).

Like other hydrobiids, these snails are sexually dimorphic. They are ovoviviparous, producing live young serially (as opposed to broods) (Taylor 1985). They are presumably fine-particle feeders on detritus and periphyton associated with the substrates (mud and vegetation).

These snails are found in mud substrates on the margins of small springs, seeps, and marshes in flowing water associated with sedges and cattails (Taylor 1987).

Distribution

In the desert Southwest, aquatic snails are distributed in geographically isolated wetland populations (Hershler et al. 1999). They likely evolved into distinct species during recent dry periods from parent species that once enjoyed a wide distribution during wetter, cooler climates. Such divergence has been well documented for aquatic and terrestrial macroinvertebrate groups within arid ecosystems of western North America (e.g., Taylor 1987, Metcalf and Smartt 1997, Bowman 1981).

The Diamond Y Spring system is a tributary drainage to the Pecos River and is composed of disjunct upper and lower watercourses, separated by about a 1 kilometer (km) (.62 mile (mi)) stretch of dry stream channel. The upper watercourse starts with the Diamond Y Spring head pool and is augmented by numerous small seeps, some of which drain into the spring outflow channel. This outflow channel converges with the Leon Creek drainage and flows through a marsh-meadow, where it is then referred to as Diamond Y Draw. The total upper watercourse is.about 1.5 km (.93 mi) in length. The lower watercourse has a smaller head pool spring (Euphrasia Spring) and outflow stream and also has several isolated pools, for example, Mansanto Pool. The total lower watercourse is about 1 km (0.62 mi) in length and may extend below the State Highway 18 bridge, during wetter seasons or years.

Taylor (1985) documented the distribution and abundance of aquatic snails in the Diamond Y Spring system. At the time of this work, Fall 1984, he found Diamond Y springsnail distribution limited to the upper watercourse. It was found present at 12 of the 14 sites sampled, with density estimates ranging from 0.5 to 108 individuals per 0.1 square meter, with very low densities in the upstream areas, near the headspring. Taylor (1985) indicates the low density areas were in definite contrast to unpublished data collected by the author in 1968, when the upstream areas of the upper watercourse harbored large numbers of Diamond Y springsnails. This study also found that Gonzales springsnail was limited to only the lower watercourse in the first 30 meters (98.4 feet) of outflow from Euphrasia Spring. These findings were confirmed by Fullington (1991).

More recent surveys have found that the Diamond Y springsnail is currently found in the isolated spring seeps near the Diamond Y Spring head pool, in side seeps at the downstream end of the upper watercourse and at the immediate outflow of Euphrasia Spring in the lower watercourse (Echelle 1999). Meanwhile, Gonzales springsnail is now found only in the outflow stream of the Diamond Y head pool in the upper watercourse. This distribution is supported by observations by Dr. Robert Hershler's reporeted in Echelle (1999) (as cited in U.S. Fish and Wildlife Service candidate assessment form). The reason for the apparent reversal in distributional patterns of the two species within the Diamond Y Spring system since the surveys by Taylor (1985) is unknown.

Although the two snail species both occur in the Diamond Y Spring system, they have never been taken together at any sample locations (Taylor 1985, 1987; Echelle 1999), with the reported exception of Fullington (1991), in which both were collected from a small seep to the side of the Diamond Y Spring head pool. Taylor (1985, 1987) suggests that the reason for this mutually exclusive distribution is likely competition rather than habitat differences because the two species appear to occupy the same microhabitats, yet are spatially segregated.

POPULATION STATUS

The entire population of this species is comprised of fewer than 1,000 individuals, on fewer than 2,000 acres encompassing fewer than 10 miles of stream length (Mehlhop in NatureServe Explorer 2001).

The Texas Natural Heritage Program ranks the Diamond Y springsnail as Critically Imperiled.

The U.S. Fish and Wildlife Service classifies the Diamond Y springsnail as a candidate for Endangered Species Act protection with a listing priority number of 2. The listing priority number was increased from 5 to 2 due to new threats from the recent introduction of an exotic snail (*Melanoides* sp.) into the species' habitat.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range:	Texas.
Current range:	Texas. The snail occurs only in the Diamond Y Spring system and associated outflows in Pecos County, Texas (Taylor 1987). There is no available information to indicate whether the species' historic distribution was more extensive than it is today. Other area springs may have contained the same species, but because these springs have been dry for more than four decades there is no opportunity to determine the potential historic distribution.
Land ownership:	The land on which the snail occurs is owned and managed by The Nature Conservancy of Texas. The surrounding watershed and surface area over contributing aquifers is all privately owned.

The primary threat to this species is the potential failure of spring flow due to excessive groundwater pumping and/or drought which would result in total habitat loss for the species. Diamond Y Spring is the last major spring still flowing in Pecos County, Texas. Over-pumping of the regional aquifer system for agricultural production of crops has resulted in the drying of most other springs in this region (Brune 1981). Other springs that have already failed include Comanche Springs, which was once a large surface spring in Fort Stockton, Texas, about eight miles from Diamond Y. This spring flowed at more than 1200 liters per second (lps) (Brune 1981) and.undoubtedly provided habitat for rare species of fishes and invertebrates, including spring snails.

The spring ceased flowing by 1962 (Brune 1981). Leon Springs, located upstream of Diamond Y in the Leon Creek watershed, was measured at 500 lps in the1930s and was also known to contain rare fish, but ceased flowing in the 1950s following significant irrigation pumping (Brune 1981). There have been no continuous records of spring flow discharge at Diamond Y Spring by which to determine any trends in spring flow.

Studies by Veni (1991) and Boghici (1997) indicate that the spring flow at Diamond Y Spring comes from the Rustler aquifers located west of the spring outlets. One significant factor that influences flows at the spring is the large groundwater withdrawals for agricultural irrigation of farms to the southwest in the Belding-Fort Stockton areas. Although The Nature Conservancy of Texas owns and manages the property surrounding the Diamond Y Spring system, it has no control over groundwater use that affects spring flow. The Supreme Court of Texas has upheld the rule of capture for groundwater use in Texas. This means that property owners have the right to withdraw as much groundwater as they desire, without considering impacts to other resources or nearby landowners.

Oil and gas activities threaten this springsnail because of the potential groundwater or surface water contamination of pollutants (Veni 1991, Fullington 1991). The Diamond Y Spring system is within an active oil and gas extraction field. At this time there are still many active wells located within a hundred meters of surface waters. In addition a natural gas refinery is located within 0.8 km (0.5 mi) upstream of Diamond Y Spring. There are also old brine pits associated with previous drilling within feet of surface waters. Oil and gas pipelines cross the spring outflow channels and marshes where the species occurs, creating a constant potential for contamination from pollutants from leaks or spills. These activities could contaminate the habitat of the springsnail by allowing foreign pollutants to enter underground aquifers that may contribute to spring flow or through point sources from spills and leaks of petroleum products.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

None known.

C. ***Disease or predation.***

None known. However, the presence of an introduced species (a *Melanoides* snail) increases the potential for foreign diseases to be introduced to the species.

D. ***The inadequacy of existing regulatory mechanisms.***

Texas State law provides no protection for these invertebrate species. There are no existing Federal, State or local regulatory mechanisms providing protection for these species. The snails are afforded some protection indirectly due to the presence of two fishes (Leon Springs pupfish and Pecos gambusia) listed as endangered by State and Federal governments that occupy similar habitats. However, the snail may be more sensitive to changes in water quality than are the fish and.are likely more directly threatened by the presence of the exotic *Melanoides* snail than are the endangered fish.

Current Conservation Efforts: None

E. *Other natural or manmade factors affecting its continued existence.*

Within the last 10 years, an exotic snail, *Melanoides* sp., has become established in Diamond Y Spring (Echelle 1999, McDermott 2000). This species is by far the most abundant snail in the upper watercourse of the Diamond Y Spring system. So far it has not been detected in the lower water course (Echelle 1999). In many locations, this exotic snail is so numerous that it essentially is the substrate in the small stream channel. The effects of this introduction are not yet known. However, this exotic snail is likely competing with the native snails for space and resources. Other changes to the ecosystem from the dominance of this species are likely to occur which could have severely detrimental effects to the native invertebrate community.

REFERENCES

Boghici, R. 1997. Hydrogeological investigations at Diamond Y Springs and surrounding area, Pecos County, Texas. Unpublished Master's Thesis, University of Texas at Austin. 120 pp.

Bowman, T.E. 1981. *Thermosphaeroma milleri* and *T. smithi*, new sphaeromatid isopod crustaceans from hot springs in Chihuahua, Mexico, with a review of the genus. Journal.of Crustacean Biology. 1:105-122.

Brune, G. 1981. Springs of Texas. Branch-Smith, Inc. Fort Worth, Texas.

Echelle, A.A. 1999. Monitoring effects of a renovation project on endangered fish and invertebrates in Diamond Y Draw. Annual Performance Report, Endangered Species Program, Texas Parks and Wildlife Department, Austin, Texas. Grant No. E-1-11, Project WER47(85). 21 pp.

Fullington, R.W. 1991. Mollusca survey of Texas Nature Conservancy Preserves: Diamond Y Springs and Independence Creek. Final Report, The Nature Conservancy of Texas, San Antonio, Texas. 7 pp.

Henry, B. 1992. The macroinvertebrate community of Diamond Y Cienega, a saline spring system in Trans-Pecos, Texas. Final Report, The Texas Nature Conservancy, San Antonio, Texas. 13 pp.

Hershler, R., Hsiu-Ping Liu, and M. Mulvey. 1999. Phylogenetic relationships within the aquatic snail genus *Tryonia*: implications for biogeography of the North American Southwest. Molecular Phylogenetics and Evolution 13:377-391.

Metcalf, A.L. and R.A. Smartt. 1997. Land snails of New Mexico. New Mexico Museum of

Natural History and Science. Bulletin No. 10. 145 pp.

McDermott, K. 2000. Distribution and infection relationships of an undescribed digenetic Trematode, its exotic intermediate host, and endangered fishes in springs of west Texas. Unpublished Master's Thesis, Southwest Texas State University, San Marcos, Texas. 26+ pp.

NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

Taylor, D. W. 1985. Status survey of aquatic molluscs in Diamond Y Draw in Pecos County, Texas. Unpublished report. 27 pp.

Taylor, D. W. 1987. Fresh-water molluscs from New Mexico and vicinity. New Mexico Bureau of Mines and Mineral Resources Bulletin 116:1-50.

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P.M. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione, and J.D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks, 2nd edition. American Fisheries Society, Special Publication 26, Bethesda, Maryland.

Veni, G. 1991. Delineation and preliminary hydrologic investigation of the Diamond Y Spring, Pecos County, Texas. Final Report, The Nature Conservancy, San Antonio, Texas. 111 pp..

PETITION TO LIST

fragile tree snail, akaleha
(*Samoana fragilis*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 11/15/94:	
CNOR 2/28/96:	C
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

The taxonomic status of the fragile tree snail, *Samoana fragilis* (Partulidae), as a valid species is uncontroversial (e.g., NatureServe Explorer 2001).

NATURAL HISTORY

Ecology

As with all terrestrial pulmonate snails, the Mariana Islands tree snails are hermaphroditic. In general, partulid snails begin reproducing in less that 12 months and may live up to 5 years. Up to 18 young are produced each year and some species, such as the humped tree snail of the Mariana Islands, may be self-fertile. While most terrestrial snails lay eggs, the partulid tree snails give birth to fully developed young. The snails are generally nocturnal, living on bushes or trees and feeding on decaying plant material. There are no known natural predators of these snails, although many of these species are threatened by alien snail predators.

This species exhibits two reproductive characteristics that are unique among Mariana Islands partulids. Adults of the fragile tree snail attain sexual maturity before reaching maximum shell size (Crampton 1925), and relatively large eggs (0.17 by 0.13 in.) (4.2 by 3.3 mm) are encapsulated in a tough, calcareous shell (Crampton 1925).

The Partulidae, including those of the Mariana Islands, prefer cool, shaded forest habitats (Crampton 1925, Cowie 1992, Smith 1995) with high humidity.

Crampton (1925) described the habitat requirements of the partulid trees snails of the Mariana Islands as follows: “...the indispensable requisites are that there shall be a sufficiently high and dense growth to provide shade, to conserve moisture, and to effect the production of a rich humus. Hence the limits to the areas occupied by Partulae are set by the more ultimate ecological conditions which determine the distribution of suitable vegetation.” In fact, the ecological settings that meet the basic requirements for partulid snail were numerous in the Mariana Islands prior to World War II. They include coastal strand vegetation, forested river borders, and lowland and highland forests (Crampton 1925). Crampton (1925) further describes the intact structure of native Mariana forests as having four general levels: the high trees; the shrubs and *Pandanus* ; the cycads and taller ferns; and the succulent herbs. He notes that the Mariana Islands partulid tree snails.preferentially live on subcanopy vegetation and do not use the high canopy trees.

Distribution

The fragile tree snail is the only member of the genus *Samoana* to occur outside southeastern Polynesia. In the Mariana Islands, it has been reported from Guam and Rota. When it was first discovered, it was considered to be rare (Crampton 1925).

The fragile tree snail was first collected on Guam in 1819 by Quoy and Gaimard during the Freycinet Uranie expedition of 1817-1819 (Crampton 1925). Since the work of Crampton (1925), no significant evaluation of the fragile tree snail occurred until the 1980's and 1990's. In 1989, Hopper and Smith (1992) resurveyed 34 of Crampton's 39 sites on Guam plus 13 new sites. Crampton (1925) found the fragile tree snail at 10 of the 39 sites and collected between one and 25 snails at each site; a total of 71 individuals were collected. This snail is extremely rare in its native habitat on Guam and Rota, and the Guam population sizes were probably not much larger that the numbers reported by Crampton. Three of the 34 sites resurveyed by Hopper and Smith (1992) still supported these snails in 1989, although these three sites were not among the 10 original sites of Crampton.

Of the13 new sites surveyed by Hopper and Smith (1992), four supported small populations of fragile tree snail; one of these was eliminated in 1991-1992 by wildfires that burned into ravine forest occupied by the snails (Smith and Hopper 1994). The U.S. Fish and Wildlife Service surveyed 15 sites on the Guam Naval Magazine and located one additional population of fragile tree snail (personal communication 1996 cited in U.S. Fish and Wildlife Service candidate assessment form). All of these are small populations, as were the populations reported by Crampton (1925). The population at Haputo is currently threatened by indirect effects of a new road cut.

The fragile tree snail has also been recorded form the island of Rota in the Commonwealth of the Northern Mariana Islands. It was first reported on this island by Kondo (1970). During a 1995 snail survey of Rota, no snails of this species were seen. However, a subsequent visit in 1996 (personal communication 1996 cited in U.S. Fish and Wildlife Service candidate assessment form) located a population of less the 50 individuals below the cliff line where Kondo first reported this snail.

The three genera and 123 tree snail species of the family Partulidae are restricted to the high-elevation Pacific islands of Polynesia (excluding Hawaii), Melanesia, and Micronesia (Cowie 1992 and Paulay 1994). These snails have received increased attention in recent years due to declining numbers throughout their range and, in many cases, due to extinction (Clarke et al. 1984, Murray et al.1988, Hopper and Smith 1992, and Miller 1993). Overall, 30 percent of the 123 partulid species are extinct and 39 percent are declining toward extinction. For 31 percent of the species, the current status cannot be characterized due to insufficient information. In no case has a partulid tree snail species been shown to have stable or increasing numbers of individuals or populations (Pearce-Kelly et al. 1994).

POPULATION STATUS

The high islands of the Mariana archipelago historically supported five species of partulid tree snails. The genus *Samoana* is represented in the Mariana Islands by a single species, *Samoana fragilis*. To date, there are 8 known sites on two islands that still support populations of this species. The best estimate for the total number of remaining snails is under 300.

The Government of Guam listed this species as endangered on Guam. It is listed as "Endangered" in the1996 IUCN Red List of Threatened Animals (Baille, 1996).

The U.S. Fish and Wildlife Service classifies the fragile tree snail as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range:	Guam; Commonwealth of the Northern Mariana Islands (island of Rota).
Current range:	Guam; Commonwealth of the Northern Mariana Islands (island of Rota).
Land ownership:	All but two of the eight sites are on lands owned by private land owners. The remaining sites are on lands owned by the U.S. Military. Land ownership issues in Guam and The Commonwealth of the Northern Mariana Islands are highly controversial.

Prior to the arrival of humans, the Mariana Islands were believed to be mostly forested (Fosberg 1960, 1971). With the arrival and population growth of the aboriginal Chamorro people 4,000 years ago (Carano and Sanchez 1964), native forests began to be cleared and savanna grasslands began to develop (Mueller- Dumbois 1981). During the Spanish occupation of the Mariana Islands (1521-1899), alien goats, pigs, cattle, and deer were introduced. Extensive herds of cattle were noted on the main islands, with some herds numbering in excess of 10,000 head. Large numbers of pigs, goats and deer were also present (Engbring et al. 1986 and Carano and Sanchez 1964). In 1742, the forested areas on the island of Tinian were described as park-like and open (Engbring et al.1986 citing Anson's journal as cited by Walter 1928). These animals along with extensive logging further contributed to the expansion of savanna grasslands and directly altered the understory plant community and overall forest microclimate. All of these changes resulted in a continuing decline in area and quality of tree snail habitat.

Sweeping ecological changes took place during the Japanese occupation from 1914-1944 (Kanehira 1936, Fosberg 1960, 1971, and Engbring et al. 1986). Extensive removal of native forests for the development of sugar cane was pursued on all of the main islands. These fields covered almost all of Tinian and much of Guam, Saipan, Rota, and Aguijan. In 1920, Crampton (1925) commented on the loss of partulid tree snail habitat. He stated that much deforestation had occurred in the southern half of Guam and that the savanna grassland habitat, which is unsuitable for tree snails, had greatly expanded during "recent centuries." He also noted that extensive wood cutting had reduced the forest canopy.

During and after World War II dramatic reductions in partulid tree snail habitats (forest, riparian, and coastal strand) occurred on the islands of Guam, Tinian, and Saipan where major military operations and landings were conducted. Following the war, open agricultural fields and other areas prone to erosion were seeded with tangantangan (*Leucaena leucocephala*) by the U.S. Military (Fosberg 1960). Tangantangan grows as a single species stand with no substantial understory. The microclimatic conditions are dry, with little accumulation of leaf litter humus, and are particularly unsuitable as partulid tree snail habitat (Hopper and Smith 1992). In addition, native forest cannot reinvade and grow where this alien weed has become established (Hopper and Smith 1992). The post-war establishment and operation of large military bases has also prevented the return of native forest that could support partulid tree snails. Today on the island of Guam, the U.S. military occupies approximately 17,500 ha or 30% of the island, most (90+%) of which once was forested habitat that supported the endemic tree snails.

The native tree snail habitat on the main islands of the Commonwealth of the Northern Mariana Islands has been greatly reduced by development and agricultural activities (Engbring et al . 1986). The island of Rota was forested in 1932, but by 1935, almost all level areas had been cleared of forest to support sugar cane production and phosphate mining (Kanehira 1936). The only areas left undisturbed were too steep for agriculture, generally along the base of cliffs, which are an extensive geological feature of the island. These areas still support native limestone forests (Fosberg 1960). Aerial photos from the World War II era show parts of Rota riddled with bomb craters and other areas denuded of vegetation primarily from agricultural activity.

Following the war, much of this area was given over to cattle grazing, urban growth, and airport development. In some areas, native forest has reestablished (Engbring et al. 1986 and Falanruw 1989). In 1988, supertyphoon Roy hit Rota with winds in excess of 150 miles per hour (240 km/hr), defoliating almost all of the forested areas and downing trees, especially along the southeast and northern cliff slopes of the central Sabana (Fancy and Snetsinger 1996). Vegetation changes associated with this storm have opened up forested areas that were excellent habitat for partulid tree snails. These open forests suffer from changes in microhabitat, such as desiccation, that make the continued survival of snails unlikely.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

Overutilization is not known to be a factor currently affecting any of the partulid tree snails from the Mariana Islands. Future overutilization of this species is not anticipated. However, necklaces or leis made from partulid snails shells are occasionally found for sale. Any collecting of the fragile tree snail could significantly contribute to the continued decline of the species and the local extinction of specific populations.

C. ***Disease or predation.***

Crampton (1925) states that "There are no other animals in the Mariana Islands whose presence or activities influence the lives or numbers of Partulae, so far as observation goes." Since World War II, several introductions of alien predators have completely changed this historic condition. Predation by the alien rosy glandina snail (*Euglandina rosea*) and the alien Manokwar flatworm (*Platydemis manokwari*) is a serious threat to the survival of all four species of partulid tree snails from the Mariana Islands. The predatory rosy glandina snail is native to the southeastern United States, and was introduced into the Mariana Islands in 1957 by the governments of Guam and the Commonwealth of the Northern Mariana Islands, following the recommendations of the State of Hawaii Department of Agriculture (Eldredge 1988). Since being introduced, this voracious predator of snails has been dispersed by humans throughout the main islands. The rosy glandina snail was imported to these and other Pacific islands as a biological control agent for another alien snail, the giant African snail (*Achatina fulica*), which is an agricultural pest. However, while its effectiveness as a biological control agent against the giant African snail is questionable (Christiansen 1984, Tillier and Clarke 1983, and Mead 1961), field observations have established that the rosy glandina snail will readily feed on native Pacific island tree snails, including the Partulidae such as those of the Mariana Islands (Murray et al. 1988, Tillier and Clarke 1983, and Miller 1993) as well as Hawaiian achatinellid tree snails (Hadfield et al. 1993).

A study of the diet of the rosy glandina snail on the island of Mauritius in the Indian Ocean showed that this alien predator preferred native snails over the targeted alien giant African snail (Griffiths et al. 1993). On some or all of these tropical islands, the rosy glandina snail has expanded its normal terrestrial feeding behavior to include native snails found in arboreal habitats (Hadfield et al. 1993, Miller 1993, and Murray et al. 1988). The rosy glandina snail has caused the extinction of many populations and species of native snails throughout the Pacific islands (Hadfield et al. 1993, Miller 1993, Hopper and Smith 1992, Murray et al. 1988, and Tillier and Clarke 1983). Where it still resides, the rosy glandina snail represents a significant threat to the survival of native Mariana Islands.snails, including all four of the four remaining partulid tree snails: *Partula gibba* , *Partula langfordi* , *Partula radiolata* , and *Samoana fragilis*.

Predation on native partulid tree snails by the terrestrial Manokwar flatworm is also a threat to the long-term survival of these snails. This voracious snail predator was introduced into Guam in 1978 and has been spread by humans throughout the main Mariana Islands (Eldredge 1988). It has proven to be an effective biological control agent for the giant African snail, but has also contributed to the decline of native tree snails, in part due to its ability to ascend into trees and bushes that support native snails. Areas with populations of the flatworm usually lack partulid tree snails or have declining numbers of snails (Hopper and Smith 1992).

The first bio-control efforts directed at the giant African snail were conducted on the small island of Aguijan (also known as Aguijan or Goat Island) in the Mariana Archipelago (see Eldredge 1988 for a reviewed the history of the giant African snail in Micronesia).

In May 1950, approximately 400 Kibwezi gonaxis snails (*Gonaxis kibweziensis*) were released on Aguijan Island. One year later, the number of Kibwezi gonaxis was estimated at 21,750, and the number of giant African snails was 1,122,500. Kondo (1952) concluded that this snail predator had little effect on the giant African snail. Two years later, Peterson (1954) observed Kibwezi gonaxis snails feeding on native snail species and on the giant African snail and cannibalizing its own young. By mid-1954, the population of Kibwezi gonaxis on Aguijan was estimated to be 80,800, and the giant African snail was estimated at 37,600 individuals (Davis 1954). Davis (1954) concluded that this snail predator was approximately 60% effective. Based on these conclusions, Kibwezi gonaxis snails were shipped to Hawaii and other Pacific islands for biological control of the giant African snail (Eldredge 1988).

D. ***The inadequacy of existing regulatory mechanisms.***

Currently, no formal or informal protection is given to the fragile tree snail by Federal agencies or by private individuals or groups. In 1996, the Government of Guam listed this species as endangered on Guam (5 GCA, Section 63205.(c), "The Endangered Species Act of Guam").

Current Conservation Efforts: On Guam the U.S. Fish and Wildlife Service is pursuing the establishment of a 11,489 ha (28,158 acre) refuge overlay on military lands. This would cover 19.6 percent of the total land area of the island of Guam, and would include two of the nine remaining populations of this species.

E. ***Other natural or manmade factors affecting its continued existence.***

Naturally occurring random (i.e., stochastic) events can affect the continued existence of the fragile tree snail due to the small numbers of populations and individuals that remain. Stochastic physical events such as typhoons and droughts could eliminate one or more of the eight remaining populations. This is especially true due to several life-history features of this and all other partulid tree snails (Cowie 1992): reproductive rates are low; eggs are not laid as in most terrestrial snails, but the young are born live; dispersal is very limited with most individuals remaining in the tree or bush into which they were born. All of these traits make these snails very sensitive to any stochastic event that could lead to a reduction or loss of reproductive individuals.

REFERENCES

Baille, J., and B. Groombridge. 1996. 1996 IUCN Red List of Threatened Animals. IUCN Species Survival Commission, Gland, Switzerland. 368 pp. Available from IUCN Publications Services Unit, 219c Huntington Road, Cambridge, CB3 0DL, United Kingdom.

Carano, P. and P.C. Sanchez. 1964. A complete history of Guam. Charles E. Tuttle, Inc., Rutland, Vermont. 452 pp.

Christensen, C.C. 1984. Are *Euglandina* and *Gonaxiis* effective agents for biological control of the giant African snail in Hawaii? Amer. Malacol. Bull., 2:98-99.

Clarke, B., J. Murray, and M.S. Johnson. 1984. The extinction of endemic species by a program of biological control. Pacific Sci. 38:97-104.

Cowie, R.H. 1992. Evolution and extinction of Partulidae, endemic Pacific island land snails. Philosophical Trans. Royal Soc. London B 335:167-191.

Crampton, H.E. 1925. Studies on the variation, distribution, and evolution of the genus *Partula* . The species of the Mariana Islands, Guam and Saipan. Carnegie Inst. Wash. Publ. 228A. vii + 116pp., 14 pl.

Davis, C.J. 1954. Report on the Davis Expedition to Aguiguan July-August 1954. Ecological studies, Island of Aguiguan, Mariana Islands as related to the African snail, *Achatina fulica* Bowdich, and its introduced predator, *Gonaxis kibweziensis* (E.A. Smith). Invertebrate Consultants Committee for the Pacific, Pacific Science Board. 24 pp.

Eldredge, L.G. 1988. Case studies of the impacts of introduced animal species on renewable resources in the U.S.-affiliated Pacific islands. Pp. 118-146. In B.D. Smith (ed.), Topic reviews in insular resource development and management in the Pacific U.S.- affiliated islands. Univ. Guam Marine Lab. Tech. Rep. 88.

Engbring, J., F. Ramsey., and V. J. Wildman. 1986. Micronesian Forest Bird Survey, 1982: Saipan, Tinian, Agiguan, and Rota. U.S. Fish and Wildlife Service, Honolulu, HI. 143 pp..

Falanruw, M.V.C. 1989. Vegetation survey of Rota, Tinian, and Saipan. Commonwealth of the Norhtern Mariana Islands. Resource Bulletin PSW-27. Berkeley, CA: Pacific Southwest Forest and Range Experimental Station, Forest Service, U.S. Department of Agriculture. 11 p. +13 maps.

Fancy, S.G. and T.J. Snetsinger. 1996. Potential reasons for the decline of the bridled white-eye population on Rota, Mariana Islands. Unpublished report, U.S.G.S., Biological Resources Division, Pacific Islands Ecosystems Research Center, Hawaii National Park, Hawaii.

Fosberg, F.R. 1960. The vegetation of Micronesia. Part 1. General descriptions, the vegetation of the Mariana Islands, and a detailed consideration of the vegetation of Guam. Bull. Amer. Mus. Nat. Hist. 119:1-75.

Fosberg, F.R. 1971. On present conditions and conservation of forests in Micronesia. In: Pacific Science Association Standing committee on Pacific Botany. Symposium: Planned utilization of the lowland tropical forests. Bogor, Indonesia.

Griffiths, O., A. Cook, and S.M. Wells. 1993. The diet of the introduced carnivorous snail *Euglandina rosea* and its implications for threatened island gastropod faunas. Journal of Zoology, 229:79-89.

Hadfield, M.G., S.E. Miller, and A.H. Carwile. 1993. The decimation of endemic Hawaiian tree snails by alien predators. Amer. Zoologist, 33:620-622.

Hopper, D.R., and B.D. Smith. 1992. The status of tree snails (Gastropoda: Partulidae) on Guam, with a resurvey of sites studied by H. E. Crampton in 1920. Pacific Sci. 46:77-85. Kanehira, R. 1936. Forests of Rota. Bot. Zool. 4:63-70.

Kondo, Y. 1952. Report on carnivorous snail experiment on Aguiguan Island; primary and secondary *Achatina* -free areas on Rota, and gigantism among *Achatina* on Guam. Invertebrates Consultants Committee for the Pacific, Pacific Science Board. 50 pp..Kondo, Y. 1970. Some aspects of Mariana Islands Partulidae (Mollusca, Pulmonata). Occas. Pap. B.P. Bishop Mus. 24(5):73-90.

Mead, A.R. 1961. The Giant African Snail: a problem in economic malacology. Univ. Chicago Press.

Miller, S.E. 1993. Final report on surveys of the arboreal and terrestrial snail fauna of American Samoa. Unpublished report submitted to U.S. Fish and Wildlife Service, Pacific Region, Honolulu. 30 pp.

Mueller-Dombois, D. 1981. Fire in tropical ecosystems. In: Fire Regimes and Ecosystem Properties. Pp.137-176. H.A. Mooney, T.M. Bonnicksen, N.L. Christensen, J.E. Lotan, and W.A. Reiners (eds.). USDA, Forest Service Gen. Tech. Rep. WO-26.

Murray, J., E. Murray, M.S. Johnson, and B. Clarke. 1988. The extinction of *Partula* on Moorea. Pacific Sci. 42:150-153.

NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

Paulay, G. 1994. Biodiversity on oceanic islands: Its origin and extinction. Am. Zoologist 34:134-144.

Pearce-Kelly, P., D. Clarke, and G. Mace. 1994. Partula 1994. An action plan for the conservation of the family Partulidae. Report of a workshop held at the Zoological Society of London, 11-13 February 1994.

Peterson, G.D. 1954. Report on progress of carnivorous snail experiments of Agiguan, Mariana Islands. Invertebrate Consultants Committee, Pacific Science Board. 9 pp.

Smith, B.D. 1995. Tree snails, tropical storms, and drought in the Mariana Islands. (Abstract only). Programs and abstracts, American Malacological Union, 61st Annual Meeting, Hilo, Hawaii.

Smith, B.D., and D.R. Hopper. 1994. The Partulidae of the Mariana Islands: Continued threats and declines. Hawaiian Shell News 42(6):10-11.

Tillier, S. and B.C. Clarke. 1983. Lutte biologique et destruction du patrimoine genetique: le cas du mollusgues.gasteropodes pulmones dans les territoires Francais du Pacifique. Sel. Evol., 15:559-566..

PETITION TO LIST

Guam tree snail, akaleha
(*Partula radiolata*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 11/15/94:	
CNOR 2/28/96:	C
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

The genus *Partula* includes four extant species found only in the Mariana Islands, and 94 additional species recorded from other Pacific islands. Thirty-seven of these 98 species are extinct in the wild, including the Guam endemic *Partula salifana*, which has not been seen since 1946 (Pearce-Kelly et al. 1994). The taxonomic status of the Guam tree snail, *Partula radiolata* (Partulidae), is uncontroversial (e.g., NatureServe Explorer 2001).

NATURAL HISTORY

Ecology

As with all terrestrial pulmonate snails, the Mariana Islands tree snails are hermaphroditic. In general, partulid snails begin reproducing in less that 12 months and may live up to 5 years. Up to 18 young are produced each year and some species, such as the humped tree snail of the Mariana Islands, may be self-fertile. While most terrestrial snails lay eggs, the partulid tree snails give birth to fully developed young. The snails are generally nocturnal, living on bushes or trees and feeding on decaying plant material. There are no known natural predators of these snails, although many of these species are currently threatened by alien snail predators. These partulids prefer cool, shaded forest habitats (Crampton 1925, Cowie 1992, and Smith 1995) with high humidity.

Distribution

The Guam tree snail was first collected by Quoy and Gaimard during the French Astrolabe expedition of 1828 (Crampton, 1925). The Guam tree snail is restricted to the island of Guam. However, Pfeiffer erroneously reported it to occur on the island of New Ireland in the Bismarck Archipelago, approximately 1,400 mi (2253 km) to the south of Guam. This error was perpetuated by other authors, most recently by Parkinson et al. (1987). This mistake in location was originally corrected by Crampton (1925) in his definitive monograph on the Partulidae of the Mariana islands. The most recent compilation of information on the entire family (Pearce-Kelly et al. 1994) agrees with Crampton in listing the Guam tree snail as endemic to the island of Guam.

Since the work of Crampton (1925), no significant evaluation of the Guam tree snail occurred until the 1980's and 1990's. In 1989, Hopper and Smith (1992) resurveyed 34 of Crampton's 39 sites on Guam plus 13 new sites. Crampton (1925) found the Guam tree snail at 37 of the 39 sites and collected between two to 312 snails from each site; a total of 2,278 individuals were collected. The actual population sizes were probably considerably larger since the purpose of Crampton’s collections were to evaluate geographic differences in shell patterns and not to assess population size. Nine of the 34 sites resurveyed by Hopper and Smith (1992) still supported these.snails in 1989.

Of the 13 new sites surveyed by Hopper and Smith (1992), seven supported populations of Guam tree snail; one of these was eliminated in 1991-1992 by wildfires that burned into ravine forest occupied by the snails (Smith and Hopper 1994). Additional surveys by Smith (1995) found five additional populations of Guam tree snail. The U.S. Fish and Wildlife Service surveyed 15 sites on the Guam Naval Magazine and located one additional population, while ground shells of tree snails were found in abundance at all locations (personal communication 1996 cited in U.S. Fish and Wildlife Service candidate assessment form).

The three genera and 123 tree snail species of the family Partulidae are restricted to the high-elevation Pacific islands of Polynesia (excluding Hawaii), Melanesia, and Micronesia (Cowie 1992 and Paulay 1994). These snails have received increased attention in recent years due to declining numbers throughout their range and, in many cases, due to extinction (Clarke et al. 1984, Murray et al. 1988, Hopper and Smith 1992, and Miller 1993). The high islands of the Mariana archipelago historically supported five species of partulid tree snails, and represent the northwestern limit of the geographical range of the *Partulidae.*

POPULATION STATUS

Overall, 30 percent of the 123 partulid species are extinct and 39 percent are declining toward extinction. For 31 percent of the species, the current status cannot be characterized due to insufficient information. In no case has a partulid tree snail species been shown to have stable or increasing numbers of individuals or populations.

Hopper and Smith (1992) estimated that the number of sites that support the Guam tree snail have decreased by 74 percent since Crampton’s work in 1920. Habitat loss to development as well as man-made and natural disasters such as wildfires and typhoons continues to threaten the continued existence of the remaining populations. If the recent rate of loss of populations (3 of 23 sites since 1989 or about 0.5 sites per year) continues, the species will be extinct by the year 2039.

The best estimate for the total number of remaining snails is fewer than 2,000. Since 1989, the Crampton site with the largest remaining population of Guam tree snail (estimated at greater than 500 snails) has been completely eliminated by the combined effects of a land clearing for a residential development and a subsequent series of typhoons in 1990, 1991, and 1992 (Smith 1995).

The U.S. Fish and Wildlife Service classifies the Guam tree snail as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. ***The present or threatened destruction, modification, or curtailment of its habitat or range.***

Historical range: Guam.

Current range: Guam. To date, there are 20 sites that still support small populations of *Partula radiolata* . At one of these sites, snails were moved to a new location due to the development of a golf course on the tree snail habitat (Smith 1995).

Land ownership: All but six of the 20 sites that currently support snails are on lands owned by private land owners. The remaining sites are on lands owned by the U.S. Military. Land ownership issues in Guam and The Commonwealth of the Northern Mariana Islands are highly controversial.

Crampton (1925) described the habitat requirements of the partulid trees snails of the Mariana Islands as follows: "...the.indispensable requisites are that there shall be a sufficiently high and dense growth to provide shade, to conserve moisture, and to effect the production of a rich humus. Hence the limits to the areas occupied by Partulidae are set by the more ultimate ecological conditions which determine the distribution of suitable vegetation." In fact, the ecological settings that meet the basic requirements for partulid snail were numerous in the Mariana Islands prior to World War II. They include coastal strand vegetation, forested river borders, and lowland and highland forests (Crampton 1925). Crampton (1925) further describes the intact structure of native Mariana forests as having four general levels: the high trees; the shrubs and *Pandanus* ; the cycads and taller ferns; and the succulent herbs. He notes that the Mariana Islands partulid tree snails preferentially live on subcanopy vegetation and do not use the high canopy trees.

Prior to the arrival of humans, the Mariana Islands were believed to be mostly forested (Fosberg 1960, 1971). With the arrival and population growth of the aboriginal Chamorro people 4,000 years ago (Carano and Sanchez 1964), native forests began to be cleared and savanna grasslands began to develop (Mueller- Dumbois 1981). During the Spanish occupation of the Mariana Islands (1521-1899), alien goats, pigs, cattle, and deer were introduced. Extensive herds of cattle were noted on the main islands, with some herds numbering in excess of 10,000 head. Large numbers of pigs, goats and deer were also present (Engbring et al. 1986 and Carano and Sanchez 1964). These animals, along with extensive logging, further contributed to the expansion of savanna grasslands and directly altered the understory plant community and overall forest microclimate. All of these changes resulted in a continuing decline in area and quality of tree snail habitat.

Sweeping ecological changes took place during the Japanese occupation from 1914-1944 (Kanehira 1936, Fosberg 1960, 1971, and Engbring et al. 1986). Extensive removal of native forests for the development of sugar cane was pursued on all of the main islands. These fields covered almost all of Tinian and much of Guam, Saipan, Rota, and Aguijan. In 1920, Crampton (1925) commented on the loss of partulid tree snail habitat. He stated that much deforestation had occurred in the southern half of Guam and that the savanna grassland habitat, which is unsuitable for tree snails, had greatly expanded during “recent centuries”. He also noted that extensive wood cutting had reduced the forest canopy.

During and after World War II dramatic reductions in partulid tree snail habitats (forest, riparian, and coastal strand) occurred on the islands of Guam, Tinian, and Saipan where major military operations and landings were conducted. Following the war, open agricultural fields and other areas prone to erosion were seeded with tangantangan (*Leucaena leucocephala*) by the U.S. Military (Fosberg 1960). Tangantangan grows as a single species stand with no substantial understory. The microclimatic conditions are dry, with little accumulation of leaf litter humus, and are particularly unsuitable as partulid tree snail habitat (Hopper and Smith 1992). In addition, native forest cannot reinvade and grow where this alien weed has become established (Hopper and Smith 1992). The post-war establishment and operation of large military bases has also prevented the return of native forest that could support partulid tree snails. Today on the island of Guam, the U.S. military occupies approximately 17,500 ha or 30% of the island, most (90+%) of which once was forested habitat that supported the endemic tree snails.

B. *Overutilization for commercial, recreational, scientific, or educational purposes.*

Overutilization is not known to be a factor currently affecting any of the Mariana Partulidae. Future overutilization of this species is not anticipated. However, necklaces or leis made from partulid snails shells are occasionally found for sale. Any collecting of the Guam tree snail could significantly contribute to the continued decline of the species and the local extinction of specific populations.

C. *Disease or predation.*

Crampton (1925) states that “There are no other animals in the Mariana Islands whose presence or activities influence the lives or numbers of Partulae, so far as observation goes." Since World War II, several introductions of alien predators have completely changed this historic condition. Predation by the alien rosy glandina snail (*Euglandina rosea*) and the alien.Manokwar flatworm (*Platydemis manokwari*) is a serious threat to the survival of all four species of partulid tree snails from the Mariana Islands. The predatory rosy glandina snail is native to the southeastern United States, and was introduced into the Mariana Islands in 1957 by the governments of Guam and the Commonwealth of the Northern Mariana Islands, following the recommendations of the State of Hawaii Department of Agriculture (Eldredge 1988). Since being introduced, this voracious predator of snails has been dispersed by humans throughout the main islands.

The rosy glandina snail was imported to these and other Pacific islands as a biological control agent for another alien snail, the giant African snail (*Achatina fulica*), which is an agricultural pest. However, while its effectiveness as a biological control agent against the giant African snail is questionable (Christiansen 1984, Tillier and Clarke 1983, and Mead 1961), field observations have established that the rosy glandina snail will readily feed on native Pacific island tree snails, including the Partulidae such as those of the Mariana Islands (Murray et al. 1988, Tillier and Clarke 1983, and Miller 1993) as well as Hawaiian achatinellid tree snails (Hadfield *et al*. 1993).

A study of the diet of the rosy glandina snail on the island of Mauritius in the Indian Ocean showed that this alien predator preferred native snails over the targeted alien giant African snail (Griffiths et al. 1993). On some or all of these tropical islands, the rosy glandina snail has expanded its normal terrestrial feeding behavior to include native snails found in arboreal habitats (Hadfield et al. 1993, Miller 1993, and Murray et al. 1988). The rosy glandina snail has caused the extinction of many populations and species of native snails throughout the Pacific islands (Hadfield et al. 1993, Miller 1993, Hopper and Smith 1992, Murray et al. 1988, and Tillier and Clarke 1983). Where it still resides, the rosy glandina snail represents a significant threat to the survival of native Mariana Islands snails, including the four remaining partulid tree snails: *Partula gibba*, *Partula langfordi*, *Partula radiolata*, and *Samoana fragilis*.

Predation on native partulid tree snails by the terrestrial Manokwar flatworm is also a threat to the long-term survival of these snails. This voracious snail predator was introduced into Guam in 1978 and has been spread by humans throughout the main Mariana Islands (Eldredge 1988). It has proven to be an effective biological control agent for the giant African snail, but has also contributed to the decline of native tree snails, in part.due to its ability to ascend into trees and bushes that support native snails. Areas with populations of the flatworm usually lack partulid tree snails or have declining numbers of snails (Hopper and Smith 1992).

The first bio-control efforts directed at the giant African snail were conducted on the small island of Aguijan (also known as Aguijan or Goat Island) in the Mariana Archipelago (see Eldredge 1988 for a reviewed the history of the giant African snail in Micronesia). In May 1950, approximately 400 Kibwezi gonaxis snails (*Gonaxis kibweziensis*) were released on Aguijan Island. One year later, the number of Kibwezi gonaxis was estimated at 21,750, and the number of giant African snails was 1,122,500. Kondo (1952) concluded that this snail predator had little effect on the giant African snail. Two years later, Peterson (1954) observed Kibwezi gonaxis snails feeding on native snail species and on the giant African snail and cannibalizing its own young. By mid-1954, the population of Kibwezi gonaxis on Aguijan was estimated to be 80,800, and the giant African snail was estimated at 37,600 individuals (Davis 1954). Davis (1954) concluded that this snail predator was approximately 60% effective. Based on these conclusions, Kibwezi gonaxis snails were shipped to Hawaii and other Pacific islands for biological control of the giant African snail (Eldredge 1988).

D. ***The inadequacy of existing regulatory mechanisms.***

Currently, no formal or informal protection is given to the Guam tree snail by Federal agencies or by private individuals or groups. In 1996, the Government of Guam listed this species as endangered on Guam (5 GCA, Section 63205.(c), “The Endangered Species Act of Guam”).

Current Conservation Efforts: On Guam the Service is pursuing the establishment of a 11,489 ha (28,158 acre) refuge overlay on military lands. This would cover 19.6% of the total land area of the island of Guam, and would include six of the 20 remaining populations of this species.

E. ***Other natural or manmade factors affecting its continued existence.***

Naturally occurring random events can affect the continued existence of the Guam tree snail due to the small numbers of populations and individuals that remain. Physical events such as typhoons and droughts could eliminate one or more of the 20 remaining populations. This is especially true due to several life-history features of this and all other partulid tree snails (Cowie 1992): reproductive rates are low; eggs are not laid as in most terrestrial snails, but the young are born live; dispersal.is very limited with most individuals remaining in the tree or bush into which they were born. All of these traits make these snails very sensitive to any stochastic event that could lead to a reduction or loss of reproductive individuals.

REFERENCES

Carano, P. and P.C. Sanchez. 1964. A complete history of Guam. Charles E. Tuttle, Inc., Rutland, Vermont. 452 pp.

Christensen, C.C. 1984. Are *Euglandina* and *Gonaxiis* effective agents for biological control of the giant African snail in.Hawaii? Amer. Malacol. Bull., 2:98-99.

Clarke, B., J. Murray, and M.S. Johnson. 1984. The extinction of endemic species by a program of biological control. Pacific Sci. 38:97-104.

Cowie, R.H. 1992. Evolution and extinction of Partulidae, endemic Pacific island land snails. Philosophical Trans. Royal Soc. London B 335:167-191.

Crampton, H.E. 1925. Studies on the variation, distribution, and evolution of the genus *Partula* .

The species of the Mariana Islands, Guam and Saipan. Carnegie Inst. Wash. Publ. 228A. vii + 116pp., 14 pl.

Davis, C.J. 1954. Report on the Davis Expedition to Aguiguan July-August 1954. Ecological studies, Island of Aguiguan, Mariana Islands as related to the African snail, *Achatina fulica* Bowdich, and its introduced predator, *Gonaxis kibweziensis* (E.A. Smith). Invertebrate Consultants Committee for the Pacific, Pacific Science Board. 24 pp.

Eldredge, L.G. 1988. Case studies of the impacts of introduced animal species on renewable resources in the U.S.-affiliated Pacific islands. Pp. 118-146. In B.D. Smith (ed.), Topic reviews in insular resource development and management in the Pacific U.S.- affiliated islands. Univ. Guam Marine Lab. Tech. Rep. 88.

Engbring, J., F. Ramsey., and V. J. Wildman. 1986. Micronesain Forest Bird Survey, 1982: Saipan, Tinian, Agiguan, and Rota. U.S. Fish and Wildlife Service, Honolulu, HI. 143 pp.

Fosberg, F.R. 1960. The vegetation of Micronesia. Part 1. General descriptions, the vegetation of the Mariana Islands, and a detailed consideration of the vegetation of Guam. Bull. Amer. Mus. Nat. Hist. 119:1-75.

Fosberg, F.R. 1971. On present conditions and conservation of forests in Micronesia. In: Pacific Science Association Standing committee on Pacific Botany. Symposium: Planned utilization of the lowland tropical forests. Bogor, Indonesia..Griffiths, O., A. Cook, and S.M. Wells. 1993. The diet of the introduced carnivorous snail *Euglandina rosea* and its implications for threatened island gastropod faunas. Journal of Zoology, 229:79-89.

Hadfield, M.G., S.E. Miller, and A.H. Carwile. 1993. The decimation of endemic Hawaiian tree snails by alien predators. Amer. Zoologist, 33:620-622.

Hopper, D.R., and B.D. Smith. 1992. The status of tree snails (Gastropoda: Partulidae) on Guam, with a resurvey of sites studied by H. E. Crampton in 1920. Pacific Sci. 46:77-85.

Kanehira, R. 1936. Forests of Rota. Bot. Zool. 4:63-70.

Kondo, Y. 1952. Report on carnivorous snail experiment on Aguiguan Island; primary and secondary *Achatina* -free areas on Rota, and gigantism among *Achatina* on Guam. Invertebrates Consultants Committee for the Pacific, Pacific Science Board. 50 pp.

Mead, A.R. 1961. The Giant African Snail: a problem in economic malacology. Univ. Chicago Press.

Miller, S.E. 1993. Final report on surveys of the arboreal and terrestrial snail fauna of American Samoa. Unpublished report submitted to U.S. Fish and Wildlife Service, Pacific Region, Honolulu. 30 pp.

Mueller-Dombois, D. 1981. Fire in tropical ecosystems. In: Fire Regimes and Ecosystem Properties. Pp.137-176. H.A. Mooney, T.M. Bonnicksen, N.L. Christensen, J.E. Lotan, and W.A. Reiners (eds.). USDA, Forest Service Gen. Tech. Rep. WO-26.

Murray, J., E. Murray, M.S. Johnson, and B. Clarke. 1988. The extinction of *Partula* on Moorea.Pacific Sci. 42:150-153.

NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Ecology and Life History 1997. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

Parkinson, B., J. Hemmen, and K. Groh. 1987. Tropical landshells of the world. Verlag Christa Hemmen, Wiesbaden, West Germany. 279 pp.

Paulay, G. 1994. Biodiversity on oceanic islands: Its origin and extinction. Am. Zoologist 34:134-144..Pearce-Kelly, P., D. Clarke, and G. Mace. 1994. Partula 1994. An action plan for the conservation of the family Partulidae. Report of a workshop held at the Zoological Society of London, 11-13 February 1994.

Peterson, G.D. 1954. Report on progress of carnivorous snail experiments of Agiguan, Mariana Islands. Invertebrate Consultants Committee, Pacific Science Board. 9 pp.

Smith, B.D. 1995. Tree snails, tropical storms, and drought in the Mariana Islands. (Abstract only). Programs and abstracts, American Malacological Union, 61st Annual Meeting, Hilo, Hawaii.

Smith, B.D., and D.R. Hopper. 1994. The Partulidae of the Mariana Islands: Continued threats and declines. Hawaiian Shell News 42(6):10-11.

Tillier, S. and B.C. Clarke. 1983. Lutte biologique et destruction du patrimoine genetique: le cas du mollusgues gasteropodes pulmones dans les territoires Francais du Pacifique. Sel. Evol., 15: 559-566.

PETITION TO LIST

humped tree snail, akaleha
(*Partula gibba*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 11/15/94:	
CNOR 2/28/96:	C
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

The genus *Partula* (Partulidae) includes four extant species found only in the Mariana Islands, and 94 additional species recorded from other Pacific islands. The humped tree snail (*Partula gibba*) is very similar to Langford's tree snail (*P. langfordi*); further study is required to resolve their taxonomic status (NatureServe Explorer 2001).

NATURAL HISTORY

Ecology

As with all terrestrial pulmonate snails, the Mariana Islands tree snails are hermaphroditic. In general, partulid snails begin reproducing in less that 12 months and may live up to 5 years. Up to 18 young are produced each year and some species, such as the humped tree snail, may be self-fertile. While most terrestrial snails lay eggs, the partulid tree snails give birth to fully developed young. The snails are generally nocturnal, living on bushes or trees and feeding on decaying plant material. There are no known natural predators of these snails, although many of these species are currently threatened by alien snail predators.

The Partulidae, including those of the Mariana Islands, prefer cool, shaded forest habitats (Crampton 1925, Cowie 1992, and Smith 1995) with high humidity. The species occupies the branches of trees in cool and shaded habitats (Crampton 1925).

Crampton (1925) described the habitat requirements of the partulid trees snails of the Mariana

Islands as follows: "...the indispensable requisites are that there shall be a sufficiently high and dense growth to provide shade, to conserve moisture, and to effect the production of a rich humus. Hence the limits to the areas occupied by Partulae are set by the more ultimate ecological conditions which determine the distribution of suitable vegetation." In fact, the ecological settings that meet the basic requirements for partulid snail were numerous in the Mariana Islands prior to World War II. They include coastal strand vegetation, forested river borders, and lowland and highland forests (Crampton 1925). Crampton (1925) further describes the intact structure of native Mariana forests as having four general levels: the high trees; the shrubs and *Pandanus* ; the cycads and taller ferns; and the succulent herbs. He notes that the Mariana Islands partulid tree snails preferentially live on subcanopy vegetation and do not use the high canopy trees.

Distribution

Thirty-seven of the 98 species of snails are extinct in the wild including the Guam endemic *Partula salifana*, which has not been seen since 1946 (Pearce-Kelly et al. 1994). An additional 37 species are declining in numbers, and 24 species are of indeterminate status due to insufficient information. The genus *Samoana* is represented in the Mariana Islands by a single species, *Samoana fragilis*. Twenty additional species are recorded from other islands in the Pacific basin. Ten of these 21 species are declining in numbers, including the Mariana Islands endemic species. The status of 11 other species is unknown (Pearce-Kelly et al. 1994). Four partulid species are in the genus *Eua*, which are confined to the Polynesian islands of Tonga and Samoa in the south Pacific. One of these is known to be declining in numbers, while the status of of the remaining three species is unknown (Pearce-Kelly et al. 1994). Overall, 30 percent of the 123 partulid species are extinct and 39 percent are declining in numbers.

The humped tree snail was first collected on Guam in 1819 by Quoy and Gaimard during the Freycinet Uranie expedition of 1817-1819 (Crampton 1925). The three genera and 123 tree snail species of the family *Partulidae* are restricted to the high-elevation Pacific islands of Polynesia (excluding Hawaii), Melanesia, and Micronesia (Cowie 1992 and Paulay 1994). These snails have received increased attention in recent years due to declining numbers throughout their range and due to their alarming rates of human-mediated extinction (Clarke et al. 1984, Murray et al. 1988, Hopper and Smith 1992, and Miller 1993). The high islands of the Mariana archipelago historically supported five species of partulid tree snails, and represent the northwestern limit of the geographical range of the *Partulidae*.

The humped tree snail is the most widely distributed tree snail in the Mariana Islands and is known from Guam, Rota, Aguijan, Tinian, Saipan, Anatahan, Sarigan, Alamagan, and Pagan. Upon its discovery, this snail was considered to be the most common tree snail on Guam. Sixty-nine years later, this species is considered to be rare throughout its range (Hopper and Smith 1992).

Since the work of Crampton (1925), no significant evaluation of the humped tree snail occurred until the 1980s and 1990s. In 1989, Hopper and Smith (1992) resurveyed 34 of Crampton's 39 sites on Guam plus 13 new sites. Crampton (1925) found the humped tree snail at 33 of the 39 sites and collected between two and 412 snails at each site; a total of 3,204 individuals were collected. The actual population sizes were probably considerably larger since the purpose of Crampton's collections were to evaluate geographic differences in shell patterns and not to assess population size. None of the 34 sites resurveyed by Hopper and Smith (1992) still supported these snails in 1989. Of the 13 new sites surveyed by Hopper and Smith (1992), only one supported a small population of humped tree snail.

Additional surveys by Smith (1995) found two additional populations of humped tree snail. The U.S. Fish and Wildlife Service surveyed 15 sites on the Guam Naval Magazine and found no additional populations, although ground shells of tree snails were found in abundance at all locations (personal communication 1996 cited in U.S. Fish and Wildlife Service candidate assessment form).

The humped tree snail has also been recorded from eight of the islands of the Commonwealth of the Northern Mariana Islands: Rota, Agujuan, Tinian, Saipan, Anatahan, Sarigan, Alamagan, and Pagan. Crampton (1925) surveyed eight sites on the island of Saipan, collecting 6,698 humped tree snails . Surveys in 1991 by Smith and Hopper (1994) could not find any snails at 12 sites visited on the island. Only two of Crampton's original eight sites still had the native vegetation needed to support the tree snails. The shells of dead *Partula* tree snails were found at all the survey sites.

All three of the Guam populations of humped tree snail are in the same coastal area. One has declined from approximately 100 snails in 1991 to 20 snails in 1995; this area has recently had a new road cut into it, and the decline in this population of snails may be due to the indirect effects of this road. The other two populations are described as being substantial, probably totaling 500 to 1,000 individuals.

The Island of Rota was recently surveyed for *Partula* tree snails (Smith 1995, and Miller and Asquith, 1996 personal communication as cited in the candidate assessment form). Of 25 surveyed sites, only five supported populations of humped tree snail . The largest of these may have up to 1,000 snails. However, this population is located along the main road of Rota in an area that is actively undergoing development. The four other populations are small and total less that 600 snails (Smith 1995). The shells of dead humped tree snails were found usually in great abundance at all of the locations surveyed. These observations indicate that this island once supported many large populations of tree snails and that these snails could be found at almost any location.

The island of Tinian has not been surveyed in recent years. However, the presence and abundance of a predatory flatworm coupled with severe loss of habitat prior to, during, and since World War II, make the continued existence of the humped tree snail on Tinian unlikely (Smith 1995).

The island of Aguijan is also a historic site for the humped tree snail. In 1985, seven adult snails were collected from the west end of the island (Smith 1995). In 1992, snails were observed at three locations on the island (Craig and Chandran 1992). A second survey in 1992 reported two humped tree snail on the northwest terrace of the island (Smith 1995).

The humped tree snail has also been reported from the remote northern islands in surveys done in 1949 and in 1994. These small volcanic islands are difficult to access and are currently uninhabited, although some are used for agricultural or military activity. The species was first reported in 1949 from six locations (28 adult snails plus numerous juveniles, with 17 adults from one location) on the island of Pagan in a thin breadfruit agroforest and from five locations (339 adult snails plus numerous juveniles, with 49 adults at a typical site) on Alamagan in wet forest (Kondo 1970). These observations probably represent a single fragmented population on each of these small islands.

In 1994, Kurozumi reported snails from Anatahan (19 snails from three locations, with 14 snails from a single site) and Sarigan (102 snails from seven locations, with 53 snails from a single site), which are between the more northern Alamagan and the more souther Saipan. Kurozumi (1994) also reported the continued existence of humped tree snail on Alamagan (123 snails from seven sites, with 58 from a single site) and Pagan (22 snails from a single site). As with the Pagan and Alamagan populations, the snails on Anatahan and Sarigan are probably part of two fragmented populations, one on each island.

The humped tree snail continues to survive on these northern islands, although since 1949 the species seems to have declined on Pagan and Alamagan Islands by over 70% for individuals and by approximately 27% for populations. A similar decline may have occurred on Anatahan and Sarigan Islands as well.

POPULATION STATUS

This rare species does not have stable or increasing numbers of individuals or populations. To date, there are 13 known populations on seven islands that still support populations of the humped tree snail. The best estimate for the total number of remaining snails is under 2,600. The snail is extinct on Saipan. On Guam and Rota, it has gone from being widely distributed and super abundant to being highly localized and rare. In the northern Mariana Islands, its numbers are in decline.

In 1996, the Government of Guam listed this species as endangered on Guam (5 GCA, Section 63205.(c), “The Endangered Species Act of Guam”).

The U.S. Fish and Wildlife Service classifies the humped tree snail as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. ***The present or threatened destruction, modification, or curtailment of its habitat or range.***

Historical range: Guam; Commonwealth of the Northern Mariana Islands (Islands of Rota, Agujuan, Tinian, Saipan, Anatahan, Sarigan, Alamagan, and Pagan).

Current range: Guam; Commonwealth of the Northern Mariana Islands (Islands of Rota, Agujuan, Tinian, Anatahan, Sarigan, Alamagan, and Pagan).

Land ownership: All but one of the 13 sites are on lands owned by private land owners. The third site is on lands owned by the U.S. Military. Land ownership issues in Guam and The Commonwealth of the Northern Mariana Islands are highly controversial.

Prior to the arrival of humans, the Mariana Islands were believed to be mostly forested (Fosberg 1960, 1971). With the arrival and population growth of the aboriginal Chamorro people 4,000 years ago (Carano and Sanchez 1964), native forests began to be cleared and savanna grasslands began to develop (Mueller- Dumbois 1981). During the Spanish occupation of the Mariana Islands (1521-1899), alien goats, pigs, cattle, and deer were introduced. Extensive herds of cattle were noted on the main islands, with some herds numbering in excess of 10,000 head. Large numbers of pigs, goats and deer were also present (Engbring et al. 1986 and Carano and Sanchez 1964). In 1742, the forested areas on the island of Tinian were described as park-like and open (Engbring et al. 1986 citing Anson’s journal as cited by Walter 1928). These animals along with extensive logging further contributed to the expansion of savanna grasslands and directly altered the understory plant community and overall forest microclimate. All of these changes resulted in a continuing decline in area and quality of tree snail habitat.

The German occupation of the the Mariana Islands, from 1899-1914, resulted in few ecological changes to the islands, although there was a recorded increase in the populations of Chamorros and Carolinians that settled on Saipan and actively developed coconut orchards (Engbring et al. 1986).

Sweeping ecological changes took place during the Japanese occupation from 1914-1944 (Kanehira 1936, Fosberg 1960, 1971, and Engbring et al. 1986). Extensive removal of native forests for the development of sugar cane was pursued on all of the main islands. These fields covered almost all of Tinian and much of Guam, Saipan, Rota, and Aguijan. In 1920, Crampton (1925) commented on the loss of partulid tree snail habitat. He stated that much deforestation had occurred in the southern half of Guam and that the savanna grassland habitat, which is unsuitable for tree snails, had greatly expanded during “recent centuries.” He also notes that extensive wood cutting has reduced the forest canopy.

During and after World War II dramatic reductions in partulid tree snail habitats (forest, riparian, and coastal strand) occurred on the islands of Guam, Tinian, and Saipan, where major military operations and landings were conducted. Following the war, open agricultural fields and other areas prone to erosion were seeded with tangantangan (*Leucaena leucocephala*) by the U.S. Military (Fosberg 1960). Tangantangan grows as a single species stand with no substantial understory. The microclimatic conditions are dry, with little accumulation of leaf litter humus, and are particularly unsuitable as partulid tree snail habitat (Hopper and Smith 1992). In addition, native forest cannot reinvade and grow where this alien weed has become established

(Hopper and Smith 1992).

The post-war establishment and operation of large military bases has also prevented the return of native forest that could support partulid tree snails. Today on the island of Guam, the U.S. military occupies approximately 17,500 ha or 30 percent of the island, most (90+%) of which once was forested habitat that supported the endemic tree snails. The native tree snail habitat on the main islands of the Commonwealth of the Northern Mariana Islands have been greatly reduced by development and agricultural activities (Engbring et al. 1986). For instance, most of the island of Rota was forested in 1932, but by 1935 almost all level areas have been cleared of forest to support sugar cane production and phosphate mining (Kanehira 1936).

The only areas left undisturbed are too steep for agriculture, generally along the base of cliffs, which are an extensive geological feature of the island. These areas still support native limestone forests (Fosberg 1960). Aerial photos from the World War II era show parts of Rota riddled with bomb craters and other areas denuded of vegetation primarily from agricultural activity. Following the war, much of this area was given over to cattle grazing, urban growth, and airport development. In some areas, native forest has reestablished (Engbring et al. 1986 and Falanruw 1989a). In 1988, supertyphoon Roy hit Rota with winds in excess of 150 miles per hour (240 km/hr), defoliating almost all of the forested areas and downing trees, especially along the southeast and northern cliff slopes of the central Sabana (Fancy and Snetsinger 1996). Vegetation changes associated with this storm have opened up forested areas that were excellent habitat for partulid tree snails. These open forests suffer from changes in microhabitat, such as desiccation, that make the continued survival of snails unlikely.

Events and changes similar to those described for Rota also apply to the other main islands of the Commonwealth of the Northern Mariana Islands. In the 1930s the island of Aguijan was mostly cleared of native forest to support sugar cane and pineapple production. The abandoned fields and an abandoned airstrip are now over grown with alien weeds. The remaining native forest understory has greatly suffered from foraging by alien goats and the invasion of weeds. The island of Tinan had seven World War II air fields that are now abandoned, and the northern two-thirds of the islands have periodically been leased by the U.S. Navy as a training site.

Approximately half of the island has been given over to cattle grazing. These human activities have almost entirely altered the island's vegetation, which now includes large stands of tangantangan that were aerially seeded by the U.S. Military. The humped tree snail is probably extinct on Tinian. On the island of Saipan, most of the native forest is gone, having been replaced by mixed second growth forests, savanna grasslands, and dense thickets of tangantangan (due to military aerial seeding). None of these vegetation types provide suitable habitat for the humped tree snail, which is now extinct on Saipan. Of the ten smaller northern islands, only Guguan, Asuncion, Maug, and Farallon de Pajaros (Uracas) are uninhabited and free of goats, pigs, and cattle (Falanruw 1989b). None of these islands are known to suppport populations of partulid tree snails.

B. *Overutilization for commercial, recreational, scientific, or educational purposes.*

Overutilization is not known to be a factor currently affecting any of the partulid tree snails from the Mariana Islands. Future overutilization of this species is not anticipated. However, necklaces or leis made from partulid snails shells are occasionally found for sale. Any collection of humped tree snail could significantly contribute to the continued decline of the species and the local extinction of specific populations.

C. *Disease or predation.*

Crampton (1925) states that “There are no other animals in the Mariana Islands whose presence or activities influence the lives or numbers of Partulae, so far as observation goes.” Since World War II, several introductions of alien predators have completely changed this historic condition. Predation by the alien rosy glandina snail (*Euglandina rosea*) and the alien Manokwar flatworm (*Platydemis manokwari*) is a serious threat to the survival of all four species of partulid tree snails from the Mariana Islands. The predatory rosy glandina snail is native to the southeastern United States, and was introduced into the Mariana Islands in 1957 by the governments of Guam and the Commonwealth of the Northern Mariana Islands, following the recommendations of the State of Hawaii Department of Agriculture (Eldredge 1988). Since being introduced, this voracious predator of snails has been dispersed by humans throughout the main islands. The rosy glandina snail was imported to these and other Pacific islands as a biological control agent for another alien snail, the giant African snail (*Achatina fulica*), which is an agricultural pest. However, while its effectiveness as a biological control agent against the giant African snail is questionable (Christiansen 1984, Tillier and Clarke 1983, and.Mead 1961), field observations have established that the rosy glandina snail will readily feed on native Pacific island tree snails, including the Partulidae such as those of the Mariana Islands (Murray et al. 1988, Tillier and Clarke 1983, and Miller 1993) as well as Hawaiian achatinellid tree snails (Hadfield et al. 1993).

A study of the diet of the rosy glandina snail on the island of Mauritius in the Indian Ocean showed that this alien predator preferred native snails over the targeted alien giant African snail (Griffiths et al. 1993). On some or all of these tropical islands, the rosy glandina snail has expanded its normal terrestrial feeding behavior to include native snails found in arboreal habitats (Hadfield et al. 1993, Miller 1993, and Murray et al. 1988). The rosy glandina snail has caused the extinction of many populations and species of native snails throughout the Pacific islands (Hadfield et al. 1993, Miller 1993, Hopper and Smith 1992, Murray et al. 1988, and Tillier and Clarke 1983). Where it still resides, the rosy glandina snail represents a significant threat to the survival of native Mariana Islands snails, including the four remaining partulid tree snails: *Partula gibba*, *Partula langfordi*, *Partula radiolata*, and *Samoana fragilis* .

Predation on native partulid tree snails by the terrestrial Manokwar flatworm is also a threat to the long-term survival of these snails. This voracious snail predator was introduced into Guam in 1978 and has been spread by humans throughout the main Mariana Islands (Eldredge 1988). It has proven to be an effective biological control agent for the giant African snail, but has also contributed to the decline of native tree snails, in part due to its ability to ascend into trees and bushes that support native snails. Areas with populations of the flatworm usually lack partulid tree snails or have declining numbers of snails (Hopper and Smith 1992).

The first bio-control efforts directed at the giant African snail were conducted on the small island of Aguijan (also known as Aguijan or Goat Island) in the Mariana Archipelago (see Eldredge 1988 for a reviewed the history of the giant African snail in Micronesia). In May 1950, approximately 400 Kibwezi gonaxis snails (*Gonaxis kibweziensis*) were released on Aguijan Island. One year later, the number of Kibwezi gonaxis was estimated at 21,750, and the number of giant African snails was 1,122,500. Kondo (1952) concluded that this snail predator had little effect on the giant African snail. Two years later, Peterson (1954) observed Kibwezi gonaxis snails feeding on native snail species and on the giant African snail, and cannibalizing its own young. By mid-1954, the population of Kibwezi gonaxis on Aguijan was estimated to be 80,800, and the giant African snail was estimated at 37,600 individuals (Davis 1954). Davis (1954) concluded that this snail predator was approximately 60% effective. Based on these conclusions, Kibwezi gonaxis snails were shipped to Hawaii and other Pacific islands for biological control of the giant African snail (Eldredge 1988).

D. ***The inadequacy of existing regulatory mechanisms.***

Currently, no formal or informal protection is given to the humped tree snail by Federal agencies or by private individuals or groups. In 1996, the Government of Guam listed this species as endangered on Guam (5 GCA, Section 63205.(c), “The Endangered Species Act of Guam”). A refuge overlay is currently being pursued with Federal military landowners on Guam. If successful, this overlay refuge will include one of the three remaining populations of this species.

Current Conservation Status: On Guam the U.S. Fish and Wildlife Service is pursuing the establishment of a 11,489 ha (28,158 acre) refuge overlay on military lands. This would cover 19.6 percent of the total land area of the island of Guam, and would include one of the 13 remaining populations of this species.

E. ***Other natural or manmade factors affecting its continued existence.***

Random environmental events can affect the continued existence of the humped tree snail due to the small numbers of populations and individuals that remain. Random environmental events such as typhoons and droughts could eliminate one or more of the 13 remaining populations. This is especially true due to several life-history features of this and all other partulid tree snails (Cowie 1992): reproductive rates are low; eggs are not laid as in most terrestrial snails, but the young are born live; dispersal is very limited with most individuals remaining in the tree or bush into which they were born. All of these traits make these snails very sensitive to any random event that could lead to a reduction or loss of reproductive individuals.

REFERENCES

Carano, P. and P.C. Sanchez. 1964. A complete history of Guam. Charles E. Tuttle, Inc., Rutland, Vermont. 452 pp.

Christensen, C.C. 1984. Are *Euglandina* and *Gonaxiis* effective agents for biological control of the giant African snail in Hawaii? Amer. Malacol. Bull., 2:98-99.

Clarke, B., J. Murray, and M.S. Johnson. 1984. The extinction of endemic species by a program of biological control. Pacific Sci. 38:97-104.

Cowie, R.H. 1992. Evolution and extinction of Partulidae, endemic Pacific island land snails. Philosophical Trans. Royal Soc. London B 335:167-191.

Craig, R.J. and R. Chandran. 1992. Wildlife species recorded during the Aguiguan Expedition: 20-25 May, 1992. pp. 1-7. In R.J. Craid (ed.), The Aguiguan Exedition. Proceedings: Marianas Research Symposium, Northern Marianas College..Crampton, H.E. 1925. Studies on the variation, distribution, and evolution of the genus *Partula* . The species of the Mariana Islands, Guam and Saipan. Carnegie Inst. Wash. Publ. 228A. vii + 116pp., 14 pl.

Davis, C.J. 1954. Report on the Davis Expedition to Aguiguan July-August 1954. Ecological studies, Island of Aguiguan, Mariana Islands as related to the African snail, *Achatina fulica* Bowdich, and its introduced predator, *Gonaxis kibweziensis* (E.A. Smith). Invertebrate Consultants Committee for the Pacific, Pacific Science Board. 24pp.

Eldredge, L.G. 1988. Case studies of the impacts of introduced animal species on renewable resources in the U.S.-affiliated Pacific islands. Pp. 118-146. In B.D. Smith (ed.), Topic reviews in insular resource development and management in the Pacific U.S.- affiliated islands. Univ. Guam Marine Lab. Tech. Rep. 88.

Engbring, J., F. Ramsey., and V. J. Wildman. 1986. Micronesain Forest Bird Survey, 1982: Saipan, Tinian, Agiguan, and Rota. U.S. Fish and Wildlife Service, Honolulu, HI. 143 pp.

Falanruw, M.V.C. 1989a. Vegetation survey of Rota, Tinian, and Saipan. Commonwealth of the Norhtern Mariana Islands. Resource Bulletin PSW-27. Berkeley, CA: Pacific Southwest Forest and Range Experimental Station, Forest Service, U.S. Department of Agriculture. 11 p. +13 maps.

Falanruw, M.V.C. 1989b. Vegetation of Asuncion: a volcanic norhtern Mariana island. Resource Bulletin PSW-28. Berkeley, CA: Pacific Southwest Forest Range Experimental Station, Forest Service, U.S. Department of Agriculture. 11 pp.

Fancy, S.G. and T.J. Snetsinger. 1996. Potential reasons for the decline of the bridled white-eye population on Rota, Mariana Islands. Unpublished report, U.S.G.S., Biological Resources Division, Pacific Islands Ecosystems Research Center, Hawaii National Park, Hawaii.

Fosberg, F.R. 1960. The vegetation of Micronesia. Part 1. General descriptions, the vegetation of the Mariana Islands, and a detailed consideration of the vegetation of Guam. Bull..Amer. Mus. Nat. Hist. 119: 1-75.

Fosberg, F.R. 1971. On present conditions and conservation of forests in Micronesia. In: Pacific Science Association Standing committee on Pacific Botany. Symposium: Planned utilization of the lowland tropical forests. Bogor, Indonesia.

Griffiths, O., A. Cook, and S.M. Wells. 1993. The diet of the introduced carnivorous snail *Euglandina rosea* and its implications for threatened island gastropod faunas. Journal of Zoology, 229:79-89.

Hadfield, M.G., S.E. Miller, and A.H. Carwile. 1993. The decimation of endemic Hawaiian tree snails by alien predators. Amer. Zoologist, 33:620-622.

Hopper, D.R., and B.D. Smith. 1992. The status of tree snails (Gastropoda: Partulidae) on Guam, with a resurvey of sites studied by H. E. Crampton in 1920. Pacific Sci. 46:77-85.

Kanehira, R. 1936. Forests of Rota. Bot. Zool. 4:63-70.

Kondo, Y. 1952. Report on carnivorous snail experiment on Aguiguan Island; primary and secondary *Achatina* -free areas on Rota, and gigantism among *Achatina* on Guam. Invertebrates Consultants Committee for the Pacific, Pacific Science Board. 50pp.

Kondo, Y. 1970. Some aspects of Mariana Islands Partulidae (Mollusca, Pulmonata). Occas. Pap. B.P. Bishop Mus. 24(5):73-90.

Kurozumi, T. 1994. Land molluscs from the northern Mariana Islands, Micronesica. Nat. Hist. Res., Spec. Iss. 1:113-119.

Mead, A.R. 1961. The Giant African Snail: a problem in economic malacology. Univ. Chicago Press.

Miller, S.E. 1993. Final report on surveys of the arboreal and terrestrial snail fauna of American Samoa. Unpublished report submitted to U.S. Fish and Wildlife Service, Pacific Region, Honolulu. 30 pp..

Mueller-Dombois, D. 1981. Fire in tropical ecosystems. In: Fire Regimes and Ecosystem Properties. Pp.137-176. H.A. Mooney, T.M. Bonnicksen, N.L. Christensen, J.E. Lotan, and W.A. Reiners (eds.). USDA, Forest Service Gen. Tech. Rep. WO-26.

Murray, J., E. Murray, M.S. Johnson, and B. Clarke. 1988. The extinction of *Partula* on Moorea. Pacific Sci. 42:150-153.

NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Ecology and Life History 1997. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

Paulay, G. 1994. Biodiversity on oceanic islands: Its origin and extinction. Am. Zoologist

34:134-144.

Pearce-Kelly, P., D. Clarke, and G. Mace. 1994. *Partula* 1994. An action plan for the conservation of the family Partulidae. Report of a workshop held at the Zoological Society of London, 11-13 February 1994.

Peterson, G.D. 1954. Report on progress of carnivorous snail experiments of Agiguan, Mariana Islands. Invertebrate Consultants Committee, Pacific Science Board. 9 pp.

Smith, B.D. 1995. Tree snails, tropical storms, and drought in the Mariana Islands. (Abstract only). Programs and abstracts, American Malacological Union, 61st Annual Meeting, Hilo, Hawaii.

Smith, B.D., and D.R. Hopper. 1994. The Partulidae of the Mariana Islands: Continued threats and declines. Hawaiian Shell News 42(6):10-11.

Tillier, S. and B.C. Clarke. 1983. Lutte biologique et destruction du patrimoine genetique: le cas du mollusgues gasteropodes pulmones dans les territoires Francais du Pacifique. Sel. Evol., 15:559-566.

PETITION TO LIST

Lanai tree snail
(*Partulina semicarinata*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 11/15/94:	
CNOR 09/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 06/13/02:	C

TAXONOMY

The large and colorful *Partulina* tree snails are a major component of the Hawaiian land snail fauna, equaling the diversity of the endangered Oahu genus *Achatinella.* The life histories of species in the two genera are similar, and each group has radiated into over 40 species. The taxonomic status of *Partulina semicarinata* (Achatinellidae) as a valid species is uncontroversial (e.g., Bishop Museum 2002).

NATURAL HISTORY

Ecology
The shells of snails in the genus *Partulina* have a very diverse and colorful array of bands and stripes. Adults require 4-7 years to reach sexual maturity; reproductive rates are low; unlike most terrestrial snails, rather than develop in eggs, young emerge fully developed from the parent; and dispersal is very limited, with most individuals remaining in the tree or bush on which they were born (Hadfield 1986, Hadfield and Miller 1989, 1993, and Kobayashi and Hadfield 1996).

Distribution
Historic populations of *Partulina semicarinata* were restricted to the wet and mesic ohia forests on the island of Lanai. While there are no historic population estimates, qualitative accounts of tree snails indicate that they were widespread and abundant in their habitat, with any single species probably numbering in the tens of thousands. In 1994, field surveys were conducted throughout the remaining native habitat (820-1018 m in elevation) of the historic range. These surveys found very few remaining individuals, which were restricted to small isolated

populations (Hadfield 1994). *Partulina semicarinata* was observed at 12 locations, and a total of 105 individual were.seen (32 adult, 56 juvenile, and 17 new born snails). Some of the sightings occurred in conjunction with a closely related and equally rare congener, *P. variabilis.*

The largest population of about 35 snails (10 adult,18 juvenile, and seven newborn snails) was found in a 5 m by 5 m stand of alien New Zealand flax (*Phormium tenox*) at the edge of the main access road (1018 m elevation). The persistence of this population might be jeopardized because it is located very close to the road and its host vegetation could be subject to removal for road widening or exotic pest control. Additionally, two dead "ground shells", typical of those eaten by rats, were found under the flax. A search of the surrounding native vegetation revealed only small numbers of snails (1 adult and 1 juvenile). Other stands of New Zealand flax were also searched but none were inhabited by *Partulina semicarinata* . A second population of 30 snails (15 adult, 12 juvenile, and 3 new born snails) was found in ohia lehua (*Metrosideros polymorpha*) at 980 m elevation. All other populations were comprised of less than 10 snails and were found on the following host plants: ohia (*Metrosideros polymorpha*), kanawao (*Broussaisia arguta*), kopiko (*Psychotria* sp.), pilo (*Coprosma* spp.), pelea (*Melicope* sp.), and dead hapuu fern (*Cibotium glaucum*).

The decline and disappearance of the Hawaiian tree snails, including the species on Lanai, are the result of many factors acting over an extended period of time (Frick 1856, Baldwin 1887, Pilsbry and Cooke 1912-1914, Bryan 1935, Kondo 1970, 1980, Hart 1975, 1978, Hadfield and Mountain 1980, and Hobdy, 1993). These factors have been reviewed by Christensen (1984) and Hadfield (1986) and are discussed below.

POPULATION STATUS

At the twelve locations a total of 105 individuals of various age classes were recorded (USFWS, 1997). One location (five by five meter area) had 35 snails, one location had 30 snails, and the remaining locations had fewer than10 snails.

Occasional visits to Lanai by malacologists have lead to the suspicion that this snail is either highly threatened or extinct. Predation by alien predators (snails and rats), loss of habitat (to agriculture and the impacts of alien ungulates), and the massive spread of non-native plant species are the major factors contributing to the decline of these snails.

The Hawaii Natural Heritage Program ranks *Partulina semicarinata* as Critically Imperiled.

The U.S. Fish and Wildlife Service classifies *Partulina semicarinata* as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range:	Hawaii, island of Lanai. Historic populations of *Partulina semicarinata* were restricted to the wet and mesic ohia forests on the island of Lanai.
Current range:	Hawaii, island of Lanai. Populations are restricted to 12 locations in wet forested areas.
Land ownership:	With the exception of a few parcels in the town of Lanai City, the entire island of Lanai is privately owned by Castle and Cooke Land Company.

Removal of forests and the introduction and spread of invasive vegetation began with the prehistoric arrival of the Polynesians and accelerated after the arrival of Europeans in 1778 (Hobdy 1993). Lower elevation lands now used for pasture, agriculture, or housing once supported native forests occupied by achatinellid snails, including *Partulina semicarinata* (Pilsbry and Cooke 1912-1914). Forests not cleared for agriculture were invaded by feral cattle, horses, goats, deer and pigs (Baldwin 1887). The grazing activities of these mammals reduced the forest understory, prevented recovery by native plants, and aided the invasion of exotic plants by spreading their seeds and creating disturbed areas where seeds could germinate (Hobdy 1993).

At the present time on Lanai, axis deer (*Axis axis*) remain a serious threat to the native forests and habitat of *Partulina semicarinata*. This alien deer is managed by the private landowner and the State of Hawaii as a game species. Human activities such as hiking and road repair and construction are also significant threats on Lanai. Roads and trails contribute to the spread of exotic vegetation. Reforestation with non-native species such as eucalyptus, ironwood, and Norfolk pine have also contributed to the loss of tree snail habitat. Forest fires have a particularly catastrophic effect on snail populations as well as their habitats. Alteration of the forest canopy and understory by all of these agents has resulted in changes in moisture and humidity which further inhibit the recovery of native forests to suitable habitat for native tree snails (Pilsbry and Cooke 1912-1914).

B. *Overutilization for commercial, recreational, scientific, or educational purposes.*

Collecting Hawaiian snails was a popular activity, especially in the late eighteen hundreds. Several private collections approached 100,000 specimens each, and many of these collections were donated or sold to museums; the collection at the Bishop Museum contains over half a million shells. Other museums also hold significant collections of these shells, including the Australian Museum, the University of Missouri, the Natural History Museum in London, the Field Museum of Natural History in Chicago, the Academy of Natural Sciences of Philadelphia, and the Museum of Comparative Zoology at Harvard University (Hadfield et al. 1989).

Historically, collecting was probably responsible for a decline in ranges and abundance of some species of Hawaiian tree snails (Hadfield 1986). In the mid- to late-1800s "land shell fever" hit the island, and hundreds of thousands of snails were collected for their shells (Emerson, Ms., undated, post-1900,.Hadfield 1986, and Solem 1990). By 1914 several species had declined drastically and were considered rare (Pilsbry and Cooke 1912-1914). Collecting of Hawaiian tree snails had abated by about 1940 but may still occur. For the remaining few *Partulina semicarinata*, the collection of a single adult snail can remove all or a large percentage of the reproductive population from a bush or tree, thereby driving that population closer to extinction. The collection of tree snails must now be viewed as a threat to the further survival of the species.

C. *Disease or predation.*

The alien carnivorous snail *Euglandina rosea* and the European black rat (*Rattus rattus*) serve as the two major predators on extant populations of Hawaiian tree snails. In particular, the black rat appears to be a major threat to *Partulina semicarinata* on Lanai (Hobdy 1993 and Hadfield 1994). Other possible predators that occur on Lanai include the terrestrial flatworm *Geoplana septemlineata*, which has been reported to feed on snails (Mead 1979), the terrestrial snail *Oxychilus alliarius* (Severns 1984), the Norway rat (*Rattus norvegicus*), and the Polynesian rat (*Rattus exulans*). Parasitism and disease, though not documented in *Partulina*, may also contribute to the decline of snail populations (Hadfield 1986 and Cunningham and Daszak 1998).
Most recently, the predatory flatworm *Platydemis manokwari* has been found on the islands of Oahu and Hawaii. It is probably on all of the main islands and may pose a threat to all of Hawaii's tree snails. Observations on Guam have documented the devastating impact of this predator of the native tree snail fauna of that island (Hopper and Smith 1992, personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form).

Euglandina rosea was introduced to Hawaii between 1955 and 1956 by the Hawaii State Department of Agriculture in an effort to control the African snail *Achatina fulica* (Hadfield and Kay 1981). *Euglandina rosea* is a voracious predator on other terrestrial and arboreal snails and is responsible for the extinction of all eight species of the *Partula* tree snails on the island of Moorea in French Polynesia (Tillier and Clarke 1983, Clarke et al. 1984, Murray et al. 1988, and Griffiths et al. 1993). *Euglandina rosea* follows mucous trails of other gastropods (Cook 1985) and will climb trees and bushes to capture its prey. Since its introduction, *E. rosea* has spread to low and.high elevations throughout the Hawaiian Islands and has been the cause of local extinction of many populations of *Achatinella* (field notes of Hadfield, Kondo, Christensen, and Chung cited in U.S. Fish and Wildlife Service candidate assessment form).

An example of the impact of *Euglandina rosea* follows:

A population of *Achatinella mustelina* occupying a 5 by 5 m quadrate at an elevation of 730 m on Kanehoa Ridge in the central Waianae Range was intensively studied by mark-recapture methods from 1974 to 1976 (Hadfield and Mountain 1980). Among other demographic parameters determined, the population of *A. mustelina* was estimated at 215 snails in the quadrate. Furthermore, the population was stable during the regular mark-recapture censusing, with a low level of mortality due to rat predation. Between 1972 and 1976 *Euglandina rosea* was observed at successively higher elevations along Kanehoa Ridge; they were observed at 300 m in 1974 and near 700 m in 1977. In August 1979, shells of *E. rosea* were abundant at the study site, and an intensive search of the quadrate failed to locate a single living individual of *A. mustelina* or any other terrestrial or arboreal snail species, many of which had previously been observed in the area. A broader search of the area around the study site showed that the invasion of once rich tree snail habitat by *E. rosea* had led to the total disappearance of the native snail fauna.

The black rat became widespread on Oahu in the 1870's (Atkinson 1977 and Perkins 1899). In 1887 Baldwin noted that it was not uncommon to find large numbers of shells around the lairs of rats and mice (Baldwin 1887). Kondo mentions in his field notes from the 1950s (Appendix II) that *Achatinella* shells damaged by rats were common beneath the snail trees at many locations. The best documented example of the impact of rats on tree snails comes from Hadfield et al. (1993). The study site at which the rat population irruption occurred had been surveyed once a month for 4 ½ years prior to the irruption.

On the basis of shells recovered on the ground at each visit, Hadfield and his colleagues estimated that about 10 percent of the shells of *Achatinella mustelina* had been broken by rats. Between January and April 1988, rats increased in this well-studied site and killed about half of the snails in the population. The rats selectively preyed on larger snails, eliminating about 76 percent of the reproductive adults and 72 percent of snails over 15 mm in length. Only 16 percent of the snails under 15 mm long were killed by rats. Even if no other disturbances occur at this site, the snail population will take years to recover from this catastrophic surge in rat-.caused mortality.

D. *The inadequacy of existing regulatory mechanisms.*

Currently, no formal or informal protection is given to *Partulina semicarinata* by Federal or State agencies or by private individuals or groups.

Current Conservation Efforts: Currently, there are no conservation actions being carried out that will benefit this species. However, a captive propagation program is currently underway in Hawaii for the closely related Oahu tree snails in the genus *Achatinella* as well as other species of *Partulina*. If the Lanai tree snails are listed as endangered or threatened, they could be included in this captive propagation program.

E. *Other natural or manmade factors affecting its continued existence.*

Random environmental events (e.g., hurricanes and droughts) could affect the continued existence of the Lanai tree snails due to the small numbers of populations and individuals that remain. This is especially true due to several life-history features of this and all other *Partulina* tree snails (Hadfield 1986, Hadfield and Miller 1989, 1993, and Kobayashi and Hadfield 1996): adults require 4-7 years to reach sexual maturity; reproductive rates are low; unlike most terrestrial snails, rather than develop in eggs, young emerge fully developed from the parent; and dispersal is very limited, with most individuals remaining in the tree or bush on which they were born. All of these traits make these snails very sensitive to any event that could lead to a reduction or loss of reproductive individuals.

REFERENCES

Atkinson, I.A.E. 1977. A reassessment of factors, particularly *Rattus rattus* L., that influenced the decline of endemic forest birds in the Hawaiian Islands. Pacific Science, 31:109-133.

Baldwin, D.D. 1887. The land shells of the Hawaiian Islands. Hawaiian Annual, 1887: 55-63.

Bishop Museum of Honolulu. Hawaiian Freshwater and Terrestrial Mollusk Checklist, revised April 9, 2002. http://www2.bishopmuseum.org/HBS/checklist/query.asp?grp=Mollusk

Bryan, E.H., Jr. 1935. Hawaiian land shells. Hawaiian Nature Notes, Honolulu Star Bulletin, Ltd., Honolulu. 208-213.

Christensen, C.C. 1984. Are *Euglandina* and *Gonaxis* effective agents for biological control of the giant African snail in Hawaii? American Malacol. Bull., 2:98-99.

Clarke, B.C., J. Murray, and M.S. Johnson. 1984. The extinction of endemic species by a program of biological control. Pacific Science, 38:97-104.

Cook, A. 1985. Functional aspects of trail following by the carnivorous snail *Euglandina rosea* . *Malacologia*, 26:173-181.

Cunningham, A.A. and P. Daszak. 1998. Extinction of a species of land snail due to infection with a microsporidian parasite. Cons. Biol., 12(5): 1139-1141..Emerson, O.P. Undated, post- 1900. The gay Achatinellidae and their habits. Unpublished manuscript, B.P. Bishop Museum.

Frick, D. 1856. Notes on Hawaiian terrestrial conchology. Sandwich Islands Monthly Magazine, 1:137-140.

Griffiths, O., A. Cook, and S.M. Wells. 1993. The diet of the introduced carnivorous snail *Euglandina rosea* and its implications for threatened island gastropod faunas. Journal of Zoology, London 229:79-89.

Hadfield, M.G. 1986. Extinction in Hawaiian achatinelline snails. Malacologia, 27:67-81.

Hadfield, M.G. 1994. Final Report: USFWS Grant No. 14-48-0001- 93715, A preliminary survey of the *Partulina* tree snails on Lanai. Unpublished U.S. Fish and Wildlife Report, Pacific Islands Office, Honolulu, Hawaii.

Hadfield, M.G. and E.A. Kay. 1981. The multiple villainies of *Euglandina rosea* (or its human proponents). Hawaiian Shell News, 29:5-6.

Hadfield, M.G. and S.E. Miller. 1989. Demographic studies on Hawaii's endangered tree snails:

Partulina proxima . Pacific Science, 43(1):1-16.

Hadfield, M.G., S.E. Miller and A.H. Carwile. 1989. Recovery plan for the Oahu tree snails of the genus *Achatinella* . U.S. Fish and Wildlife Service, 300 Ala Moana Blvd., Honolulu, Hawaii 96850.

Hadfield, M.G., S.E. Miller, and A.H. Carwile. 1993. The decimation of endemic Hawaiian tree snails by alien predators. American Zoologist, 33:620-622.

Hadfield, M.G., and B.S. Mountain. 1980. A field study of a vanishing species, *Achatinella mustelina* (Gastropoda, Pulmonata), in the Waianae Mountains of Oahu. Pacific Science, 34:345- 358.

Hart, A.D. 1975. Living jewels imperiled. Defenders, 50(6):482- 486..Hart, A.D. 1978. The onslaught against Hawaii's tree snails. Natural History. December; 46-57 pp.

Hobdy, B. 1993. Lanai ! a case study: the loss of biodiversity on a small Hawaiian island. Pacific Science, 47(3):201-210.

Hopper, D.R. and B.D. Smith. 1992. The status of tree snails (Gastropoda: Partulidae) on Guam, with a resurvey of sites studies by H.E. Crampton in 1920. Pacific Science, 46:77-85.

Kobayashi, S.R., and M.G. Hadfield. 1996. An experimental study of growth and reproduction in the Hawaiian tree snails *Achatinella mustelina* and *Partulina redfieldii* (Achatinellinae). Pacific Science, 50:339-354.

Kondo, Y. 1970. Colloquium on endangered species of Hawaii; extinct land molluscan species. Rept., meeting at U.S. National Museum.

Kondo, Y. 1980. Endangered land shells, Pacific. Text of paper delivered to Internat. Union for Conservation of Nature and Natural Resources. 15 pp.

Mead, A. 1979. Economic malacology with particular reference to *Achatina fulica* Fretter, V. and Peake, J. (eds.): Pulmonates, 2B. Academic Press, London. 150 pp.

Murray, J.J., E. Murray, M.S. Johnson, and B.C. Clarke. 1988. The extinction of *Partula* on Moorea. Pacific Science, 42:150-153.

Perkins, R.C.L. 1899. Introduction. In: Sharp D. (ed.). Fauna Hawaiiensis. Cambridge University Press, Cambridge, U.K., I: xv-ccxxviii.

Pilsbry, H.A. and C.M. Cooke, Jr. 1912-1914. Achatinellidae. Manual of Conchology, 2nd Ser., Vol. 21.

Severns, M. 1984. Another threat to Hawaii’s endemics. Hawaii Shell News, 32(12): 1, 9.

Solem, A. 1990. How many Hawaiian land snail species are left? And what we can do for them. Bishop Museum Occasional Papers, 3:27-40

Tillier, S. and B.C. Clarke. 1983. Lutte biologique et destruction du patrimoine genetique: le cas du mollusques gasteropodes pulmones dans les territoires francais du Pacifique. Sel. Evol., 15:559-566..

U.S. Fish and Wildlife Service. 1997. Category and Listing Priority Forms.

PETITION TO LIST

Lanai tree snail
(*Partulina variabilis*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 11/15/94:	
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

The large and colorful *Partulina* tree snails are a major component of the Hawaiian land snail fauna, equaling the diversity of the endangered Oahu genus *Achatinella.* The life histories of species in the two genera are similar, and each group has radiated into over 40 species. The taxonomic status of *Partulina variabilis* (Achatinellidae) as a valid species is uncontroversial (e.g., Bishop Museum 2002).

NATURAL HISTORY

Ecology
The shells of snails in the genus *Partulina* have a very diverse and colorful array of bands and stripes. Adults require 4-7 years to reach sexual maturity; reproductive rates are low; unlike most terrestrial snails, rather than develop in eggs, young emerge fully developed from the parent; and dispersal is very limited, with most individuals remaining in the tree or bush on which they were born (Hadfield 1986, Hadfield and Miller 1989, 1993, and Kobayashi and Hadfield 1996).

Distribution
Historic populations of *P. variabilis* were restricted to the wet and mesic ohia forests on the island of Lanai. While there are no historic population estimates, qualitative accounts of tree snails indicate that they were widespread and abundant in their habitat, with any single species probably numbering in the tens of thousands. In 1994, field surveys were conducted throughout the remaining native habitat (820-1018 m in elevation) of the historic range, indicating that there are very few remaining individuals restricted to small isolated populations (Hadfield 1994).

Partulina variabilis was observed at 16 locations, and a total of 175 individual were seen (28 adult, 111 juvenile, and 36 new born snails). Some of the sightings occurred in conjunction with a closely related and equally rare congener, *Partulina semicarinata* . All of the populations of these snails had only 1-2 adults and were found on the following host plants: ohia (*Metrosideros polymorpha*), kanawao (*Broussaisia arguta*), kopiko (*Psychotria* sp.), pilo (*Coprosma* spp.), pelea (*Melicope* sp.), and dead hapuu fern (*Cibotium glaucum*). Alien vegetation used by *Partulina variabilis* includes guava (*Psidium gunjava*)and New Zealand ti (*Cordyline australis*).

The decline and disappearance of the Hawaiian tree snails, including the species on Lanai, are the result of many factors acting over an extended period of time (Frick 1856, Baldwin 1887, Pilsbry and Cooke 1912-1914, Bryan 1935, Kondo 1970, 1980, Hart 1975, 1978, Hadfield and Mountain 1980, and Hobdy 1993). These factors have been reviewed by Christensen (1984) and Hadfield (1986) and are discussed below.

POPULATION STATUS

Restricted to 16 locations that face multiple threats. At the 16 locations a total of 175 individuals of various age classes were recorded (USFWS, 1997). Each location only contained one to two adults.

Occasional visits to Lanai by malacologists have lead to the suspicion that this snail is either highly threatened or extinct. Predation by alien predators (snails and rats), loss of habitat (to agriculture and the impacts of alien ungulates), and the massive spread of non-native plant species are the major factors contributing to the decline of this snail.

The Hawaii Natural Heritage Program ranks *Partulina variabilis* as Critically Imperiled.

The U.S. Fish and Wildlife Service classifies *Partulina variabilis* as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range:	Hawaii. Restricted to the wet and mesic ohia forests on the island of Lanai.
Current range:	Hawaii (island of Lanai). Populations are restricted to 16 locations in wet forested areas.
Land ownership:	With the exception of a few parcels in the town of Lanai City, the entire island of Lanai is privately owned by Castle and Cooke Land Company.

Removal of native forests and the introduction and spread of invasive vegetation began with the prehistoric arrival of the Polynesians and accelerated after the arrival of Europeans in 1778 (Hobdy 1993). Lower elevation lands, now used for pasture, agriculture, or housing, once supported native forests occupied by achatinellid snails, including *Partulina variabilis* (Pilsbry and Cooke 1912-1914). Forests not cleared for agriculture were invaded by feral cattle, horses, goats, deer and pigs (Baldwin 1887). The grazing activities of these mammals reduced the forest understory, prevented recovery by native plants, and aided the invasion of exotic plants by spreading their seeds and creating disturbed areas where seeds could germinate (Hobdy 1993).

At the present time on Lanai, axis deer (*Axis axis*) remain a serious threat to the native forests and habitat of *Partulina variabilis* . This alien deer is managed by the private landowner and the State of Hawaii as a game species. Human activities such as hiking and road repair and construction are also significant threats on Lanai. Roads and trails contribute to the spread of exotic vegetation. Reforestation with non- native species such as eucalyptus, ironwood, and Norfolk pine has also contributed to the loss of tree snail habitat. Forest fires have a particularly catastrophic effect on snail populations as well as their habitats. Alteration of the forest canopy and understory by all of these agents have resulted in changes in moisture and humidity which further inhibit the recovery of native forests to suitable habitat for native tree snails (Pilsbry and Cooke 1912-1914).

B. *Overutilization for commercial, recreational, scientific, or educational purposes.*

Collecting Hawaiian snails was a popular activity, especially in the late eighteen hundreds. Several private collections approached 100,000 specimens each, and many of these collections were donated or sold to museums; the collection at the Bishop Museum contains over half a million shells. Other museums also hold significant collections of these shells, including the Australian Museum, the University of Missouri, the Natural History Museum in London, the Field Museum of Natural History in Chicago, the Academy of Natural Sciences of Philadelphia, and the Museum of Comparative Zoology at Harvard University (Hadfield et al. 1989).

Historically, collecting was probably responsible for a decline in ranges and abundance of some species of Hawaiian tree snails (Hadfield 1986). In the mid-to late-1800s "land shell fever" hit the island, and hundreds of thousands of snails were collected for their shells (Emerson, Ms., undated, post-1900, Hadfield 1986, and Solem 1990). By 1914 several species had declined drastically and were considered rare (Pilsbry and Cooke 1912-1914). Collecting of Hawaiian tree snails had abated by about 1940 but may still occur periodically. For the remaining few *Partulina variabilis*, the collection of a single adult snail can remove all or a large percentage of the reproductive population from a bush or tree, thereby driving that population closer to extinction. The collection of tree snails must now be viewed as a threat to the further survival of the species.

C. *Disease or predation.*

The carnivorous snail *Euglandina rosea* and the European black rat (*Rattus rattus*) serve as the two major predators on.extant populations of Hawaiian tree snails. In particular, the black rat

appears to be a major threat to *Partulina variabilis* on Lanai (Hobdy 1993 and Hadfield 1994). Other possible predators that occur on Lanai include the terrestrial flatworm *Geoplana septemlineata*, which has been reported to feed on snails (Mead 1979), the terrestrial snail *Oxychilus alliarius* (Severns 1984), the Norway rat (*Rattus norvegicus*), and the Polynesian rat (*Rattus exulans*). Parasitism and disease, though not documented in *Partulina*, may also contribute to the decline of snail populations (Hadfield 1986 and Cunningham and Daszak 1998).
Most recently, the predatory flatworm *Platydemis manokwari* has been found on the islands of Oahu and Hawaii. It is probably on all of the main islands and may pose a great threat to all of Hawaii's tree snails. Observations on Guam have documented the devastating impact of this predator of the native tree snail fauna of that island (Hopper and Smith 1992 and personal communication 1995 cited in U.S. Fish and Wildlife Service candidate assessment form).

Euglandina rosea was introduced to Hawaii between 1955 and 1956 by the Hawaii State Department of Agriculture in an effort to control the African snail, *Achatina fulica* (Hadfield and Kay 1981). *Euglandina rosea* is a voracious predator on other terrestrial and arboreal snails and is responsible for the extinction of all eight species of the *Partula* tree snails on the island of Moorea in French Polynesia (Tillier and Clarke 1983, Clarke et al. 1984, Murray et al. 1988, and Griffiths et al. 1993). *Euglandina rosea* follows mucous trails of other gastropods (Cook 1985) and will climb trees and bushes to capture its prey. Since its introduction, *E. rosea* has spread to low and high elevations throughout the Hawaiian Islands and has been the cause of local extinction of many populations of *Achatinella* (field notes of Hadfield, Kondo, Christensen, and Chung cited in U.S. Fish and Wildlife Service candidate assessment form).

An example of the impact of Euglandina rosea follows:

A population of *Achatinella mustelina* occupying a 5 by 5 m quadrate at an elevation of 730 m on Kanehoa Ridge in the central Waianae Range was intensively studied by mark-recapture methods from 1974 to 1976 (Hadfield and Mountain 1980). Among other demographic parameters determined, the population of *A. mustelina* was estimated at 215 snails in the quadrate. Furthermore, the population was stable during the regular mark-recapture censusing, with a low level of mortality due to rat predation. Between 1972 and 1976 *Euglandina rosea* was observed at successively higher elevations along Kanehoa Ridge; they were observed at 300 m in 1974 and near 700 m in 1977. In August 1979, shells of *E. rosea* were abundant at the study site, and an intensive search of the quadrate failed to locate a single living individual of *A. mustelina* or any other terrestrial or arboreal snail species, many of which had previously been observed in the area. A broader search of the area around the study site showed that the invasion of once rich tree snail habitat by *E. rosea* had led to the total disappearance of the native snail fauna.

The black rat became widespread on Oahu in the 1870's (Atkinson 1977 and Perkins 1899). In 1887 Baldwin noted that it was not uncommon to find large numbers of shells around the lairs of rats and mice (Baldwin 1887). Kondo mentions in his field notes from the 1950's (Appendix II) that *Achatinella* shells damaged by rats were common beneath the snail trees at many locations. The best documented example of the impact of rats on tree snails comes from Hadfield et al. (1993). The study site where rat populations irrupted had been surveyed once a month for 4 ½ years prior to the irruption. On the basis of shells recovered on the ground at each visit, Hadfield and his colleagues estimated that about 10 percent of the shells of *Achatinella mustelina* had been broken by rats. Between January and April 1988, rats increased in this well-studied site and killed about half of the snails in the population. The rats selectively preyed on larger snails, eliminating about 76 percent of the reproductive adults and 72 percent of snails over 15 mm in length. Only 16 percent of the snails under 15 mm long were killed by rats. Even if no other disturbances occur at this site, the snail population will take years to recover from this catastrophic surge in rat- caused mortality.

D. *The inadequacy of existing regulatory mechanisms.*

Currently, no formal or informal protection is given to *Partulina variabilis* by Federal or State agencies or by private individuals or groups.

Current Conservation Efforts: Currently, there are no conservation actions being carried out that will benefit this species. However, a captive propagation program is currently underway in Hawaii for the closely related Oahu tree snails in the genus *Achatinella* as well as other species of *Partulina* . If the Lanai tree snails are listed as endangered or threatened, they could be included in this captive propagation program.

E. *Other natural or manmade factors affecting its continued existence.*

Random environmental events (e.g., hurricanes and droughts) could affect the continued existence of the Lanai tree snails due to the small numbers of populations and individuals that remain. The snails very sensitive to any event that could lead to a reduction or loss of reproductive individuals.

REFERENCES

Atkinson, I.A.E. 1977. A reassessment of factors, particularly *Rattus rattus* L., that influenced the decline of endemic forest birds in the Hawaiian Islands. Pacific Science, 31:109-133.

Baldwin, D.D. 1887. The land shells of the Hawaiian Islands. Hawaiian Annual, 1887:55-63.

Bryan, E.H., Jr. 1935. Hawaiian land shells. Hawaiian Nature Notes, Honolulu Star Bulletin, Ltd., Honolulu. 208-213.

Christensen, C.C. 1984. Are *Euglandina* and *Gonaxis* effective agents for biological control of the giant African snail in Hawaii? American Malacol. Bull., 2:98-99.

Clarke, B.C., J. Murray, and M.S. Johnson. 1984. The extinction of endemic species by a program of biological control. Pacific Science, 38:97-104.

Cook, A. 1985. Functional aspects of trail following by the carnivorous snail *Euglandina rosea*. Malacologia, 26:173-181.

Cunningham, A.A. and P. Daszak. 1998. Extinction of a species of land snail due to infection with a microsporidian parasite. Cons. Biol., 12(5): 1139-1141.

Emerson, O.P. Undated, post-1900. The gay Achatinellidae and their habits. Unpublished manuscript, B.P. Bishop Museum.

Frick, D. 1856. Notes on Hawaiian terrestrial conchology. Sandwich Islands Monthly Magazine, 1:137-140.

Griffiths, O., A. Cook, and S.M. Wells. 1993. The diet of the introduced carnivorous snail *Euglandina rosea* and its implications for threatened island gastropod faunas. Journal of Zoology, London 229:79-89.

Hadfield, M.G. 1986. Extinction in Hawaiian achatinelline snails. Malacologia, 27:67-81.

Hadfield, M.G. 1994. Final Report: USFWS Grant No. 14-48-0001- 93715, A preliminary survey of the *Partulina* tree snails on Lanai. Unpublished U.S. Fish and Wildlife Report, Pacific Islands Office, Honolulu, Hawaii.

Hadfield, M.G. and E.A. Kay. 1981. The multiple villainies of *Euglandina rosea* (or its human proponents). Hawaiian Shell News, 29:5-6.

Hadfield, M.G. and S.E. Miller. 1989. Demographic studies on Hawaii's endangered tree snails: *Partulina proxima* . Pacific Science, 43(1):1-16.

Hadfield, M.G., S.E. Miller and A.H. Carwile. 1989. Recovery plan for the Oahu tree snails of the genus *Achatinella* . U.S. Fish and Wildlife Service, 300 Ala Moana Blvd., Honolulu, Hawaii 96850.

Hadfield, M.G., S.E. Miller, and A.H. Carwile. 1993. The decimation of endemic Hawaiian tree snails by alien predators. American Zoologist, 33:620-622.

Hadfield, M.G., and B.S. Mountain. 1980. A field study of a vanishing species, *Achatinella mustelina* (Gastropoda, Pulmonata), in the Waianae Mountains of Oahu. Pacific Science, 34:345- 358.

Hart, A.D. 1975. Living jewels imperiled. Defenders, 50(6):482- 486.

Hart, A.D. 1978. The onslaught against Hawaii's tree snails. Natural History. December;46-57 pp..

Hobdy, B. 1993. Lanai ! a case study: the loss of biodiversity on a small Hawaiian island. Pacific

Science, 47(3):201-210.

Hopper, D.R. and B.D. Smith. 1992. The status of tree snails (Gastropoda: Partulidae) on Guam, with a resurvey of sites studies by H.E. Crampton in 1920. Pacific Science, 46:77-85.

Kobayashi, S.R., and M.G. Hadfield. 1996. An experimental study of growth and reproduction in the Hawaiian tree snails *Achatinella mustelina* and *Partulina redfieldii*

(Achatinellinae). Pacific Science, 50:339-354..Kondo, Y. 1970. Colloquium on endangered species of Hawaii; extinct land molluscan species. Rept., meeting at U.S. National Museum.

Kondo, Y. 1980. Endangered land shells, Pacific. Text of paper delivered to Internat. Union for Conservation of Nature and Natural Resources. 15 pp.

Mead, A. 1979. Economic malacology with particular reference to *Achatina fulica* Fretter, V. and Peake, J. (eds.): Pulmonates, 2B. Academic Press, London. 150 pp.

Murray, J.J., E. Murray, M.S. Johnson, and B.C. Clarke. 1988. The extinction of *Partula* on Moorea. Pacific Science,42:150-153.

Perkins, R.C.L. 1899. Introduction. In: Sharp D. (ed.). Fauna Hawaiiensis. Cambridge University Press, Cambridge, U.K., I: xv-ccxxviii.

Pilsbry, H.A. and C.M. Cooke, Jr. 1912-1914. Achatinellidae. Manual of Conchology, 2nd Ser., Vol. 21.

Severns, M. 1984. Another threat to Hawaii's endemics. Hawaii Shell News, 32(12):1, 9.

Solem, A. 1990. How many Hawaiian land snail species are left nd what we can do for them? Bishop Museum Occasional Papers, 3:27-40.

Tillier, S. and B.C. Clarke. 1983. Lutte biologique et destruction du patrimoine genetique: le cas du mollusques gasteropodes pulmones dans les territoires francais du Pacifique. Sel. Evol., 15:559-566..

U.S. Fish and Wildlife Service. 1997. Category and Listing Priority Forms.

PETITION TO LIST

Langford’s tree snail, akaleha (*Partula langfordi*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 11/15/94:	
CNOR 2/28/96:	C
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

The genus *Partula* (Partulidae) includes four extant species found only in the Mariana Islands, and 94 additional species recorded from other Pacific islands. *Partula langfordi* is very similar to *P. gibba*; further study is required to resolve their taxonomic status (NatureServe Explorer 2001).

NATURAL HISTORY

The biology of several of the partulid tree snails of the.Mariana Islands is being studied by B.D. Smith at the University of Guam (personal communication cited in U.S. Fish and Wildlife Service candidate assessment form). While detailed information from these studies is not currently available, general information on the biology of closely related partulid tree snails has been published and reviewed by Cowie (1992). As with all terrestrial pulmonate snails, the Mariana Islands tree snails are hermaphroditic. In general, partulid snails begin reproducing in less that 12 months and may live up to 5 years. Up to 18 young are produced each year and some species, such as the humped tree snail (*Partula gibba*) of the Mariana Islands, may be self-fertile. While most terrestrial snails lay eggs, the partulid tree snails give birth to fully developed young. The snails are generally nocturnal, living on bushes or trees and feeding on decaying plant material. There are no known natural predators of these snails, although many of these species are currently threatened by alien snail predators.

The Partulidae, including those of the Mariana Islands, prefer cool, shaded forest habitats (Crampton 1925, Cowie 1992, and Smith 1995) with high humidity.

The high islands of the Mariana archipelago historically supported five species of partulid tree snails, and represents the northwestern limit of the geographical range of the Partulidae.

POPULATION STATUS

Langford's tree snail is restricted to the small island of Aguijan where it occurs sympatrically with *Partula gibba* (Kondo 1970). In 1985, five adult *Partula langfordi* were collected from the west end of the island (Smith 1995). In 1992, one live snail was observed on the northwest terrace of the island (Smith 1995). Currently, this is the only known individual of this species. In no case has a partulid tree snail species been shown to have stable or increasing numbers of individuals or populations.

Thirty percent of the 123 partulid species are extinct and 39 percent are declining toward extinction. The current status of 31 percent of the species cannot be characterized due to insufficient information.

In 1996, the Government of Guam listed this species as endangered on Guam (5 GCA, Section 63205.(c), "The Endangered Species Act of Guam").

The U.S. Fish and Wildlife Service classifies the Langford's tree snail as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. ***The present or threatened destruction, modification, or curtailment of its habitat or range.***

Historical range:	Commonwealth of the Northern Mariana Islands (Aguijan).
Current range:	Commonwealth of the Northern Mariana Islands (Aguijan).
Land ownership:	The island of Aguijan is owned by the Commonwealth of the Northern Mariana Islands.

Crampton (1925) described the habitat requirements of the partulid trees snails of the Mariana Islands as follows: "...the indispensable requisites are that there shall be a sufficiently high and dense growth to provide shade, to conserve moisture, and.to effect the production of a rich humus. Hence the limits to the areas occupied by Partulae are set by the more ultimate ecological conditions which determine the distribution of suitable vegetation." In fact, the ecological settings that meet the basic requirements for partulid snail were numerous in the Mariana Islands prior to World War II. They include coastal strand vegetation, forested river borders, and lowland and highland forests (Crampton 1925). Crampton (1925) further describes the intact structure of native Mariana forests as having four general levels: the high trees; the shrubs and *Pandanus* ; the cycads and taller ferns; and the succulent herbs. He notes that the Mariana Islands partulid tree snails preferentially live on subcanopy vegetation and do not use the high canopy trees.

Prior to the arrival of humans, the Mariana Islands were believed to be mostly forested (Fosberg 1960, 1971). With the arrival and population growth of the aboriginal Chamorro people 4,000 years ago (Carano and Sanchez 1964), native forests began to be cleared and savanna grasslands began to develop (Mueller- Dumbois 1981). During the Spanish occupation of the Mariana Islands (1521-1899), alien goats, pigs, cattle, and deer were introduced (Engbring et al. 1986 and Carano and Sanchez 1964), which lead to a continuing decline in area and quality of tree snail habitat. On Aguijan, goats have been the main source of habitat loss.

Sweeping ecological changes took place during the Japanese occupation from 1914-1944 (Kanehira 1936, Fosberg 1960, 1971, and Engbring et al. 1986). Extensive removal of native forests for the development of sugar cane was pursued on all of the main islands. These fields covered almost all of Tinian and much of Guam, Saipan, Rota, and Aguijan. In 1920, Crampton (1925) commented on the loss of partulid tree snail habitat. He stated that much deforestation had occurred in the southern half of Guam and that the savanna grassland habitat, which is unsuitable for tree snails, had greatly expanded during "recent centuries." He also noted that extensive wood cutting had reduced the forest canopy. In the 1930s the island of Aguijan was mostly cleared of native forest to support sugar cane and pineapple production. The abandoned fields and an abandon airstrip are now over grown with alien weeds. The remaining native forest understory has greatly suffered from foraging by alien goats and the invasion of weeds.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

Overutilization is not known to be a factor currently affecting any of the partulid tree snails from the Mariana Islands. Future overutilization of this species is not anticipated. However, necklaces or leis made from partulid snails shells are occasionally found for sale. Any collection of *Partula langfordi* could significantly contribute to the continued decline of the species and the local extinction of specific populations.

C. ***Disease or predation.***

Crampton (1925) states that "There are no other animals in the Mariana Islands whose presence or activities influence the lives or numbers of Partulae, so far as observation goes." Since World War II, several introductions of alien predators have completely changed this historic condition. Predation by the alien rosy glandina snail (*Euglandina rosea*) and the alien Manokwar flatworm (*Platydemis manokwari*) is a serious threat to the survival of all four species of partulid tree snails from the Mariana Islands.

The predatory rosy glandina snail is native to the southeastern United States, and was introduced into the Mariana Islands in 1957 by the governments of Guam and the Commonwealth of the Northern Mariana Islands, following the recommendations of the State of Hawaii Department of Agriculture (Eldredge 1988). Since being introduced, this voracious predator of snails has been dispersed by humans throughout the main islands. The rosy glandina snail was imported to these and other Pacific islands as a biological control agent for another alien snail, the giant African snail (*Achatina fulica*), which is an agricultural pest. However, while its effectiveness as a biological control agent against the giant African snail is questionable (Christiansen 1984, Tillier and Clarke 1983, and Mead 1961), field observations have established that the rosy glandina snail will readily feed on native Pacific island tree snails, including the Partulidae such as those of the Mariana Islands (Murray et al. 1988, Tillier and Clarke 1983, and Miller 1993), as well as Hawaiian achatinellid tree snails (Hadfield et al. 1993). A study of the diet of the rosy glandina snail on the island of Mauritius in the Indian Ocean showed that this alien predator preferred native snails over the targeted alien giant African snail (Griffiths et al. 1993).

On some or all of these tropical islands, the rosy glandina snail has expanded its normal terrestrial feeding behavior to include native snails found in arboreal habitats (Hadfield et al. 1993, Miller 1993, and Murray et al. 1988). The rosy glandina snail has caused the extinction of many populations and species of native snails throughout the Pacific islands (Hadfield et al. 1993, Miller 1993, Hopper and Smith 1992, Murray et al. 1988, and Tillier and Clarke 1983). Where it still resides, the rosy glandina snail represents a significant threat to the survival of native Mariana Islands snails, including the four remaining partulid tree snails: *Partula gibba*, *Partula langfordi*, *Partula radiolata*, and *Samoana fragilis*.

Predation on native partulid tree snails by the terrestrial Manokwar flatworm is also a threat to the long-term survival of these snails. This voracious snail predator was introduced into Guam in 1978 and has been spread by humans throughout the main Mariana Islands (Eldredge 1988). It has proven to be an effective biological control agent for the giant African snail, but has also contributed to the decline of native tree snails, in part due to its ability to ascend into trees and bushes that support native snails. Areas with populations of the flatworm usually lack partulid tree snails or have declining numbers of snails (Hopper and Smith 1992).

The first bio-control efforts directed at the giant African snail were conducted on the small island of Aguijan (also known as Aguijan or Goat Island) in the Mariana Archipelago (see Eldredge 1988 for a reviewed the history of the giant African snail in Micronesia). In May 1950, approximately 400 Kibwezi gonaxis snails (*Gonaxis kibweziensis*) were released on Aguijan Island. One year later, the number of Kibwezi gonaxis was estimated at 21,750, and the number of giant African snails was 1,122,500. Kondo (1952) concluded that this snail predator had little effect on the giant African snail. Two years later, Peterson (1954) observed Kibwezi gonaxis snails feeding on native snail species and on the giant African snail and cannibalizing its own young. By mid-1954, the population of Kibwezi gonaxis on Aguijan was estimated to be 80,800, and the giant African snail was estimated at 37,600 individuals (Davis, 1954). Davis (1954) concluded that this snail predator was approximately 60 percent effective. Based on these conclusions, Kibwezi gonaxis snails.were shipped to Hawaii and other Pacific islands for biological control of the giant African snail (Eldredge, 1988).

D. ***The inadequacy of existing regulatory mechanisms.***

Currently, no formal or informal protection is given to *Partula langfordi* by Federal agencies or by private individuals or groups. In 1996, the Government of Guam listed this species as endangered on Guam (5 GCA, Section 63205.(c), "The Endangered Species Act of Guam").

Current Conservation Efforts: None.

E. ***Other natural or manmade factors affecting its continued existence.***

Naturally occurring random events can affect the continued existence of the Langford's tree snail due to the small number of individuals that remain. Physical events such as typhoons and droughts could eliminate the one remaining population. This is especially true due to several life-history features of this and all other partulid tree snails (Cowie 1992): reproductive rates are low; unlike most terrestrial snails, young are born live rather than develop in eggs; dispersal is very limited with most individuals remaining in the tree or bush into which they were born. All of these traits make these snails very sensitive to any stochastic event that could lead to a reduction or loss of reproductive individuals.

REFERENCES

Carano, P. and P.C. Sanchez. 1964. A complete history of Guam. Charles E. Tuttle, Inc., Rutland, Vermont. 452 pp.

Christensen, C.C. 1984. Are *Euglandina* and *Gonaxiis* effective agents for biological control of the giant African snail in Hawaii? Amer. Malacol. Bull., 2:98-99.

Clarke, B., J. Murray, and M.S. Johnson. 1984. The extinction of endemic species by a program of biological control. Pacific Sci. 38:97-104.

Cowie, R.H. 1992. Evolution and extinction of Partulidae, endemic Pacific island land snails. Philosophical Trans. Royal Soc. London B 335:167-191.

Crampton, H.E. 1925. Studies on the variation, distribution, and evolution of the genus *Partula* . The species of the Mariana Islands, Guam and Saipan. Carnegie Inst. Wash. Publ. 228A. vii + 116pp., 14 pl.

Davis, C.J. 1954. Report on the Davis Expedition to Aguiguan July-August 1954. Ecological studies, Island of Aguiguan, Mariana Islands as related to the African snail , *Achatina fulica* Bowdich, and its introduced predator, *Gonaxis kibweziensis* (E.A. Smith). Invertebrate Consultants Committee for the Pacific, Pacific Science Board. 24pp.

Eldredge, L.G. 1988. Case studies of the impacts of introduced animal species on renewable resources in the U.S.-affiliated Pacific islands. Pp. 118-146. In B.D. Smith (ed.), Topic reviews in insular resource development and management in the Pacific U.S.- affiliated islands. Univ. Guam Marine Lab. Tech. Rep. 88..Engbring, J., F. Ramsey., and V. J. Wildman. 1986.

Micronesain Forest Bird Survey, 1982: Saipan, Tinian, Agiguan, and Rota. U.S. Fish and Wildlife Service, Honolulu, HI. 143 pp.

Fosberg, F.R. 1960. The vegetation of Micronesia. Part 1. General descriptions, the vegetation of the Mariana Islands, and a detailed consideration of the vegetation of Guam. Bull. Amer. Mus. Nat. Hist. 119:1-75.

Fosberg, F.R. 1971. On present conditions and conservation of forests in Micronesia. In: Pacific Science Association Standing committee on Pacific Botany. Symposium: Planned utilization of the lowland tropical forests. Bogor, Indonesia.

Griffiths, O., A. Cook, and S.M. Wells. 1993. The diet of the introduced carnivorous snail *Euglandina rosea* and its implications for threatened island gastropod faunas. Journal of Zoology, 229:79-89.

Hadfield, M.G., S.E. Miller, and A.H. Carwile. 1993. The decimation of endemic Hawaiian tree snails by alien predators. Amer. Zoologist, 33:620-622.

Hopper, D.R., and B.D. Smith. 1992. The status of tree snails (Gastropoda: Partulidae) on Guam, with a resurvey of sites studied by H. E. Crampton in 1920. Pacific Sci. 46:77-85.

Kanehira, R. 1936. Forests of Rota. Bot. Zool. 4:63-70.

Kondo, Y. 1952. Report on carnivorous snail experiment on Aguiguan Island; primary and secondary *Achatina* -free areas on Rota, and gigantism among *Achatina* on Guam. Invertebrates Consultants Committee for the Pacific, Pacific Science Board. 50 pp.

Kondo, Y. 1970. Some aspects of Mariana Islands Partulidae (Mollusca, Pulmonata). Occas. Pap. B.P. Bishop Mus. 24(5):73-90.

Mead, A.R. 1961. The Giant African Snail: a problem in economic malacology. Univ. Chicago Press.

Miller, S.E. 1993. Final report on surveys of the arboreal and.terrestrial snail fauna of American Samoa. Unpublished report submitted to U.S. Fish and Wildlife Service, Pacific Region, Honolulu. 30 pp.

Mueller-Dombois, D. 1981. Fire in tropical ecosystems. In: Fire Regimes and Ecosystem Properties. Pp.137-176. H.A. Mooney, T.M. Bonnicksen, N.L. Christensen, J.E. Lotan, and W.A. Reiners (eds.). USDA, Forest Service Gen. Tech. Rep. WO-26.

Murray, J., E. Murray, M.S. Johnson, and B. Clarke. 1988. The extinction of *Partula* on Moorea. Pacific Sci. 42:150-153.

NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Ecology and Life History 1997. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

Paulay, G. 1994. Biodiversity on oceanic islands: Its origin and extinction. Am. Zoologist 34:134-144.

Pearce-Kelly, P., D. Clarke, and G. Mace. 1994. Partula 1994. An action plan for the conservation of the family Partulidae. Report of a workshop held at the Zoological Society of London, 11-13 February 1994.

Peterson, G.D. 1954. Report on progress of carnivorous snail experiments of Agiguan, Mariana Islands. Invertebrate Consultants Committee, Pacific Science Board. 9pp.

Smith, B.D. 1995. Tree snails, tropical storms, and drought in the Mariana Islands. (Abstract only). Programs and abstracts, American Malacological Union, 61st Annual Meeting, Hilo, Hawaii.

Tillier, S. and B.C. Clarke. 1983. Lutte biologique et destruction du patrimoine genetique: le cas du mollusgues gasteropodes pulmones dans les territoires Francais du Pacifique. Sel. Evol., 15:559-566..

PETITION TO LIST

Phantom Lake cavesnail
(*Cochliopa texana*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 4/28/76:
CNOR 5/22/84:
CNOR 1/6/89:
CNOR 11/21/91:
CNOR 11/15/94:
CNOR 10/30/01: C
CNOR 6/13/02: C

TAXONOMY

Burch (1989) and Turgeon et al. (1998) note that the generic placement of *Cochliopa texana* is uncertain, but do not question the validity of the taxon as a distinct species.

NATURAL HISTORY

The Phantom Lake cavesnail was first described by Pilsbury (1935). It is a very small snail, measuring only 1 to 1.4 mm in length (Dundee and Dundee 1969). It is found mainly on firm substrates (rocks and vegetation) on the margins of spring outflows (Taylor 1987). The physiographic setting of the San Solomon Spring System is that of a largely alluviated, arid karst terrain. The aridity of the region restricts the available habitat for spring-dependent species, and limits the available recharge to replenish and maintain spring flow. Pumping of the regional aquifer has significantly affected other springs in the area, including Comanche Springs and Leon Springs near Fort Stockton, which were once important habitat for rare desert aquatic species, but have ceased flowing.

The Phantom Lake cavesnail is found only in three spring systems and associated outflows (Phantom Lake, San Solomon, and East Sandia springs) in the Toyah Basin of Jeff Davis County and Reeves County, Texas (Landye 1980). There is no available information to indicate whether the species' historic distribution was more extensive than it is today. Other area springs may have contained the same species, but because these springs have been dry for many decades there is no opportunity to determine the potential historic occurrence of the snail fauna.

In the desert Southwest, aquatic snails are distributed in isolated geographically-separate wetland populations (Hershler et al. 1999). They likely evolved into distinct species during recent dry periods from parent species that once enjoyed a wide distribution during wetter, cooler climates. Such divergence has been well-documented for aquatic and terrestrial macroinvertebrate groups within arid ecosystems of western North America (e.g., Taylor 1987, Metcalf and Smartt 1997, Bowman 1981).

POPULATION STATUS

No recent information is available on the status of the species at San Solomon Spring. In the summer of 2000, East Sandia Spring was surveyed for aquatic macroinvertebrates for the first time. A healthy abundance and diversity of springsnails (including what appears to be the Phantom Lake cavesnail) were present in the small stream that makes up the spring outflow. The entire habitat is less than 150 meters in length.

The San Solomon Spring System is located in the Toyah Basin at the foothills of the Davis Mountains near Balmorhea, Texas. The system includes Phantom Lake, San Solomon, Giffin, Saragosa and Sandia Springs and several other minor springs at higher elevations to the south and southwest. In addition to rare snails, the springs are also important aquatic habitat for two federally endangered fish species, the Comanche Springs pupfish (*Cyprinodon elegan*s) and the Pecos gambusia (*Gambusia nobili*s) and endemic amphipods of the *Gammarus pecos* complex (Cole 1985).

Historically, Phantom Lake Spring, located at the base of the Davis Mountains, about five miles west of Balmorhea, was a large desert cienega with a pond of water more than several acres in size. The pristine condition of the spring outflow is at about 3200 feet elevation and would have provided ideal habitat for the endemic native aquatic fauna. During the 1940s the spring outflow was modified into a concrete-lined irrigation ditch so that the total outflow from the spring could be captured and used for irrigation of agriculture lands. The native aquatic snails persisted, though probably in reduced numbers, in the small pool of water at the mouth of the spring (Phantom Cave) and in the irrigation canals downstream.

The U.S. Bureau of Reclamation, Albuquerque Area Office, (Reclamation) owns and manages Phantom Lake Spring and a surrounding area of about 17 acres. A refugium was built by Reclamation in 1993 (Young et al. 1993) to increase the available aquatic habitat at Phantom Lake Spring. Although still an artificial habitat, Winemiller and Anderson (1997) showed that the refuge channel is used by endangered fish species when water is available. Unfortunately, the refuge channel was constructed for a design flow down to 0.5 cubic feet per second (cfs), which at the time of construction was the lowest flow ever recorded out of Phantom Lake Spring. Recent declines in spring flow have diminished the usefulness of the refugium because it is has been completely dry for the past year.

San Solomon Spring is located within Balmorhea State Park, encompassing about 45.9 acres.southwest of Balmorhea in Reeves County and owned and managed by the Texas Parks and Wildlife Department. The Park was built by the Civilian Conservation Corps (CCC) in the early 1930s and was opened as a State Park in 1968. The entire spring head was converted into a concrete-lined swimming pool. The outflow from the pool is completely contained in concrete irrigation channels. Recently TPWD created the San Solomon Cienega which uses some spring flow to recreate more natural aquatic habitats for the benefit of the endangered fishes in the Park.

East Sandia Spring is located on the Sandia Springs Preserve recently (1997) purchased by The Nature Conservancy of Texas (TNC). There are two disjunct tracts (East and West Sandia Springs) that together make up 240 acres of preserved land. East Sandia Spring is located just east of the town of Balmorhea in Reeves County, Texas. West Sandia Spring has ceased flowing in recent times. East Sandia Spring discharges at an elevation of 977 m (3,205 ft) from alluvial sand and gravel, but the water is probably derived from Comanchean limestone underlying the alluvium (Brune 1981). The small flow from the springs is used by the local farming community for agricultural irrigation. The primary threat is the loss of surface flows due to declining groundwater levels from drought and pumping. TNC provides protection of the land around the spring, but can not prevent declining spring flows due to groundwater pumping in other areas.

Despite the fact that Phantom Lake Spring has been drastically altered from its original state, the native snails (Phantom springsnail (*Tryonia cheatumi*) and Phantom Lake cavesnail (*Cochliopa texana*)) occurred in the irrigation canal in 1968 in such tremendous numbers that the sides of the canal appeared black from the cover of snails (Dundee and Dundee 1969). Today the snails are limited to low densities in the small pool at the mouth of Phantom Cave and cannot be found in the irrigation canal downstream (*in litt*, 2000 cited in U.S. Fish and Wildlife Service candidate assessment form). A similar situation occurs at San Solomon Spring, which has been significantly altered. Taylor (1987) reported the snail was abundant and generally distributed in the canals from 1965 - 1981.

The Texas Natural Heritage Program ranks the Phantom Lake cavesnail as Critically Imperiled.

The U.S. Fish and Wildlife Service classifies the Phantom Lake cavesnail as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range: Texas. Three spring systems and associated outflows (Phantom Lake, San Solomon, and East Sandia springs) in the Toyah Basin of Jeff Davis County and Reeves County, Texas (Landye 1980).

Current range: Texas. Three spring systems and associated outflows (Phantom Lake, San

Solomon, and East Sandia springs) in the Toyah Basin of Jeff Davis County and Reeves County, Texas (Landye 1980).

Land ownership: The land on which the snail occurs is owned and managed by U.S. Bureau of Reclamation, Texas Parks and Wildlife Department, and The Nature Conservancy of Texas. The surrounding watershed and surface area over contributing aquifers is all privately owned.

The most significant threat to the continued existence of this snail is the degradation and eventual loss of spring habitat (flowing water) due to the decline of groundwater levels of the supporting aquifer. Overpumping of the regional aquifer system for agricultural production of crops have resulted in the drying of most other springs in this region (Brune 1981). Other springs that have already failed include Comanche Springs, which was once a large surface spring in Fort Stockton, Texas. This spring flowed at more than 1200 liters per second (lps) (Brune 1981) and undoubtably provided habitat for rare species of fishes and invertebrates, including springsnails. The spring ceased flowing by 1962 (Brune 1981). Leon Springs, located about 40 miles east of Balmorhea, was measured at 500 lps in the 1930s and was known to contain rare fish, but ceased flowing in the 1950s following significant irrigation pumping (Brune 1981).

Phantom Lake Spring has experienced a long-term, consistent decline in spring flows. Discharge data have been recorded from the spring six to eight times per year since the 1940s by the U.S. Geological Survey (Schuster 1997). The record shows a steady decline of flows, from greater than 10 cfs in the 1940s to 0 cfs in 2000. The data also show that the spring can have short term flow peaks resulting from local rainfall events in the Davis Mountains (Sharp et al. 1999). These peaks are from fast recharge and discharge, not surface runoff, because the spring is not within a drainage basin. However, after each increase the “base flow” has returned to the same declining trend within a few months. There have been extremely low flows from Phantom Lake Spring since the summer of 1998.

Rainfall in the late summer of 1999 provided a temporary increase in flow, but by autumn the flow had returned to near zero. A small amount of water has, until recently, continued to flow from the cave to keep the refugium functional with shallow water and provide limited habitat for the endangered fish. Currently, water surface elevation from the cave has declined further and the refuge channel is now dry. Only the small pool at the cave mouth continues to provide some aquatic habitat. This last remaining habitat will be gone as the water surface elevation declines. The exact causes for the decline in flow from Phantom Lake Spring are unknown. Some of the obvious reasons are groundwater pumping of the supporting aquifer and decreased recharge of the aquifer from drought. Unfortunately the supporting aquifer for the springs is not well defined. Recent studies (LaFave and Sharp 1987, Schuster 1997, Sharp et al. 1999) support the idea that that, although the spring is locally recharged by runoff from the Davis Mountains (resulting in the flow spikes), the “base flow” comes from a regional groundwater system. The source of the springs is likely the aquifer of the Capitan Reef associated with the Apache Mountains, with recharge areas in the Wildhorse Flat Basin to the northwest of the Toyah Basin. Sharp et al. (1999) further proposed that the decline in flows are most likely the result of groundwater pumping in this region.

Ashworth et al. (1997) carried out a cursory study to examine the cause of declining spring flows in the Toyah Basin. The conclusion from this study was that "recent declines in spring flows are more likely to be the result of diminished recharge due to the extended dry period rather than from groundwater pumpage" (Ashworth et al. 1997). However, drought alone is unlikely the only reason for declines because the drought of record in the 1950s had no effect on the overall flow trend.

Exploration of Phantom Cave by cave divers has led to additional information about the nature of the spring and its supporting aquifer (personal communication 1999 cited in U.S. Fish and Wildlife Service candidate assessment form). Beyond the entrance, the cave is a substantial conduit that transports a large volume of water generally from the northwest to the southeast, consistent with the regional flow pattern hypothesis. Over 8,000 feet of the cave conduit have been mapped so far. In addition, flows have been measured and are in the 25 cfs range. The relatively small flow at Phantom Lake Spring is essentially an overflow of a larger flow system underground.

Although long-term data are scarce, San Solomon Spring flows have declined somewhat over the history of record, but not as much as Phantom Lake Spring (Schuster 1997, Sharp et al. 1999). Some recent declines in overall flow have likely occurred due to drought conditions and declining aquifer levels. San Solomon Spring is a much larger volume spring; discharges are usually in the 25 to 30 cfs range (Ashworth et al. 1997, Schuster 1997) and are consistent with the theory that the water bypassing under Phantom Lake is later discharged at the San Solomon Spring. Giffin Spring (located within a mile to the northwest of San Solomon Spring) maintains a near constant 3 to 4 cfs outflow (Ashworth et al. 1997). Giffin Spring is on private land and the status of the snails there is uncertain. Similar water chemistry, and near constant temperatures of about 26° C, among these three springs (Phantom, San Solomon, and Giffin) also supports the hypothesis that their waters originate from the same source (Schuster 1997).

The water discharging from East Sandia Spring is likely from a shallow groundwater source and water chemistry differences indicate it is not connected with the other Toyah Basin springs being considered (Schuster 1997). However, it may be even more susceptible to overpumping in the area of the local aquifer that supports the spring. Brune (1981) noted that flows were declining from Sandia Springs. Measured discharges in 1995 and 1996 ranged from 0.45 to 4.07 cfs (Schuster 1997).

Another threat to the habitat of the snail is the potential degradation of water quality from point and non-point pollutant sources. This can occur either directly into surface water or indirectly through contamination of groundwater that eventually discharges into spring run habitats used by the snail. The primary threat for contamination comes from herbicide and pesticide use in nearby agricultural areas.

Two of the three known occurrences of the species are in degraded habitats (the exception being East Sandia Spring) because the natural conditions of the springs have been substantially modified for human use. Any additional modification to the spring flow habitats at Phantom Lake Spring, San Solomon Spring or East Sandia Spring could further threaten the remaining populations of the species.

B. *Overutilization for commercial, recreational, scientific, or educational purposes.*

None known.

C. *Disease or predation.*

None known. However, the presence of introduced species increases the potential for foreign diseases to be introduced to the species.

D. *The inadequacy of existing regulatory mechanisms.*

Texas State law provides no protection for these invertebrate species. There are no existing Federal, State or local regulatory mechanisms providing protection for these species. The snails are afforded some protection indirectly due to the presence of two fishes (Comanche Springs pupfish and Pecos gambusia) that occupy similar habitats and are listed as endangered by State and Federal governments. However, the snails may be more sensitive to changes in water quality than are the fish and are likely more directly threatened by the presence of the exotic *Melanoides* snail than are the endangered fish.

Some protection for the habitat of this species is provided with the ownership of the springs by Federal (Phantom Lake) and State (San Solomon) agencies, and by TNC (East Sandia). However, this land ownership provides no protection for maintaining necessary groundwater levels to ensure adequate spring flows.

Current Conservation Efforts: None.

E. *Other natural or manmade factors affecting its continued existence.*

Within the last 10 years, an exotic snail, *Melanoides* sp., has become established in Phantom Lake Spring (*in litt*. 1993 cited in U.S. Fish and Wildlife Service candidate assessment form; McDermott 2000). The species has been at San Solomon Spring for some time longer, but is not found in East Sandia Spring. In many locations at San Solomon Spring, this exotic snail essentially is the substrate in the small stream channel. The effects of this introduction are not known. However, this exotic snail is likely competing with the native snails for space and resources. Other changes to the ecosystem are likely to result from the dominance of this species, which could have detrimental effects on the native invertebrate community.

REFERENCES

Ashworth, J.B., D.B. Coker, and W. Tschirhart. 1997. Evaluation of diminished spring flows in the Toyah Creek Valley, Texas. Open File Report 97-03. Texas Water Development

Board, Austin, Texas. 12pp.

Boghici, R. 1997. Hydrogeological investigations at Diamond Y Springs and surrounding area, Pecos County, Texas. Unpublished Master's Thesis, University of Texas at Austin. 120 pp.

Bowman, T.E. 1981. *Thermosphaeroma milleri* and *T. smithi*, new sphaeromatid isopod crustaceans from hot springs in Chihuahua, Mexico, with a review of the genus. Journal of Crustacean Biology. 1:105-122.

Brune, G. 1981. Springs of Texas. Branch-Smith, Inc. Fort Worth, Texas.

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

Cole, G. A. 1985. Analysis of the *Gammarus pecos* complex (Crustacea: Amphipoda) in Texas and New Mexico, USA. Journal of the Arizona-Nevada Academy of Science 20:93-103.

Dundee, D. and H. Dundee. 1969. Notes concerning two Texas molluscs, *Cochliopa texana* Pilsbry and *Lyrodes cheatumi* Pilsbry (Mollusca: Hydrobiidae). Transactions of the American Microscipical Society 88(2):205-210.

Hershler, R., Hsiu-Ping Liu, and M. Mulvey. 1999. Phylogenetic relationships within the aquatic snail genus *Tryonia*: implications for biogeography of the North American Southwest. Molecular Phylogenetics and Evolution 13:377-391.

Landye, J. 1980. Status of rare, endangered and/or threatened molluscan species of Texas and Oklahoma. Report submitted to U.S. Fish and Wildlife Service, Albuquerque, New Mexico, Contract #14-16-0002-79-202. 12 pp.

LaFave, J.I. and J.M. Sharp. 1987. Origins of groundwater discharging at the Springs of Balmorhea. West Texas Geological Society Bulletin 26:5-14.

Metcalf, A.L. and R.A. Smartt. 1997. Land snails of New Mexico. New Mexico Museum of Natural History and Science. Bulletin No. 10. 145 pp.

McDermott, K. 2000. Distribution and infection relationships of an undescribed digenetic Trematode, its exotic intermediate host, and endangered fishes in springs of west Texas. Unpublished Master's Thesis, Southwest Texas State University, San Marcos, Texas. 26+ pp.

Pilsbry, H.A. 1935. Western and southwestern Amnicolidae and a new *Humboldtiana*. Nautilus 48:91-94.

Schuster, S.K. 1997. Hydrogeology and local recharge analysis in the Toyah Basin Aquifer.

Masters Thesis, Geological Sciences, University of Texas at Austin. 130 pp.

Sharp, J.M., Uliana, M.M., and R. Boghici. 1999. Fracture controls on regional groundwater flow in a semiarid environment and implications for long-term maintenance of spring flows. Water 99 Joint Congress, Inst. of Engineers. Australia, Brisbane. v. 2, p.1212-1217..

Taylor, D. W. 1987. Fresh-water molluscs from New Mexico and vicinity. New Mexico Bureau of Mines and Mineral Resources Bulletin 116:1-50.

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P.M. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione, and J.D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks, 2nd edition. American Fisheries Society, Special Publication 26, Bethesda, Maryland.

Winemiller, K.O. and A.A. Anderson. 1997. Response of endangered desert fish populations to a constructed refuge. Restoration Ecology 5:204-213.

Young, D.A., K.J. Fritz, G.P. Garrett, and C. Hubbs. 1993. Status review of construction, native species introductions, and operation of an endangered species refugium channel, Phantom Lake Spring, Texas. Proceedings of the Desert Fishes Council 25:22-25..

PETITION TO LIST

Tutuila tree snail, sisi vao
(*Eua zebrina*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 11/15/94:
CNOR 2/28/96: C
CNOR 9/19/97: C
CNOR 10/25/99: C
CNOR 10/30/01: C
CNOR 6/13/02: C

TAXONOMY

The taxonomic status of the Tutuila tree snail, *Eua zebrina* (Partulidae), as a valid species is uncontroversial (e.g., Bishop Museum 2001).

NATURAL HISTORY

Ecology

The biology of Samoan partulid tree snails has not been extensively studied. However, there is considerable information (reviewed by Cowie 1992) on the partulid tree snails of the Mariana Islands (Crampton 1925a and Hopper and Smith 1992) and the Society Islands (Crampton 1925b, 1932, Murray et al. 1982, and Johnson et al. 1986a, b). This ancient family of snails is considered to be ovoviviparous, although viviparity may be a more accurate description, as considerable growth occurs before birth. Some species in the family are known to be self-fertile while other partulids, including *Samoana conica* of Tutuila, rely predominantly on outcrossing (Johnson et al. 1986a). In the genus *Partula* , shell length at birth is 3-3.5 mm and sexual maturity is attained in less than one year at a shell length of 11-30 mm, depending on the species. Adults live for about 5 years and give birth about every 20 days, producing about 18 offspring per year (Cowie 1992). Most members of the family are arboreal herbivores, feeding mainly on decaying plant material (Murray et al. 1982). One exception to this general feeding preference was reported by Cooke (1928) for *Eua zebrina* . He reported that this species feeds on other non-partulid snails during periodic visits to the forest floor.

Cooke (1928) also suggested that habitat partitioning may occur among the three partulids of Tutuila. *Samoana conica* and *S. abbreviata* were commonly found on trunks and branches, and *Eua zebrina* was commonly found on leaves. A similar partitioning of habitat has.been reported for the *Partula* of the Society Islands (Murray et al. 1982).

Distribution
The family Partulidae is widely distributed throughout the high islands of Polynesia, Melanesia and Micronesia in the south- and west-Pacific basin (Cowie 1992). Many of the 120 partulid species (Kondo 1968) are restricted to single islands or isolated groups of islands. The Samoan partulid tree snails are a good example of this endemism.

The two large islands of Western Samoa (Savai'i and 'Upolu) are home to five partulid tree snails. Three partulid species are endemic to single islands in American Samoa; *Samoana abbreviata* (considered to be extinct) and *Eua zebrina* , both on the island of Tutuila, and *S. thurstoni* on the island of Ofu.

The population on Nu'usetoga Island was probably isolated from an ancestral parent population of the main island of Tutuila in prehistoric time. No live *Euglandina rosea* or *Gonaxis kibweziensis* (two alien predatory snails) were found on this offshore islet. Thus, the *Eua zebrina* on this island are, for the moment, safe from predatory snails. However, predation by rats is a problem, and several rat-damaged shells were found.

There is very little data that can be used to assess long-term temporal changes in the snail fauna of American Samoa. However, qualitative comparisons can be made between a 1993 survey (Miller 1993) and surveys done in 1975 (Solem 1975 and Christensen 1980). Of the 15 endemic species recorded alive in 1975, living individuals of five species and the shells of two additional species were seen in 1993. This qualitative comparison plus the more recent survey data indicate that the native snail fauna have declined dramatically and that the partulid tree snails and several other terrestrial and arboreal species are on the verge of extinction.

POPULATION STATUS

In a recent survey, only 34 individuals of *Eua zebrina* were seen alive; eleven at Sauma Ridge (122-168 m elevation) and 23 on Nu'usetoga Island (73 m elevation; about 100 m offshore of Tutuila)(Miller 1993). At both sites, the snails were found scattered on understory vegetation in a forest with an intact canopy 10-20 m above the ground. At Sauma Ridge, the alien predatory snail *Euglandina rosea* was found alive within meters of some of these snails. Shells of *Eua zebrina* and another Samoan partulid (*Samoana conica*) were found on the ground at several of the locations surveyed on Tutuila, along with numerous shells and an occasional live individual of *E. rosea.* Although this snail is known to have been widespread and abundant until the dramatic decline seen in recent years, only two populations with a total of 34 individuals are extant. This decline is concurrent with the introduction of the carnivorous alien snail *Euglandina rosea* which remains a serious threat.

The species is listed as "Endangered" in the 1996 IUCN Red List of Threatened Animals (Baille in IUCN, 1996).

The U.S. Fish and Wildlife Service classifies the Tutuila tree snail as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range:	American Samoa (island of Tutuila). Endemic to the island of Tutuila and historically widespread there (based on extensive collections in Bishop Museum, Honolulu).
Current range:	American Samoa (island of Tutuila). Currently known from only two locations: Tiatauala Ridge and Nu'usetoga Island (Miller, 1993).
Land ownership:	Land ownership in American Samoa generally follows a historic village tradition. Large sections of land around each village is controlled by that village for the use of the village residents. The Nu’usetoga Island population of *Eua zebrina* is within the bounds of Masefau Village, while the Sauma Ridge population of this snail is within the bounds of Amalau Village.

The declines of these native snails have resulted from: (1) predation by introduced snails and rats; (2) loss of habitat to forestry and agriculture; and (3) loss of forest structure to hurricanes and alien weeds that establish after these storms. These threats may interact to greatly exacerbate the loss of populations and species.

Loss of habitat to agriculture and to storms has greatly reduced the native habitat of Samoan snails. All live *Eua zebrina* tree snails were found on understory vegetation beneath remaining intact forest canopy. No snails were found in areas bordering agricultural plots or in forest areas that were severely damaged by three recent hurricanes (1987, 1990, and 1991). Under natural historic conditions, loss of forest canopy to storms did not pose a great threat to the long-term survival of these snails. Enough intact forest with healthy populations of snails would support dispersal back into newly regrown canopy forest. However, the presence of introduced alien weeds such as mile-a minute vine (*Mikania micrantha*) and weedy tree species such as *Funtumia elastica* may reduce the likelihood that native forest will become re-established in areas damaged by hurricanes (Whistler 1992).

This loss of habitat to storms is greatly exacerbated by an expanding agriculture needed to support one on the world’s highest human population growth rates (Craig et al. 1993). Agricultural plots have spread from low elevation up to middle and some high elevations on all the islands, greatly reducing the forest area and thus reducing the resilience of the forest and its populations of native snails. These reductions also increase the likelihood that future storms will lead to the extinction of populations or species that rely on the remaining canopy forest.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

In the past, snails were used in ornamental products. This is no longer a major threat since populations of *E. zebrina* are now difficult to locate. However, at the present time, collecting a few adult snails can remove a large percentage of the reproductive population in a bush or tree, thereby driving that population closer to extinction. Collecting of tree snails must now be viewed as a threat to the further survival of the species.

C. ***Disease or predation.***

The alien giant African snail, *Achatina fulica*, was introduced into American Samoa prior to 1977. This snail is a crop pest and an intermediate host of the rat lung worm, *Angiostrongylus cantonensis*, which can cause human eosinophilic meningoencephalitis (Alicata 1962 and Mead 1979). The most commonly recommended biological control agent of the giant African snail is the predatory snail *Euglandina rosea.* However, *E. rosea* is also a host to the rat lung worm (Wallace and Rosen 1969) and occupies a wider range of habitats than does the giant African snail (van der Schalie 1969 and Mead 1961), potentially spreading the rat lung worm through a wider area. It is not known if the parasite can be maintained in populations of native snails or if a parasite load would have negative effects on snail reproduction.

In an effort to eradicate the giant African snail, alien predatory snails, *Euglandina rosea* and *Gonaxis kibweziensis*, were introduced in 1980 and 1977, respectively. *Achatina fulica* and *E. rosea* have spread throughout the main island of Tutuila and have also spread to the island of Ta’u. By 1984, *E. rosea* was considered to be well established on Tutuila (Eldredge 1988). *Gonaxis kibweziensis* is present only on Tutuila and seems to be in decline.

After an initial increase lasting up to several years, the populations of giant African snails typically go into decline (Mead 1961). Available data does not definitively show that reductions in population size are due to predation by carnivorous snails (Mead 1961, Hadfield and Kay 1981, Christensen 1984,and Eldredge 1988). In fact, *Euglandina rosea* is probably not of great importance as a predator of giant African snails (Mead 1961), preferring instead to feed on small snails (Cook 1989 and Griffiths *et al.* 1993), which include most of the native snails on the Pacific islands to which it has been introduced.

The lack of evidence for predatory control of the giant African snail has not stopped the intentional spread of snail predators like *E. rosea* into and throughout the Pacific basin, although numerous studies show that *E. rosea* feeds on endemic island snails and is a major agent in their declines and extinctions (van der Schalie 1969, Colman 1977, Hart 1978, Howarth 1983, 1985, and 1991, Clarke et al. 1984, Pointier and Blanc 1984, Murray et al. 1988, Hadfield and Mountain 1981, Hadfield 1986, Hadfield et al. 1989 and 1993, and Kinzie 1992). At present, the major threat to long-term survival of the native snail fauna in American Samoa is predation by

Euglandina rosea.

Recent surveys recorded partulid tree snail shells that were damaged in a fashion that is typical of rat predation; the shell is missing a large piece of the body whorl or the apex. Old shells may be weathered in a similar fashion, except that the fracture lines are not sharp and angular. Signs of rat predation were seen at the sites with the largest remaining populations of partulid tree snails (Sauma Ridge and Nu'usetoga Island). Studies in Hawaii (Hadfield *et al.* 1993) have shown that both rats and *Euglandina rosea* can quickly devastate tree snail populations. Live trapping in Hawaii has implicated the Polynesian rat, *Rattus exulans*, although *R. rattus* and *R. norvegicus* may also be significant threats to native snail populations. All three species have been introduced throughout the Pacific islands.

D. *The inadequacy of existing regulatory mechanisms.*

Currently, no formal or informal protection is given to *Eua zebrina* by the Federal or American Samoa governments or by private individuals or groups.

Current Conservation Efforts: None.

E. *Other natural or manmade factors affecting its continued existence.*

Random environmental events, such as hurricanes and droughts, could affect the continued existence of the *Eua zebrina* due to the small numbers of populations and individuals that remain. This is especially true due to several life-history features of this and all other partulid tree snails (Cowie 1992). Adults require 11 months to reach sexual maturity; reproductive rates are low; unlike most terrestrial snails, the young are born live rather than developing in eggs; and dispersal is very limited, with most individuals remaining in the tree or bush into which they were born. All of these traits make these snails very sensitive to any random event that could lead to a reduction or loss of reproductive individuals.

REFERENCES

Alicata, J.E. 1962. *Angiostrongylus cantonensis* (Nematoda: Metastronglidae) as a causative agent of eosinophilic meningitis of man in Hawaii and in Tahiti. Can. J. Zool. 40:5-8.

Baille, J., and B. Groombridge. 1996. 1996 IUCN Red Lisst of Threatened Animals. IUCN Species Survival Commission, Gland, Switzerland. 368 pp. Available from IUCN Publications Services Unit, 219c Huntington Road, Cambridge, CB3 0DL, United Kingdom.

Bishop Museum of Honolulu. Samoan Snails Searchable Database, revised June 19, 2001. http://www2.bishopmuseum.org/PBS/samoasnail/query.asp

Christensen, C.C. 1980. Preliminary summary of the terrestrial mollusks of Tutuila, American Samoa. B.P. Bishop Museum, unpublished report.

Christensen, C.C. 1984. Are *Euglandina* and *Gonaxis* effective agents for biological control of the giant African snail in Hawaii? American Malacol. Bull. 2:98-99.

Clarke, B.C., J.J. Murray, and M.S. Johnson. 1984. The extinction of endemic species by a program of biological control. Pacific Science 38:97-104.

Colman, P.H. 1977. An introduction of *Achatina fulica* to Australia. Malacol. Rev. 10:77-78..Cook, A. 1989. Factors affecting prey choice and feeding technique in the carnivorous snail *Euglandina rosea* Ferrusac. J. Molluscan Stud. 155: 469-477.

Cooke, C. M. 1928. Food habits of *Partula zebrina* Gould. Bull. B. P. Bishop Museum 47:5-12.

Cowie, R.H. 1992. Evolution and extinction of Partulidae, endemic Pacific island land snails. Phil. Trans. R. Soc. Lond. B 335:167-191.

Craig, P., P. Trail, G. Grant, J. Craig, and D. Itano. 1993. American Samoa: Natural History and Conservation Topics. Volume 1. Biological Report Series, Report Number 42. Department of Marine and Wildlife Resources, American Samoa Government.

Crampton, H.E. 1925a. Studies on the variation, distribution, and evolution of the genus *Partula*. The species of the Mariana Islands, Guam and Siapan. Carnegie Inst. Washington Publ. 228a, vii + 116 pp.,14 pll.

Crampton, H.E. 1925b. Contemporaneous organic differentiation in the species of *Partula* living in Moorea, Society Islands. Am. Nat. 59:5-35.

Crampton, H.E. 1932. Studies on the variation, distribution, and evolution of the genus *Partula* . The species inhabiting Moorea. Carnegie Inst. Washington Publ. 410, vi + 335 pp., 24 pll.

Eldredge, L.G. 1988. Case studies of the impacts of introduced animal species on renewable resources in the U.S.-affiliated Pacific islands. In: B.D. Smith (ed), Topic reviews in insular resource development and management in the Pacific U.S.-affiliated islands. University of Guam Technical Report No. 88, pp. 118-146.

Griffiths, O., A. Cook, and S.M. Wells. 1993. The diet of the introduced carnivorous snail *Euglandina rosea* in Mauritius and its implications for threatened island gastropod faunas. Journal of Zoology, London 229:79-89.

Hadfield, M.G. 1986. Extinction in Hawaiian achatinelline.snails. Malacologia 27:67-81.

Hadfield, M.G. and E.A. Kay. 1981. The multiple villainies of *Euglandina rosea* (or its human proponents). Hawaiian Shell News 29:5-6.

Hadfield, M.G., S.E. Miller and A.H. Carwile. 1989. Recovery plan for the O'ahu tree snails of the genus *Achatinella* . U.S. Fish and Wildlife Service 300 Ala Moana Blvd., Honolulu, Hawaii 96850.

Hadfield, M.G., S.E. Miller and A.H. Carwile. 1993. The decimation of endemic Hawai'ian tree snails by alien predators. Am. Zool. in press.

Hadfield, M.G. and B.S. Mountain. 1981. A field study of a vanishing species, *Achatinella mustelina* (Gastropoda, Pulmonata) in the Wai'anae Mountains of O'ahu. Pacific Sci. 34:345-358.

Hart, A.D. 1978. The onslaught against Hawaii's tree snails. Natural History. December; 46-57.

Hopper, D.R. and B.D. Smith. 1992. The status of tree snails (Gastropoda: Partulidae) on Guam, with a resurvey of sites studies by H.E. Crampton in 1920. Pacific Science 46:77-85.

Howarth, F.G. 1983. Classical biocontrol: Panacea or Pandora's box? Proc. Hawaiian entomol. Soc. 24:239-244.

Howarth, F.G. 1985. Impacts of alien land arthropods and mollusks on native plants and animals in Hawaii. In: C.P. Stone and J.M. Scott, eds., Hawaii's terrestrial ecosystems: preservation and management. Cooperative National Park Research Studies Unit, Honolulu, Hawaii. 149-179.

Howarth, F.G. 1991. Environmental impacts of classical biological control. Ann. Rev. Entomol. 36:485-509.

Johnson, M.S., J.J. Murray and B.C. Clarke. 1986a. High genetic similarities and low heterozygosities in land snails of the genus *Samoana* from the Society Islands. Malacologia 27:97- 106..Johnson, M.S., J.J. Murray and B.C. Clarke. 1986b. An electrophoretic analysis of phylogeny and evolutionary rates in the genus *Partula* from the Society Islands. Proc. r. Soc. Lond. B. 227:161-177.

Kinzie, R.A. 1992. Predation by the introduced carnivorous snail *Euglandina rosea* (Ferussac) on endemic aquatic lymnaeid snails in Hawaii. Biological Conservation 60:149- 155.

Kondo, Y. 1968. Partulidae: preview of anatomical revision. Nautilus 81: 73-77.

Mead, A.R. 1961. The giant African snail: a problem in economic malacology. University of Chicago Press. 257 pp.

Mead, A.R. 1979. Economic malacology with particular reference to *Achatina fulica* . In V. Fretter and J. Peake (eds.), The Pulmonates, Vol. 2B. Academic Press, N.Y.

Miller, S.E. 1993. Final report on surveys of the arboreal and terrestrial snail fauna of American Samoa. Unpublished report to the U.S. Fish and Wildlife Service, Pacific Islands Office, Honolulu, Hawaii. 30 pp.

Murray, J.J., M.S. Johnson and B.C. Clarke. 1982. Microhabitat differences among genetically similar species of *Partula* . Evolution 36:316-325.

Murray, J.J., E. Murray, M.S. Johnson, and B.C. Clarke. 1988. The extinction of *Partula* on Moorea. Pacific Science 42:150-153.

NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

Pointier, J.D. and C. Blanc. 1984. *Achatina fulica* en Polynesie Francaise. Situation en 1982-83 en Polynesie Francaise apres l'introduction des escargots geants en 1967. Centre de l'Environment, Moorea, Rapport RA13. 42 pp.

Solem, A. 1975. Final report, Office of Endangered Species. Contract No. 14-16-0008- 837. van der Schalie, H. 1969. Man meddles with nature - Hawaiian style. The Biologist 51:136-146..Wallace G.D. and L. Rosen. 1969. Studies on eosinophilic meningitis. V. Molluscan hosts of *Angiostrongylus cantonensis* on Pacific islands. Am. J. Trop. Med. & Hygiene 18:206-216.

Whistler, W.A. 1992. Vegetation of Samoa and Tonga. Pacific Science 46: 159-178.

PETITION TO LIST

Phantom springsnail
(*Tryonia cheatumi*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 4/28/76:	
CNOR 5/22/84:	
CNOR 1/6/89:	
CNOR 11/21/91:	
CNOR 11/15/94:	
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

The taxonomic status of the Phantom springsnail, *Tryonia cheatumi* (Hydrobiidae), as a valid species is uncontroversial (e.g., Turgeon et al. 1998; Hershler et al. 1999). This species is also known as the Phantom tryonia.

NATURAL HISTORY

Morphology
The Phantom springsnail was first described by Pilsbury (1935). It is a very small snail,measuring only 2.9 millimeters (mm) (0.11 inches (in)) to 3.6 mm (0.14 in) in length (Taylor 1987). The shell is narrowly conical, with obtuse apex and broadly rounded anterior end (Taylor 1987).Whorls are 4.75 to 5.75 in larger males and 5-6 in larger females, regularly convex and separated by a deeply incised suture (Taylor 1987).

Behavior
Like other hydrobiids, these snails are sexually dimorphic. They are ovoviviparous, producing live young serially (as opposed to broods). They are presumably fine-particle feeders on detritus and periphyton associated with the substrates (mud and vegetation); Dundee and Dundee (1969) found diatoms to be the primary component in the digestive tract.

Habitat

The Phantom springsnail is found on both soft and firm substrates on the margins of spring outflows (Taylor 1987). The general physiographic setting of the San Solomon Spring System is that of a largely alluviated, arid, karst terrain. The aridity of the region restricts the available habitat for spring-dependent species, and limits the available recharge to replenish and maintain spring flow. Pumping of the regional aquifer has significantly affected other springs in the area, including Comanche Springs and Leon Springs near Fort Stockton, which were once important habitat for rare desert aquatic species, but have ceased flowing.

Distribution

The Phantom springsnail is an aquatic snail occurring only in three spring systems and associated outflows (Phantom Lake, San Solomon, and East Sandia springs) in the Toyah Basin of Jeff Davis County and Reeves County, Texas (Taylor 1987). There is no available information to indicate whether the species' historic distribution was more extensive than it is today. Other area springs may have contained the same species, but because these springs have been dry for many decades, there is no opportunity to determine the potential historic occurrence of the snail fauna.

In the desert Southwest, aquatic snails are distributed in geographically isolated wetland populations (Hershler et al. 1999). They likely evolved into distinct species during recent dryperiods from parent species that once enjoyed a wide distribution during wetter, cooler climates. Such divergence has been well-documented for aquatic and terrestrial macroinvertebrate groups within arid ecosystems of western North America (e.g., Taylor 1987, Metcalf and Smartt 1997, Bowman 1981).

No recent information is available on the status of the species at San Solomon Spring.In the summer of 2000, East Sandia Spring was surveyed for aquatic macroinvertebrates for the first time. A healthy abundance and diversity of springsnails (including what appears to be the Phantom springsnail) were present in the small stream that makes up the spring outflow. The entire habitat is less than 150 meters in length.

The San Solomon Spring System is located in the Toyah Basin at the foothills of the DavisMountains near Balmorhea, Texas. The system includes Phantom Lake, San Solomon, Giffin,Saragosa and Sandia Springs and several other minor springs at higher elevations to the southand southwest. In addition to rare snails, the springs are also important aquatic habitat for twofederally endangered fish species, the Comanche Springs pupfish (*Cyprinodon elegan*s) and thePecos gambusia (*Gambusia nobili*s) and endemic amphipods of the *Gammarus pecos* complex (Cole 1985).

Historically, Phantom Lake Spring, located at the base of the Davis Mountains, about five mileswest of Balmorhea, was a large desert cienega with a pond of water more than several acres insize. The pristine condition of the spring outflow is at about 3200 feet elevation and would have provided ideal habitat for the endemic native aquatic fauna. During the 1940's the spring outflow was modified into a concrete-lined irrigation ditch so that the total outflow from the spring could be captured and used for irrigation of agriculture lands. The native aquatic snails persisted, though probably in reduced numbers, in the small pool of water at the mouth of the spring (Phantom Cave) and in the irrigation canals downstream.

The U.S. Bureau of Reclamation, Albuquerque Area Office, (Reclamation) owns and manages Phantom Lake Spring and a surrounding area of about 17 acres. A refugium was built by Reclamation in 1993 (Young et al. 1993) to increase the available aquatic habitat at PhantomLake Spring. Although still an artificial habitat, Winemiller and Anderson (1997) showed thatthe refuge channel is used by endangered fish species when water is available. Unfortunately,the refuge channel was constructed for a design flow down to 0.5 cubic feet per second (cfs),which at the time of construction was the lowest flow ever recorded out of Phantom Lake SpringRecent declines in spring flow have diminished the usefulness of the refugium because it is hasbeen completely dry for the past year.

San Solomon Spring is located within Balmorhea State Park encompassing about 45.9 acres southwest of Balmorhea in Reeves County and owned and managed by the Texas Parks and Wildlife Department. The Park was built by the Civilian Conservation Corps (CCC) in the early 1930s and was opened as a State Park in 1968. The entire spring head was converted into a concrete-lined swimming pool. The outflow from the pool is completely contained in concrete irrigation channels. Recently TPWD created the San Solomon Cienega which uses some spring flow to recreate more natural aquatic habitats for the benefit of the endangered fishes in the Park.

East Sandia Spring is located on the Sandia Springs Preserve recently (1997) purchased by TheNature Conservancy of Texas (TNC). There are two disjunct tracts (East and West SandiaSprings) that together make up 240 acres of preserved land. East Sandia Spring is located justeast of the town of Balmorhea in Reeves County, Texas. West Sandia Spring has ceased flowingin recent times. East Sandia Spring discharges at an elevation of 977 m (3,205 ft) from alluvialsand and gravel, but the water is probably derived from Comanchean limestone underlying thealluvium (Brune 1981). The small flow from the springs is used by the local farming communityfor agricultural irrigation. The primary threat is the loss of surface flows due to decliningroundwater levels from drought and pumping. TNC provides protection of the land around thespring, but cannot prevent declining spring flows due to groundwater pumping in other areas.

POPULATION STATUS

Despite the fact that Phantom Lake Spring has been drastically altered from its original state, the native snails (Phantom springsnail (*Tryonia cheatumi*) and Phantom Lake cavesnail (*Cochliopa texana*)) occurred in the irrigation canal in 1968 in such tremendous numbers that the sides of the canal appeared black from the cover of snails. Today the snails are limited to low densities in the small pool at the mouth of Phantom Cave and can not be found in the irrigation canal downstream (*in litt*, 2000 cited in U.S. Fish and Wildlife Service candidate assessment form). A similar situation occurs at San Solomon Spring, which has been significantly altered. Taylor (1987) reported the snail was abundant and generally distributed in the canals from 1965 - 1981.

The Texas Natural Heritage Program ranks the Phantom Lake cavesnail as Critically Imperiled.

The U.S. Fish and Wildlife Service classifies the Phantom springsnail as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range:	Texas. Three spring systems and associated outflows (Phantom Lake, San Solomon, and East Sandia springs) in the Toyah Basin of Jeff Davis County and Reeves County, Texas (Landye 1980).
Current range:	Texas. Three spring systems and associated outflows (Phantom Lake, San Solomon, and East Sandia springs) in the Toyah Basin of Jeff Davis County and Reeves County, Texas (Landye 1980).
Land ownership:	The land on which the snail occurs is owned and managed by U.S. Bureau of Reclamation, Texas Parks and Wildlife Department, and The Nature Conservancy of Texas. The surrounding watershed and surface area over contributing aquifers is all privately owned.

The most significant threat to the continued existence of this snail is the degradation and eventual loss of spring habitat (flowing water) due to the decline of groundwater levels of the supportingaquifer. Over pumping of the regional aquifer system for agricultural production of crops haveresulted in the drying of most other springs in this region (Brune 1981). Other springs that havealready failed include Comanche Springs, which was once a large surface spring in FortStockton, Texas. This spring flowed at more than 1200 liters per second (lps) (Brune 1981) andundoubtably provided habitat for rare species of fishes and invertebrates, including springsnails.The spring ceased flowing by 1962 (Brune 1981). Leon Springs, located about 40 miles east ofBalmorhea, was measured at 500 lps in the 1930s and was also known to contain rare fish, butceased flowing in the 1950s following significant irrigation pumping (Brune 1981).

Phantom Lake Spring has experienced a long-term, consistent decline in spring flows. Dischargedata have been recorded from the spring six to eight times per year since the 1940s by the U.S.Geological Survey (Schuster 1997). The record shows a steady decline of flows, from greaterthan 10 cfs in the 1940s to 0 cfs in 2000. The data also show that the spring can have short termflow peaks resulting from local rainfall events in the Davis Mountains (Sharp et al. 1999). Thesepeaks are from fast recharge and discharge, not surface runoff because the spring is not within adrainage basin. However, after each increase, the “base flow” has returned to the same decliningtrend within a few months. There have been extremely low flows from Phantom Lake Spring since the summer of 1998.

Rainfall in the late summer of 1999 provided temporary increase in flow, but by the fall flow hadreturned to near zero. A small amount of water has, until recently, continued to flow from thecave to keep the refugium functional with shallow water and provide limited habitat for theendangered fish. Currently, water surface elevation from the cave has declined further and therefuge channel is now dry. Only the small pool at the cave mouth continues to provide someaquatic habitat. This last remaining habitat will be gone as the water surface elevation declines.

Some of the obvious reasons for decreased flows are groundwater pumping of the supporting aquifer and decreased recharge of the aquifer from drought. Unfortunately the supporting aquifer for the springs is not well defined. Recent studies (LaFave and Sharp 1987, Schuster 1997, Sharp et al. 1999) support the idea that, although the spring is locally recharged by runoff from the Davis Mountains (resulting in the flow spikes), the "base flow" comes from a regional groundwater system. The source for the springs is likely the aquifer of the Capitan Reef associated with the Apache Mountains, with recharge areas in the Wildhorse Flat Basin to the northwest of the Toyah Basin. Sharp et al. (1999) further proposed that the declines in flow are most likely the result of groundwater pumping in this region.

Ashworth et al. (1997) carried out a cursory study to examine the cause of declining spring flowsin the Toyah Basin. The conclusion from this study was that "recent declines in springflows are more likely to be the result of diminished recharge due to the extended dry periodrather than from groundwater pumpage" (Ashworth et al. 1997). Although certainly a factor,drought alone is unlikely the only reason for declines because the drought of record in the 1950shad no effect on the overall flow trend.

Exploration of Phantom Cave by cave divers has led to additional information about the nature ofthe spring and its supporting aquifer (personal communication 1999 cited in U.S. Fish and Wildlife Service candidate assessment form). Beyond the entrance, the cave is a substantial conduit that transports a large volume of water generally from the northwest to the southeast, consistent with regional flow pattern hypothesis. Over 8,000 feet of the cave conduit have been mapped so far. In addition, flows have been measured and are in the 25 cfs range. The relatively small flow at Phantom Lake Spring is essentially an overflow of a larger flow system underground.

Although long-term data are scarce, San Solomon Spring flows have declined somewhat over thehistory of record, but not as much as Phantom Lake Spring (Schuster 1997, Sharp et al. 1999).Some recent declines in overall flow have likely occurred due to drought conditions anddeclining aquifer levels. San Solomon Spring is a much larger volume spring and discharges areusually in the 25 to 30 cfs range (Ashworth et al. 1997, Schuster 1997) and are consistent withthe theory that the water bypassing under Phantom Lake is later discharged at the San SolomonSpring. Giffin Spring (located within a mile to the northwest of San Solomon Spring) maintains anear constant 3 to 4 cfs outflow (Ashworth et al. 1997). Giffin Spring is on private land and thestatus of the snails there is uncertain.

Similar water chemistry, and near constant temperatures of about 26/C, among these three springs (Phantom, San Solomon, and Giffin) also supports the idea that their waters originate from the same source (Schuster 1997). The water discharging from East Sandia Spring is likely from a shallow groundwater source and water chemistry differences indicate it is not connected with the other Toyah Basin springs being considered (Schuster 1997). However, it may be even more susceptible to over pumping in the area of the local aquifer that supports the spring. Brune (1981) noted that flows were declining from Sandia Springs. Measured discharges in 1995 and 1996 ranged from 0.45 to 4.07 cfs (Schuster 1997).

Another threat to the habitat of the snail is the potential degradation of water quality from point and non-point pollutant sources. This can occur either directly into surface water or indirectly through contamination of groundwater that eventually discharges into spring run habitats used by the snail. The primary threat for contamination comes from herbicide and pesticide use in nearby agricultural areas.

Two of the three known occurrences of the species are in degraded habitats (the exception being East Sandia Spring) because the natural conditions of the springs have been substantially modified for human use. Any additional modification to the spring flow habitats at Phantom Lake Spring, San Solomon Spring or East Sandia Spring could further threaten the remaining populations of the species.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

None known.

C. ***Disease or predation.***

None known. However, the presence of introduced species increases the potential for foreign diseases to be introduced to the species.

D. ***The inadequacy of existing regulatory mechanisms.***

Texas State law provides no protection for these invertebrate species. There are no existing Federal, State or local regulatory mechanisms providing protection for these species. The snails are afforded some protection indirectly due to the presence of two fishes (Comanche Springs pupfish and Pecos gambusia) listed as endangered by State and Federal governments that occupy similar habitats. However, the snails may be more sensitive to changes in water quality than are the fish and are likely more directly threatened by the presence of the exotic *Melanoides* snail than are the endangered fish.

Some protection for the habitat of this species is provided with the ownership of the springs by Federal (Phantom Lake) and State (San Solomon) agencies, and by TNC (East Sandia). However, this land ownership provides no protection for maintaining necessary groundwater levels to ensure adequate spring flows.

Current Conservation Efforts: None.

E. *Other natural or manmade factors affecting its continued existence.*

Within the last 10 years, an exotic snail, *Melanoides* sp., has become established in Phantom Lake Spring (*in litt*. 1993 cited in U.S. Fish and Wildlife Service candidate assessment form; McDermott 2000). The species has been at San Solomon Spring for some time longer, but is not found in East Sandia Spring. In many locations at San Solomon Spring, this exotic snail essentially is the substrate in the small stream channel. The effects of this introduction are not known. However, this exotic snail is likely competing with the native snails for space and resources. Other changes to the ecosystem are likely to result from the dominance of this species, which could have detrimental effects on the native invertebrate community.

REFERENCES

Ashworth, J.B., D.B. Coker, and W. Tschirhart. 1997. Evaluation of diminished spring flows in the Toyah Creek Valley, Texas. Open File Report 97-03. Texas Water Development Board, Austin, Texas. 12pp.

Boghici, R. 1997. Hydrogeological investigations at Diamond Y Springs and surrounding area, Pecos County, Texas. Unpublished Master's Thesis, University of Texas at Austin. 120 pp.

Bowman, T.E. 1981. *Thermosphaeroma milleri* and *T. smith*i, new sphaeromatid isopod crustaceans from hot springs in Chihuahua, Mexico, with a review of the genus. Journal of Crustacean Biology. 1:105-122.

Brune, G. 1981. Springs of Texas. Branch-Smith, Inc. Fort Worth, Texas. Cole, G. A. 1985. Analysis of the *Gammarus pecos* complex (Crustacea: Amphipoda) in Texas and New Mexico, USA. Journal of the Arizona-Nevada Academy of Science 20:93-103.

Dundee, D. and H. Dundee. 1969. Notes concerning two Texas molluscs, *Cochliopa texana* Pilsbry and *Lyrodes cheatumi* Pilsbry (Mollusca: Hydrobiidae). Transactions of the American Microscipical Society 88(2):205-210.

Hershler, R., Hsiu-Ping Liu, and M. Mulvey. 1999. Phylogenetic relationships within the aquatic snail genus *Tryonia*: implications for biogeography of the North American Southwest. Molecular Phylogenetics and Evolution 13:377-391.

LaFave, J.I. and J.M. Sharp. 1987. Origins of groundwater discharging at the Springs of Balmorhea. West Texas Geological Society Bulletin 26:5-14.

Metcalf, A.L. and R.A. Smartt. 1997. Land snails of New Mexico. New Mexico Museum of Natural History and Science. Bulletin No. 10. 145 pp.

McDermott, K. 2000. Distribution and infection relationships of an undescribed digenetic Trematode, its exotic intermediate host, and endangered fishes in springs of west Texas. Unpublished Master’s Thesis, Southwest Texas State University, San Marcos, Texas. 26+ pp.

Pilsbry, H.A. 1935. Western and southwestern Amnicolidae and a new *Humboldtian*a. Nautilus 48:91-94.

Schuster, S.K. 1997. Hydrogeology and local recharge analysis in the Toyah Basin Aquifer. Masters Thesis, Geological Sciences, University of Texas at Austin. 130 pp.

Sharp, J.M., Uliana, M.M., and R. Boghici. 1999. Fracture controls on regional groundwater flow in a semiarid environment and implications for long-term maintenance of spring flows. Water 99 Joint Congress, Inst. of Engineers. Australia, Brisbane. v. 2, p.1212-1217.

Taylor, D. W. 1987. Fresh-water molluscs from New Mexico and vicinity. New Mexico Bureau of Mines and Mineral Resources Bulletin 116:1-50.

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P.M. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione, and J.D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks, 2nd edition. American Fisheries Society, Special Publication 26, Bethesda, Maryland.

Winemiller, K.O. and A.A. Anderson. 1997. Response of endangered desert fish populations to a constructed refuge. Restoration Ecology 5:204-213..Young, D.A., K.J. Fritz, G.P. Garrett, and C.

Hubbs. 1993. Status review of construction, native species introductions, and operation of an endangered species refugium channel, Phantom Lake Spring, Texas. Proceedings of the Desert Fishes Council 25:22-25..

PETITION TO LIST

Gonzales springsnail
(*Tryonia circumstriata*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 1/6/89:	
CNOR 11/21/91	
CNOR 11/15/94:	
CNOR 2/28/96:	C
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

The taxonomic status of the Gonzales springsnail, *Tryonia circumstriata* (Hydrobiidae), as a valid species is uncontroversial (e.g., Turgeon et al. 1998; Hershler et al. 1999). *Tryonia stocktonensis* is a junior synonym (Turgeon et al. 1998).

NATURAL HISTORY

Ecology

The Gonzales springsnail is a very small snail, measuring only 3.0 to 3.7 millimeters (0.11 to 0.14 inches) in length. The shell is narrowly conical, with an obtuse apex and a broadly rounded anterior end (Taylor 1987). Whorls 5 to 6 in larger females, regularly convex, separated by a deeply incised suture (Taylor 1987).

Like other hydrobiids, these snails are are sexually dimorphic. They are ovoviviparous, producing live young serially (as opposed to broods) (Taylor 1985). They are presumably fine-particle feeders on detritus and periphyton associated with the substrates (mud and vegetation).

The Gonzales springsnail is found on mud substrates on the margins of small springs, seeps, and marshes in flowing water associated with sedges and cattails (Taylor 1987).

Distribution

In the desert Southwest, aquatic snails are distributed in geographically isolated wetland populations (Hershler et al. 1999). They likely evolved into distinct species during recent dry periods from parent species that once enjoyed a wide distribution during wetter, cooler climates. Such divergence has been well-documented for aquatic and terrestrial macroinvertebrate groups within arid ecosystems of western North America (e.g., Taylor 1987, Metcalf and Smartt 1997, Bowman 1981).

The Gonzales springsnail occurs only in the Diamond Y Spring system and associated outflows in Pecos County, Texas (Taylor 1987). There is no available information to indicate whether the species' historic distribution was more extensive than it is today. Other area springs may have contained the same species, but because these springs have been dry for more than four decades, there is no opportunity to determine the potential historic distribution.

The Diamond Y Spring system is a tributary drainage to the Pecos River and is composed of disjunct upper and lower watercourses, separated by about a 1-kilometer (km) (0.62 miles (mi)) stretch of dry stream channel. The upper watercourse starts with the Diamond Y Spring head pool and is augmented by numerous small seeps, some of which drain into the spring outflow channel. This outflow channel converges with the Leon Creek drainage and flows through a marsh-meadow, where it is then referred to as Diamond Y Draw. The total upper watercourse is about 1.5 km (.93 mi) in length. The lower watercourse has a smaller head pool spring. (Euphrasia Spring) and outflow stream and also has several isolated pools, for example, Mansanto Pool. The total lower watercourse is about 1 km (0.62 mi) in length and may extend below the State Highway 18 bridge, during wetter seasons or years.

Taylor (1985) documented the distribution and abundance of aquatic snails in the Diamond Y Spring system. At the time of this work, Fall 1984, he found Diamond Y springsnail distribution limited to the upper watercourse. It was present at 12 of the 14 sites sampled, with density estimates ranging from 0.5 to 108 individuals per 0.1 square meter, with very low densities in the upstream areas, near the headspring. Taylor (1985) indicates the low density areas were in definite contrast to unpublished data collected by the author in 1968, when the upstream areas of the upper watercourse harbored large numbers of Diamond Y springsnails. This study also found that Gonzales springsnail was limited to only the lower watercourse in the first 30 meters (98.4 feet) of outflow from Euphrasia Spring. These findings were confirmed by Fullington (1991).

More recent surveys have found that Diamond Y springsnail is currently found in the isolated spring seeps near the Diamond Y Spring head pool, in side seeps at the downstream end of the upper watercourse and at the immediate outflow of Euphrasia Spring in the lower watercourse (Echelle 1999). Meanwhile, Gonzales springsnail is now found only in the outflow stream of the Diamond Y head pool in the upper watercourse. This distribution is supported by recent observations of Dr. Robert Hershler's reported in Echelle (1999) (cited in U.S. Fish and Wildlife Service candidate Assessment form). The reason for the apparent reversal in distributional patterns of the two species within the Diamond Y Spring system since the surveys by Taylor (1985) is unknown.

Although the two snail species both occur in the Diamond Y Spring system, they have not been taken together at any sample locations (Taylor 1985, 1987; Echelle 1999), with the reported exception of Fullington (1991), who collected both species from a small seep to the side of the Diamond Y Spring head pool. Taylor (1985, 1987) suggests the reason for this mutually exclusive distribution is likely competition rather than habitat differences, because the two species appear to occupy the same microhabitats, yet are spatially segregated.

POPULATION STATUS

Over-pumping of the regional aquifer system for agricultural production of crops has resulted in severely decreased water flows. As a result, this once numerous species has been reduced to fewer than 1,000 individuals on less than 2,000 acres of land, on less than 10 miles of stream (Opler and Morrison in NatureServe Explorer 2001). The introduction of an exotic snail species, and oil and gas pumping in the immediate vicinity, also pose a serious threat to the species.

The Texas Natural Heritage Program ranks the Gonzales springsnail as Critically Imperiled.

The U.S. Fish and Wildlife Service classifies the Gonzales springsnail as a candidate for Endangered Species Act protection with a listing priority number of 2. The listing priority number was increased from 5 to 2 due to new threats from the recent introduction of an exotic snail (*Melanoides* sp.) into the species' habitat.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range:	Texas. Diamond Y Spring system and associated outflows in Pecos County, Texas (Taylor 1987). There is no available information to indicate whether the species' historic distribution was ever more extensive than it is today.
Current range:	Texas. Diamond Y Spring system and associated outflows in Pecos County.
Land ownership:	The land on which the snail occurs is owned and managed by The Nature Conservancy of Texas. The surrounding watershed and surface area over contributing aquifers is all privately owned.

The primary threat to this species is the potential failure of spring flow due to excessive groundwater pumping and/or drought which would result in total habitat loss for the species. Diamond Y Spring is the last major spring still flowing in Pecos County, Texas. Over-pumping of the regional aquifer system for agricultural production of crops have resulted in the drying of most other springs in this region (Brune 1981). Other springs that have already failed include Comanche Springs, which was once a large surface spring in Fort Stockton, Texas, about eight miles from Diamond Y. This spring flowed at more than 1200 liters per second (lps) (Brune 1981) and undoubtably provided habitat for rare species of fishes and invertebrates, including springsnails.

The spring ceased flowing by 1962 (Brune 1981). Leon Springs, located upstream of Diamond Y in the Leon Creek watershed, was measured at 500 lps in the 1930s and was also known to contain rare fish, but ceased flowing in the 1950's following significant irrigation pumping (Brune 1981). There have been no continuous records of spring flow discharge at Diamond Y Spring by which to determine any trends in spring flow.

Studies by Veni (1991) and Boghici (1997) indicate that the spring flow at Diamond Y Spring comes from the Rustler aquifers located west of the spring outlets. One significant factor that influences flows at the spring is the large groundwater withdrawals for agricultural irrigation of farms to the southwest in the Belding-Fort Stockton areas. Although The Nature Conservancy of Texas owns and manages the property surrounding the Diamond Y Spring system, it has no control over groundwater use that affects spring flow. The Supreme Court of Texas has upheld the rule of capture for groundwater use in Texas. This means that property owners have the right to withdraw as much groundwater as they desire, without considering impacts to other resources or nearby landowners.

Oil and gas activities threaten this springsnail because of the potential groundwater or surface water contamination of pollutants (Veni 1991, Fullington 1991). The Diamond Y Spring system is within an active oil and gas extraction field. At this time there are still many active wells located within a hundred meters of surface waters. In addition a natural gas refinery is located within 0.8 km (0.5 mi) upstream of Diamond Y Spring. There are also old brine pits associated with previous drilling within feet of surface waters. Oil and gas pipelines cross the spring outflow channels and marshes where the species occurs, creating a constant potential for contamination from pollutants from leaks or spills. These activities could contaminate the habitat of the springsnail by allowing foreign pollutants to enter underground aquifers that may contribute to spring flow or through point sources from spills and leaks of petroleum products.

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

None known.

C. ***Disease or predation.***

None known. However, the presence of introduced species (a *Melanoides* snail) increases the potential for foreign diseases to be introduced to the species.

D. ***The inadequacy of existing regulatory mechanisms.***

Texas State law provides no protection for these invertebrate species. There are no existing

Federal, State or local regulatory mechanisms providing protection for these species. The snails are afforded some protection indirectly due to the presence of two fishes (Leon Springs pupfish and Pecos gambusia) listed as endangered by State and Federal governments that occupy similar habitats. However, the snail may be more sensitive to changes in water quality than are the fish and is likely more directly threatened by the presence of the exotic *Melanoides* snail than are the.endangered fish.

Current Conservation Efforts: None.

E. *Other natural or manmade factors affecting its continued existence.*

Within the last 10 years, an exotic snail, *Melanoides* sp., has become established in Diamond Y Spring (Echelle 1999, McDermott 2000). The species is by far the most abundant snail in the upper watercourse of the Diamond Y Spring system. So far it has not been detected in the lower water course (Echelle 1999). In many locations, this exotic snail is so numerous that it essentially is the substrate in the small stream channel. The effects of this introduction are not yet known. However, this exotic snail is likely competing with the native snails for space and resources. Other changes to the ecosystem are likely to result from the dominance of this species, which could have detrimental effects on the native invertebrate community.

REFERENCES

Boghici, R. 1997. Hydrogeological investigations at Diamond Y Springs and surrounding area, Pecos County, Texas. Unpublished Master's Thesis, University of Texas at Austin. 120 pp.

Bowman, T.E. 1981. *Thermosphaeroma milleri* and *T. smithi*, new sphaeromatid isopod crustaceans from hot springs in Chihuahua, Mexico, with a review of the genus. Journal of Crustacean Biology. 1:105-122.

Brune, G. 1981. Springs of Texas. Branch-Smith, Inc. Fort Worth, Texas.

Echelle, A.A. 1999. Monitoring effects of a renovation project on endangered fish and invertebrates in Diamond Y Draw. Annual Performance Report, Endangered Species Program, Texas Parks and Wildlife Department, Austin, Texas. Grant No. E-1-11, Project WER47(85). 21 pp.

Fullington, R.W. 1991. Mollusca survey of Texas Nature Conservancy Preserves: Diamond Y Springs and Independence Creek. Final Report, The Nature Conservancy of Texas, San Antonio, Texas. 7 pp.

Henry, B. 1992. The macroinvertebrate community of Diamond Y Cienega, a saline spring system in Trans-Pecos, Texas. Final Report, The Texas Nature Conservancy, San

Antonio, Texas. 13 pp.

Hershler, R., Hsiu-Ping Liu, and M. Mulvey. 1999. Phylogenetic relationships within the aquatic snail genus *Tryonia*: implications for biogeography of the North American Southwest. Molecular Phylogenetics and Evolution 13:377-391.

Metcalf, A.L. and R.A. Smartt. 1997. Land snails of New Mexico. New Mexico Museum of Natural History and Science. Bulletin No. 10. 145 pp.

McDermott, K. 2000. Distribution and infection relationships of an undescribed digenetic Trematode, its exotic intermediate host, and endangered fishes in springs of west Texas. Unpublished Master's Thesis, Southwest Texas State University, San Marcos, Texas. 26+ pp.

Opler, P.A. and M. Morrison in NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

Taylor, D. W. 1985. Status survey of aquatic molluscs in Diamond Y Draw in Pecos County, Texas. Unpublished report. 27 pp.

Taylor, D. W. 1987. Fresh-water molluscs from New Mexico and vicinity. New Mexico Bureau of Mines and Mineral Resources Bulletin 116:1-50.

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P.M. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione, and J.D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks, 2nd edition. American Fisheries Society, Special Publication 26, Bethesda, Maryland.

Veni, G. 1991. Delineation and preliminary hydrologic investigation of the Diamond Y Spring, Pecos County, Texas. Final Report, The Nature Conservancy, San Antonio, Texas. 111 pp..

PETITION TO LIST

Huachuca springsnail
(*Pyrgulopsis thompsoni*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 1/6/89:	
CNOR 11/21/91:	
CNOR 11/15/94:	
CNOR 2/28/96:	C
CNOR 9/19/97:	C
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 6/13/02:	C

TAXONOMY

The taxonomic status of the Huachuca springsnail, *Pyrgulopsis thompsoni* (Hydrobiidae), as a valid species is uncontroversial (e.g., Turgeon et al. 1998).

NATURAL HISTORY

Morphology and Ecology
Hershler and Landye (1988) describe the Huachuca springsnail as medium to large relative to other hydrobiid snails, with a shell 1.7 to 3.2 mm long. The shell is ovate-conic with 3.25 to five moderately convex, slightly shouldered whorls. The aperture may be fused or separate from the body whorl. The pigmentation of the snout and anterior part of the foot tends from light to dark with the remaining portion and the head generally unpigmented. There appears to be some sexual dimorphism in two of four populations studied, in one case the males being larger than the females and vice versa in the other population. The identification is based upon characteristics of the reproductive organs. The penis which is considered moderate in size may be "squat to elongate." The ventral penial lobe surface has a glandular ridge, this is generally located at the tip of the lobe. The penial filament may be 35 to 103 percent of the penis length and centered at 80 to 93 percent of the penis length. The whole of the penis exhibits a dark pigmentation. The testis and prostrate make up 37 to 54 percent and 7 to 8 percent of the body length, respectively. Between 55 and 85 percent of the bursa length is posterior to the albumen gland.

Little is known about the life cycle and ecology of the species**.** It is unknown how long individuals live and their reproductive potential has not been assessed.

The Huachuca springsnail is typically found in marshy areas characterized by various aquatic and emergent plant species that occur within plains grassland, oak and pine-oak woodlands, and coniferous forest vegetation communities. The species is typically found in the shallower areas of springs or cienegas, often in rocky seeps at the spring source.

Distribution
The species inhabits springs and cienegas at 4,500 to 7,200 feet elevation in southeastern Arizona and adjacent portions of Sonora, Mexico. Range is the upper portion of the Santa Cruz and San Pedro River basins in Arizona and Sonora, Mexico. Originally it covered only six sites in Santa Cruz County, Arizona and Sonora, Mexico. These sites were: Cottonwood Springs, Monkey Spring, Canelo Hills Cienega, Sheehy Spring, Peterson Ranch Springs, and Ojo Caliente, (Hershler and Landye, 1988). Since that time, Landye in 1992 examined 16 springs on Fort Huachuca Military Base in the Huachuca Mountains and found occurrences at nine springs. The nine additional sites are Upper Garden Canyon Spring, Lower Garden Canyon Spring, McClure Spring, Broken Pipe Spring, Cave Spring, Sawmill Canyon Spring, Upper Water Supply Spring, Lower Water Supply Spring, Blacktail Spring. An additional site in Mexico was reported at Cienega Los Fresnos (NatureServe Explorer 2001).

POPULATION STATUS

All populations of Huachuca springsnail are limited to very small sites that are many miles apart. The habitat is under current threat from Federal grazing programs, water diversion, and ground water pumping associated with Fort Huachuca and the surrounding town, Sierra Vista.

The Arizona Natural Heritage Program ranks the Huachuca springsnail as Imperiled.

The U.S. Fish and Wildlife Service classifies the Huachuca springsnail as a candidate for Endangered Species Act protection with a listing priority number of 5.

LISTING CRITERIA

A. ***The present or threatened destruction, modification, or curtailment of its habitat or range.***

Historical range:	Arizona, Sonora, MX. Cienegas and isolated springs in the upper Santa Cruz and San Pedro River drainages. A long-term historical distribution of the species is unknown.
Current range:	Arizona, Sonora, MX. Cienegas and isolated springs in the upper Santa Cruz and San Pedro River drainages.

Land ownership: USA: Federal: 55%, private: 45%; Mexico: private: 100%. Six locations are found on the Fort Huachuca Military Reservation, one site is owned by The Nature Conservancy, one site is within the Sierra Vista District of the Forest Service and three are on private property (USFWS, 1997).

The historical distribution of the species is unknown, as it was first collected in 1969. However, loss of cienegas during the last century in southeastern Arizona is well-documented, and it is likely that the species occurred at many more than 13 localities in the past. Causes of cienega loss are debated, but probably include overgrazing, timber harvest, altered fire regimes, drought, and mining. After cienegas and watersheds were degraded by these activities, severe storms and periods of high precipitation caused erosion and sedimentation, accelerating loss of cienegas and riparian areas.

Many of the sites at which the springsnail occurs are developed springs where flows have been altered by dams, springboxes, and diversions. The effects of these alterations on the springsnail are difficult to assess because pre-development conditions are unknown. Fuel loads are abnormally high in the Huachuca Mountains, where fire regimes have been altered from one of frequent ground fires to infrequent catastrophic crown fires. Loss of cover, and subsequent erosion and sedimentation following a catastrophic fire, could result in loss of habitat and extirpation of one or more of the seven populations in the Huachuca Mountains. Grazing can result in trampling and denuding of vegetation in the shallow waters of cienegas where the springsnail occurs, but grazing has been excluded from most springsnail localities. Development and associated groundwater pumping threatens populations in the Sonoita Creek basin.

B. *Overutilization for commercial, recreational, scientific, or educational purposes.*

Not a known threat.

C. *Disease or predation.*

Not a known threat for the Huachuca springsnail. Other species are known to serve as the intermediate hosts for a variety of trematodes (parasitic flatworms) and as a prey item for non-native fish and crayfish.

D. *The inadequacy of existing regulatory mechanisms.*

Existing regulatory mechanisms are not adequate to address threats such as fire and environmental catastrophe. The species is afforded some indirect protection by occurring with or near other listed species (Huachuca water umbel, Sonora tiger salamander, Mexican spotted owl) at some localities.

The Huachuca springsnail is protected by the State under Commission Order 42 which establishes a closed season for the species. This order prohibits direct take and collection of Huachuca springsnails but does not prevent habitat modification or destruction.

Current Conservation Efforts: None. The U.S. Fish and Wildlife Service failed to implement a conservation agreement with the Federal landowner (Fort Huachuca) in 1995.

E. *Other natural or manmade factors affecting its continued existence.*

All populations of Huachuca springsnail are limited to very small sites that are often many miles apart. Extirpation of a population could occur as a result of major storms, drought, fire, or other forms of environmental instability. Because populations are isolated, once extirpated, sites are unlikely to be recolonized without active management. Small populations are also subject to genetic deterioration and demographic variability, which increases the likelihood of extinction.

REFERENCES

Bequaert, J.C. and W.B. Miller. 1973. The mollusks of the arid southwest. The University of Arizona Press, Tucson, Arizona, pp 213-214.

Hershler R., and J.J. Landye, 1988. Arizona Hydrobiidae (Prosobranchia: Rissoacea). Smithsonian Contributions to Zoology. Number 459. 63 pp.

Landye, J. Undated field notes. Huachuca springsnail populations located on the Fort Huachuca Army Post. Fish and Wildlife Service, Pinetop, Arizona.

NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Version 1.6 . Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer.

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P.M. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione, and J.D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks, 2nd edition. American Fisheries Society, Special Publication 26, Bethesda, Maryland.

U.S. Fish and Wildlife Service. 1997. Category and Listing Priority Forms.

PETITION TO LIST

Black River springsnail
(*Pyrgulopsis trivialis*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 1/6/89:
CNOR 11/21/91:
CNOR 11/15/94:
CNOR 10/30/01: C
CNOR 6/13/02: C

TAXONOMY

The taxonomic status of the Black River springsnail, *Pyrgulopsis trivialis* (Hydrobiidae), as a valid species is uncontroversial (e.g., Turgeon et al 1998). The U.S. Fish and Wildlife Service uses the common name Three Forks springsnail, but Turgeon et al. (1998) list "Black River springsnail" as the accepted common name, and this name more accurately reflects the distribution of this snail.

NATURAL HISTORY

Ecology
Hydrobiid snails occur in springs, seeps, marshes, spring pools, outflows, and diverse lotic (flowing) waters. The most common habitat for *Pyrgulopsis* is a rheocrene, or a.spring emerging from the ground as a free-flowing stream. Black River springsnail habitats are isolated, permanently saturated, spring-fed aquatic climax communities commonly described as ciénegas. Firm substrates such as cobble, gravel, woody debris, and aquatic vegetation are typical. *Pyrgulopsis* snails are rarely found on or in soft sediment. Aquatic vegetation within these habitats includes watercress (*Nasturtium* spp.), *Ranunculu*s, and filamentous green algae. Springsnails are commonly found among watercress. Other mollusks include *Anodonta californiensi*s, *Valvata humeralis, Physa gyrina, Radix auriculari*a, *Gyraulus parvu*s, *Pisidium casertanum*, *P. compressum*, and *P. variabil*e.

Distribution

The Black River springsnail is an endemic species with distribution limited to the Three Forks Springs (T5N, R29E) and Boneyard Springs (T6N, R29E) that are complexes in the North Fork East Fork Black River Watershed of east-central Arizona. The springsnail is known from free-flowing spring heads, concrete boxed spring heads, spring runs, and spring seepage at these sites. Three Forks Springs consists of about five spring heads confined to an area of approximately 0.1 km^2.

POPULATION STATUS

Due to crayfish predation, the Black River springsnail is entirely absent from at least two boxed spring heads within which it was previously abundant in Three Forks Springs. No information is available on current population sizes, although the species can be locally abundant when conditions allow.

The Arizona Natural Heritage Program ranks the Black River springsnail as Critically Imperiled.

The U.S. Fish and Wildlife Service classifies the Black River springsnail as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. ***The present or threatened destruction, modification, or curtailment of its habitat or range.***

Historical range:	Arizona. The Black River springsnail is limited to the Three Forks Springs (T5N, R29E) and Boneyard Springs (T6N, R29E) that are complexes in the North Fork and East Fork of the Black River Watershed of east-central Arizona.
Current range:	Arizona. The Black River springsnail is limited to the Three Forks Springs (T5N, R29E) and Boneyard Springs (T6N, R29E) that are complexes in the North Fork and East Fork of the Black River Watershed of east-central Arizona.
Land ownership:	The entire range of the species is within lands managed by the Apache/Sitgreaves National Forests.

Throughout most of the 20thcentury, Three Forks and Boneyard Springs have been subjected to various levels of livestock grazing. In the mid-and late 1990s livestock were fenced out of the immediate areas containing the spring complexes, although trespass livestock may occasionally gain access to springsnail sites. Cattle grazing can result in significant degradation of the aquatic environment and has been implicated in the extirpation of other hydrobiid snails.

Although cattle have largely been removed, free-ranging elk (*Cervus elaphu*s) have access to all spring areas containing springsnails. Bank degradation is a result of excessive elk trampling and wallowing at both Boneyard and Three Forks Springs. Elk populations are at or near the local carrying capacity of the environment and are disrupting the dynamic equilibrium of the spring ecosystems. Grass and shrub cover at both Boneyard and Three Forks Springs are being severely overgrazed and the banks of the springs and spring runs are experiencing accelerated erosion and head cutting. Bank degradation is causing obvious changes to the aquatic environment of both spring complexes, including decreased gradient, increased sedimentation, and high turbidity.

These habitat conditions are largely non-conducive to occupation by springsnails and the species is conspicuously absent, or in reduced numbers, in areas most affected by elk trampling. At Three Forks Springs, the effects of elk tramping is confounded by increases in populations of non-native crayfish (*Oronectes virile*s). Elk trampling and crayfish burrowing seem to be acting synergistically to contribute to accelerated bank destabilization. If elk and crayfish threats at Three Forks Springs, and elk threats alone at Boneyard Springs, are not immediately ameliorated, the aquatic environments of both spring complexes will become unsuitable for the Three Forks springsnail.

Three Forks Springs has also been affected by modifications of natural springhead integrity. During the 1930s concrete boxes were constructed around four of the springheads at the Three Forks site. However, it does not appear that these modifications have negatively affected habitat suitability for the species, and springsnails have been known to be locally abundant within spring boxes and associated outflows.

B. *Overutilization for commercial, recreational, scientific, or educational purposes.*

The Black River springsnail has been subjected to a limited number of scientific studies aimed at determining taxonomic and distributional status. However, these studies have occurred on a small scale and are not believed to have had discernible effects on any population. The springsnail is not utilized for commercial or recreational purposes.

C. *Disease or predation.*

Non-native crayfish (*Oronectes virile*s) have invaded several spring heads within Three Forks Springs and they are known to directly prey upon aquatic invertebrates such as springsnails. Crayfish are also known to consume aquatic macrophytes and algae that springsnails rely on for grazing and egg laying. Due to its geographic isolation, the Black River springsnail is not evolutionarily adapted to cope with crayfish, making the species particularly susceptible to crayfish predation.

The Black River springsnail is entirely absent from at least two boxed spring heads within which it was previously abundant in Three Forks Springs. The extirpation of the species from these spring boxes seems to coincide with the invasion of crayfish. Crayfish also appear to be most abundant in areas most heavily affected by elk trampling. In the absence of an intensive crayfish removal program, populations of crayfish will continue to grow and place significant unnatural predatory pressure on the Black River springsnail. Localized extirpations at Three Forks Springs will continue, and springsnail numbers are likely to decline. Presently, crayfish are not known to occur in Boneyard Springs.

D. ***The inadequacy of existing regulatory mechanisms.***

The Black River springsnai is currently not protected by any Federal statutes or regulations. The springsnail is listed under Arizona Game and Fish Commission Order 42 which establishes no open season for the species. This order prohibits direct taking of the species but does not prohibit spring modification or habitat destruction.

Current Conservation Efforts: None.

E. ***Other natural or manmade factors affecting its continued existence.***

The North Fork East Fork Black River watershed is a popular area for public recreation such as fishing, hiking, hunting, and wildlife viewing. Recreation affects springsnails through habitat vandalism, introduction of pollutants or other contaminants, and introduction and spread of non-native aquatic organisms. Three Forks Springs is particularly susceptible because it is adjacent to a major Forest Service road and the North Fork East Fork of the Black River, which provides good fishing opportunities. The spread of crayfish at Three Forks Springs is primarily due to "bait bucket" releases by anglers. Additionally, campers and day hikers have been known to wash dishes and other camping equipment at Three Forks Springs, resulting in the introduction of detergents, bleach, and other pollutants that can impair essential physiological processes of springsnails. Boneyard Springs is less susceptible to these threats because it is more isolated with access only possible by hiking from a 4-wheel drive road. Lastly, endemic springsnails whose populations exhibit a high degree of geographic isolation are extremely susceptible to stochastic extinction resulting from catastrophic natural disasters such as fires, floods, or changes in spring water chemistry.

REFERENCES

Fernandez, P.J. and P.C. Rosen. 1996. Effects of the introduced crayfish *Oronectes virilis* on native aquatic herpetonfauna in Arizona. Final Report to Heritage Program, Arizona Game and Fish Department. 70 p.

Hershler, R. and J.J. Landye. 1988. Arizona Hydrobiidae (Prosobranchia: Rissoacea). Smithsonian Contributions to Zoology. No. 459. 63 p.

Hershler, R. 1994. A review of the North American freshwater snail genus *Pyrgulopsis* (Hydrobiidae). Smithonian Contributions to Zoology, Number 554. Smithsonian Institution Press. Washington D.C. 52 p.

Landye, J.J. 1973. Status of inland aquatic and semi-aquatic mollusks of the American southwest. USDI Fish and Wildlife Service (Bureau of Sport Fisheries and Wildlife), Washington, D.C. 60 p.

Landye, J.J. 1981. Current status of endangered, threatened, and/or rare mollusks of New Mexico and Arizona. USDI Fish and Wildlife Service (Bureau of Sport Fisheries and Wildlife), Albuquerque, NM. 35 p.

Taylor, D.W. 1987. Fresh-water molluscs from New Mexico and vicinity. New Mexico Bureau of Mines and Mineral Resources. Bulletin 116. Socorro, New Mexico. p 30-32.

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P.M. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione, and J.D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks, 2nd edition. American Fisheries Society, Special Publication 26, Bethesda, Maryland.

PETITION TO LIST

Newcomb's tree snail
(*Newcombia cumingi*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 11/15/94:	
CNOR 02/28/96:	
CNOR 09/19/97:	
CNOR 10/25/99:	C
CNOR 10/30/01:	C
CNOR 06/13/02:	C

TAXONOMY

The taxonomic status of Newcomb's tree snail, *Newcombia cumingi* (Achatinellidae), as a valid species is uncontroversial (e.g., Bishop Museum 2002).

NATURAL HISTORY

This small snail reaches an adult length of approximately 21 mm (Thacker and Hadfield 1988).

As with other achatinellid tree snails of Hawaii, *Newcombia cumingi* likely feeds on fungi and algae which grow on the leaves and trunks of living trees. Based on the short study period on which information is currently based, *N. cumingi* is believed to exhibit the slow growth and low reproductive rate of other Hawaiian tree snails belonging to this family.

This species is found within a range of some 242 m^2 (62,677 ha). Early collectors noted this species occurring in montane areas (> 3280 ft in elevation (1000 m) to just above sea level (<800 ft (240 m)).

Newcombia cumingi is endemic to the island of Maui. Until 1995, *N. cumingi* had not been observed in over 50 years. Early collection records of Maui tree snails indicate that this snail had a relatively wide distribution, being found from the western slopes of Haleakala on east Maui and throughout west Maui.

In 1994, natural resource personnel located a small population of *N. cumingi* while monitoring transects for alien species in the mountains of west Maui. Previous natural resource activity in the area, as well as surveys conducted in adjacent areas for tree snails, had failed to locate this species. After this finding, more focused surveys in the area failed to locate additional sites where *N. cumingi* was present.

POPULATION STATUS

Population studies of the single known population on privately owned land estimated total numbers at 86 individuals restricted to an area of 25,000 ft^2 (0.232 ha) in the mountains of west Maui. Feral pigs, rats, and carnivorous snails currently threaten this small population.

The U.S. Fish and Wildlife Service classifies Newcomb's tree snail a candidate for Endangered Species Act protection with a listing priority number of 5.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range:	State of Hawaii (island of Maui). Historically, this snail had a relatively wide distribution, being found from the western slopes of Haleakala on east Maui and throughout west Maui.
Current range:	State of Hawaii, mountains of west Maui.
Land ownership:	Only known population is located on private lands.

The single known population of *Newcombia cumingi* occurs on private land which is currently zoned and managed as conservation land. The population occurs in habitat dominated by native plants and is largely protected from alien ungulates through active management (e.g., fencing). Alien plant species present in the area pose ongoing threats to native habitats (e.g., *Rubus* spp.; Smith 1992). Despite current conservation management efforts, wet montane habitats of the Hawaiian Islands have been impacted by alien ungulates (pigs) and invasive weeds. Feral pigs are present in nearly all Hawaiian wet forests, and have only recently been excluded from a small area of such forest on protected lands. Their rooting opens pristine areas of forest and allows the establishment and growth of seeds carried in their fur and feces, as well as seeds brought in by other means (e.g., bird droppings; Stone 1992). Other invasive alien plants are a constant threat to native Hawaiian forest and constant management efforts are required to keep them under control in pristine areas (Smith 1992).

B. *Overutilization for commercial, recreational, scientific, or educational purposes.*

The Hawaiian tree snails in the family Achatinellidae were extensively collected for scientific as well as recreational purposes in the 18th to early 20th centuries. While these impacts may have been especially severe to some species and populations in the genera *Achatinella* and *Partulina*, it has not yet been determined if *Newcombia* was impacted by such collections.

C. *Disease or predation.*

Although diseases have been shown to have impacted other rare snail species (Ferber 1998), this has not been documented to have contributed to declines in the Hawaiian tree snail fauna. Predation has been well documented to have had severe impacts on the tree snail fauna of Hawaii and other Pacific islands (Cowie 1992, Hadfield and Mountain 1980, Hadfield 1986, and Solem 1990). Both introduced rats (*Rattus* spp.) and the introduced rosy carnivore snail (*Euglandina rosea*) have long been documented to prey on Hawaiian tree snails, virtually wiping out some populations (Hadfield and Mountain 1980). During Hadfield's surveys for *Newcombia cumingi* (Thacker and Hadfield 1998), evidence of rat predation on other tree snail species within the study area was documented. In addition, the rosy carnivore snail was found on the ground directly below trees containing *N. cumingi*. There is little doubt that these predators have had major impacts on Hawaiian tree snails in the past and are likely the most serious threat at this time.

D. *The inadequacy of existing regulatory mechanisms.*

Newcombia cumingi does not currently receive protection under any legal statutes.

Current Conservation Efforts: Aside from partial funding for surveys for *Newcombia cumingi*, the U.S. Fish and Wildlife Service has failed to initiate any conservation activities. All conservation activities targeting this species are solely those of the landowner's.

E. *Other natural or manmade factors affecting its continued existence.*

While not an imminent threat, some development activities have been proposed for areas below the known population of *Newcombia cumingi*. Any additional human activity in the area could provide an avenue for the establishment and/or spread of new or established alien species. The main Maui airport in Kahului is currently proposed to be expanded for the accommodation of direct flights of commercial airliners from mainland and international origins. Direct flights will inadvertently result in the introduction of a greater number of invasive alien species to Hawaii.

REFERENCES

Bishop Museum of Honolulu. Hawaiian Freshwater and Terrestrial Mollusk Checklist, revised April 9, 2002. http://www2.bishopmuseum.org/HBS/checklist/query.asp?grp=Mollusk

Cowie, R.H. 1992. Evolution and extinction of Partulidae, endemic Pacific island land snails.

Phil. Trans. R. Soc. London, 335:167-191.

Cowie, R.H, N.L. Evenhuis, and C.C. Christensen. 1995. Catalog of the Native Land and Freshwater Molluscs of the Hawaiian Islands. Backhuys Pub., Leiden, Netherlands. 248 pp.

Ferber, D. 1998. Bug vanquishes species. Science, 282:215 pp.

Hadfield, M.G. 1986. Extinction in Hawaiian Achatinelline snails. Malacologia, 27:67-81.

Hadfield, M.G. and B.S. Mountain. 1980. A field study of a vanishing species, *Achatinella mustelina* (Gastropoda, Pulmonata), in the Waianae Mountains of Oahu. Pac. Sci.,.6 34:345-358.

Smith, C.W. 1989. Non-native plants.In: C.P. Stone and D.B. Stone (eds.) Conservation Biology in Hawaii. University of Hawaii Cooperative National Park Resources Studies Unit, Honolulu, Hawaii. 60-69 pp.

Solem, A. 1990. How many Hawaiian land snails species are left? and what we can do for them. Bishop Museum Occasional Papers, 30:2-40.

Stone, C.P. 1992. Non-native land vertebrates. In: C.P. Stone and D.B. Stone (eds.). Conservation Biology in Hawaii. University of Hawaii Cooperative National Park Resources Studies Unit. Honolulu, Hawaii. 88-95.

Thacker, R.W. and M.G. Hadfield. 1998. The Status of Newcomb's Tree Snail, *Newcombia cumingi* , on West Maui. Report to U.S. Fish & Wildlife Service.

PETITION TO LIST

Altamaha spinymussel
(*Elliptio spinosa*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 05/22/84:
CNOR 01/06/89:
CNOR 11/21/91:
CNOR 11/15/94:
CNOR 06/13/02: C

TAXONOMY

The Altamaha spinymussel (*Elliptio spinosa*) was described from the Altamaha River from a site near its mouth at Darien, Georgia, in 1836 (Johnson 1970). Its taxonomic status as a valid species is uncontroversial (e.g., Turgeon et al. 1998).

NATURAL HISTORY

The Altamaha spinymussel is a freshwater mussel endemic to the Altamaha River drainage of southeastern Georgia (Johnson 1970). The Altamaha spinymussel is associated with stable, coarse to fine sandy sediments of sandbars and sloughs and appears to be restricted to swiftly flowing water (Sickel 1980). Johnson (1970) reported that Altamaha spinymussels are found buried approximately 2 to 4 inches below the substrate surface. The Altamaha spinymussel is medium to large in size, reaching a shell length of approximately 110 millimeters (4.3 inches). The shell is subrhomboidal or subtriangular in outline and moderately inflated. In young specimens, the outside layer or covering of the shell (periostracum) is greenish-yellow with faint greenish rays, but as the animals get older, they typically become a deep brown. Some raying may still be evident in older individuals. The interior layer of the shell (nacre) is pink or purplish. As the name implies, the shells of these animals are adorned with one to five prominent spines. These spines may by straight or crooked, reach lengths from 1-2.5 cm, and are arranged in a single row that is somewhat parallel to the posterior ridge (Johnson 1970). Adult freshwater mussels are filter-feeders, siphoning phytoplankton, diatoms, and other microorganisms from the water column. For their first several months juvenile mussels employ foot (pedal) feeding, and are thus suspension feeders that feed on algae and detritus. Mussels tend to grow relatively rapidly for the first few years, then slow appreciably at sexual maturity (when energy is being diverted from growth to reproductive activities). As a group, mussels are extremely long-lived, living from a few decades to a maximum of approximately 200 years. Large, heavy-shelled riverine species tend to have longer life spans. No age specific information is available for the Altamaha spinymussel. However, considering that it is a fairly large, heavyshelled riverine species, it would seem probable that it is relatively long-lived. Most mussels, including the Altamaha spinymussel, have separate sexes. Males expel clouds of sperm into the water column, which are drawn in by females through their incurrent siphons. Fertilization takes place internally, and the resulting zygotes develop into specialized larvae termed glochidia inside the water tubes of her gills. Glochidia must come into contact with a specific host fish(es) and parasitize that fish for a short time in order for their survival to be ensured. Without the proper host fish, the glochidia will perish. After a few weeks parisitizing the host fish's gill tissues, newly-metamorphosed juveniles drop off to begin a free-living existence on the stream bottom. Unless they drop off in suitable habitat, they will die. Thus, the complex life history of the Altamaha spinymussel and other mussels has many weak links that may prevent successful reproduction and/or recruitment of juveniles to existing populations.

POPULATION STATUS

The historical range of the Altamaha spinymussel was restricted to the Coastal Plain portion of the Altamaha River and the lower portions of its three major tributaries, the Ohoopee, Ocmulgee, and Oconee rivers (Johnson 1970; personal communication 2001 cited in U.S. Fish and Wildlife Service candidate assessment form). The Altamaha River is formed by the confluence of the Ocmulgee and Oconee rivers and lies entirely within the State of Georgia. Since its description, the Altamaha spinymussel has been sought by many collectors and is found in numerous public and private collections. However, large scale, targeted surveys for the mussel have been conducted only since the 1970s (Keferl 1994).

Recent surveys have revealed a dramatic decline in the number of populations and number of individuals within populations throughout the species' historical range. In a survey of the Ohoopee River, Keferl (1981) found the Altamaha spinymussel in thinly scattered beds in the lower five miles of the river, and live specimens were found at seven of eight collection sites there. By the early 1990s, however, only two live specimens were found at the same sites in the lower Ohoopee River (Keferl 1993). Stringfellow and Gagnon (2001) resurveyed these sites using techniques similar to those used by Keferl (1981), but did not find any live Altamaha spinymussels in the Ohoopee River. Therefore, it is either extirpated from the system or present in such low numbers that it is undetectable. Ironically, Keferl (1981) initially considered the Ohoopee River to be a possible refugium for the Altamaha spinymussel and other endemic Altamaha River mussel species.

In the Ocmulgee River, the Altamaha spinymussel was known historically from its confluence with the Oconee River to an area about 35 miles upstream, near Jacksonville, Georgia (Stringfellow and Gagnon 2001). This reach of river was surveyed by Keferl in the mid 1990s and again by Georgia Department of Natural Resources (GDNR) personnel in 2000 and 2001. Nearly 50 sites have been surveyed in this reach since 1993, but Altamaha spinymussels were found at only eight of those sites. From those eight sites, fewer than 20 live Altamaha spinymussels were found. Dr. Grace Thomas, of the University of Georgia, documented the Altamaha spinymussel at its farthest known upstream location at Red Bluff in the early 1960s. She and others collected a total of 40 individuals from two visits to the area (personal communication 2001 cited in U.S. Fish and Wildlife Service candidate assessment form). These collections are deposited at the University of Georgia's Museum of Natural History. Dr. David Stansbery, of Ohio State University, made a collection of 11 live individuals from the Ocmulgee River at the U.S. Highway 441 bridge near Jacksonville in 1986. However, in their 2001 surveys, GDNR personnel found no live Altamaha spinymussels at Red Bluff or at U.S. Highway 441 (personal communication 2001 cited in U.S. Fish and Wildlife Service candidate assessment form). They did, however, find three Altamaha spinymussels approximately one mile upstream of the U.S. Highway 441 bridge. Similarly, early collecting efforts in the Ocmulgee River near its confluence with the Oconee River yielded many live Altamaha spinymussels. Herb Athearn, of the Museum of Fluviatile Mollusks in Cleveland, Tennessee, made a single collection of 40 live spinymussels downstream of U.S. Highway 341 near Lumber City in 1962. In the 2001 GDNR surveys, eight surveyors found only six live Altamaha spinymussels at a sandbar in the same general area on the Oconee River. There are few historical records of Altamaha spinymussels from the Oconee River (Johnson 1970). The species has not been collected there since the late 1960s, and it is probably extirpated from the Oconee River system (personal communication 2001 cited in U.S. Fish and Wildlife Service candidate assessment form).

No Altamaha spinymussels were found during surveys conducted by the GDNR over the past two years. Most surveys for Altamaha spinymussels have been conducted in the Altamaha River. Early surveys at the U.S. Highway 301 crossing were successful, including collections of 20 individuals in 1963, seven in 1965, and 43 in 1970. In the fall of 1994, Keferl (1994) surveyed 180 sites throughout the Altamaha River and its tributaries. The Altamaha spinymussel was found at 27 of the surveyed sites; 41 live mussels and shells representing 53 dead mussels were reported. During the fall of 2001, O'Brien and Brim Box (in prep., cited in U.S. Fish and Wildlife Service candidate assessment form) surveyed 48 sites on the Altamaha River from the confluence of the Ocmulgee and Oconee Rivers to just downstream of U.S. Highway 301 near Jesup, Georgia. Of these 48 sites, 18 of them had historical records of Altamaha spinymussels. Five of these sites yielded one or two live individuals, including three individuals that were considered juveniles approximately five years old. Of the 13 remaining historic populations surveyed, two sites yielded one freshly dead (i.e., flesh was still present) Altamaha spinymussel each, six sites yielded only shells, and five sites showed no evidence of Altamaha spinymussels.

Although Altamaha spinymussels were found in the past two years from the Ocmulgee and Altamaha Rivers, the recent surveys reveal some disturbing trends. First, no Altamaha spinymussels were found in the Ohoopee River. Second, most of the historical collection sites on the Ocmulgee and Altamaha rivers no longer have Altamaha spinymussels. Third, the historical locations that had extant populations of Altamaha spinymussels had significantly reduced numbers. Fewer than 25 live mussels were found in over 250 person hours of searching throughout the historical range, which is in sharp contrast to historical collections when as many as 60 individuals were found in a single bed (Sickel 1980). Fourth, although juvenile mussels are generally difficult to find, historical surveys were successful at finding some juvenile Altamaha spinymussels (Keferl 1981). Recent surveys utilized the same sampling techniques as previous surveys failed to find many juveniles (two personal communications 2001 cited in U.S. Fish and Wildlife Service candidate assessment form). This suggests that little recruitment is occurring within the populations. The survey results detailed above present strong evidence that the range and numbers of individuals of the Altamaha spinymussel have declined dramatically over the past 30 years. The species appears to be extirpated from the Ohoopee and Oconee rivers, and its numbers are greatly reduced in the Ocmulgee and Altamaha Rivers. Collectors in the 1960s were able to find more Altamaha spinymussels at a single site than researchers in the past two years were able to find in more that 250 hours of searching.

The Georgia Natural Heritage Program ranks the Altamaha spinymussel as Imperiled.

The U.S. Fish and Wildlife Service classifies the Altamaha spinymussel as a candidate for Endangered Species Act protection with a listing priority number of 5.

LISTING CRITERIA

A. ***The present or threatened destruction, modification, or curtailment of its habitat or range.***

Historical range:	In Georgia, the Coastal Plain portion of the Altamaha River and the lower portions of its three major tributaries, the Ohoopee, Ocmulgee, and Oconee Rivers.
Current range:	Altamaha and Ocmulgee Rivers.
Land ownership:	Approximately one-third of the Altamaha River floodplain is under State ownership and two-thirds is owned by private individuals and forest product industries. The State of Georgia manages several Wildlife Management Areas (WMA) along the river; however, some of this acreage is leased to the State by forest industries and is heavily logged. The following is a breakdown of ownership patterns in the floodplain of the Altamaha River: 1) private (41,613 acres or 34 percent); 2) forest industry (40,512 acres or 33 percent); 3) State (33,684 acres or 27 percent); 4) subdivision (2,848 acres or 2 percent); 5) non-forest industry (1,271 acres or 1 percent); 6) The Nature Conservancy (TNC) (1,105 acres or approximately 1 percent); 7) county (59 acres or approximately 1 percent); and 8) other/unknown (24 acres or approximately 1 percent). Detailed land use information for the Oconee and Ocmulgee rivers is not currently known.

Altamaha spinymussels face severe habitat degradation from a number of sources. Primary among these are threats from sedimentation and contaminants within the streams that the Altamaha spinymussel inhabits. These threats to the Altamaha spinymussel are further compounded by its limited distribution and the low populations sizes identified in recent survey efforts. Sedimentation, including siltation from surface runoff, has been implicated as the primary factor in water quality impairment in the United States (Neves et al. 1997) and has contributed to the decline of mussel populations in streams throughout the country (Ellis 1931, 1936; Imlay 1972; Coon et al. 1977; Marking and Bills 1979; Wilber 1983; Dennis 1985; Aldridge et al. 1987; Schuster et al. 1989; Wolcott and Neves 1991; Houp 1993; Richter et al. 1997). Specific impacts on mussels from sediments include reduced feeding and respiratory efficiency, disrupted metabolic processes, reduced growth rates, increased substrata instability, and the physical smothering of mussels (Ellis 1936; Stansbery 1971; Markings and Bills 1979; Kat 1982; Aldridge et al. 1987; Hartfield and Hartfield 1996; Brim Box and Mossa 1999). In addition, sediment can eliminate or reduce the recruitment of juvenile mussels (Negus 1966; Brim Box and Mossa 1999), act as a vector in delivering contaminants to streams (Salomons et al. 1987), and interfere with feeding activity (Dennis 1984).

Sickel (1980) characterized the habitat of the Altamaha spinymussel as coarse to fine grain sandbars, and suggested that this may make the Altamaha spinymussel susceptible to adverse effects from sediment (i.e., siltation). Sediments deposited on the stable sandbars required by the Altamaha spinymussel could make sandbars unstable, suffocate Altamaha spinymussels, or simply change the texture of the substrate. These alterations to the sandbars make them unsuitable for the species. There are numerous potential sources of sediment within the Altamaha River basin including unpaved roads, kaolin mines, and agriculture, silviculture, and construction sites. Many southeastern streams have increased turbidity levels due to siltation (van der Schalie 1938). Some mussels attract host fishes with visual cues, luring fish into perceiving that their glochidia are prey items. This reproductive strategy depends on clear water during the time of the year when mussels are releasing their glochidia (Hartfield and Hartfield 1996). Therefore, since turbidity is a limiting factor that impedes the ability of sight-feeding fishes to forage (Burkhead and Jenkins 1991), turbidity within the Altamaha River basin during the times that Altamaha spinymussels attempt to attract host fishes may have contributed and may continue to contribute to the decline of the Altamaha spinymussel by reducing its efficiency at attracting the fish hosts necessary for reproduction. Industrial forest management is practiced on approximately 40,000 acres (33 percent) of the floodplain of the Altamaha River (Lambert 2001).

Although land use studies are not available for the remainder of the Altamaha River basin, large portions of the basin are under forest management. Typical forest management regimes in the Altamaha River basin use timber harvest methods and conduct other activities that result in ground disturbances. These ground disturbances can result in transport of sediment to streams during and after precipitation events. In addition to the sediment that is produced by ground-disturbing timber harvesting activities, forest management operations often require miles of unpaved roads to extract timber and to provide access for management activities. These roads, in conjunction with existing unpaved county roads that are prevalent throughout the Altamaha River basin, may also contribute significantly to sediment loading in streams after precipitation events. In addition, a number of kaolin mines are located along the Fall Line within the Oconee and Ocmulgee river basins. The operation of these mines and their supporting infrastructure has the potential to increase downstream sediment loads if adequate erosion control measures are not maintained to stabilize areas subjected to mining-associated ground disturbances. The operations of the Edwin I. Hatch Nuclear Power Plant (Plant Hatch), located on the Altamaha River in Appling County, pose a threat to the Altamaha spinymussel. In a letter dated November 27, 2001, regarding the relicensing of Plant Hatch, the U.S Fish and Wildlife Service expressed concerns about potential adverse impacts to aquatic fauna through entrainment of potential host fishes and thermal discharges and concluded that Plant Hatch had not adequately studied these potential impacts (U.S Fish and Wildlife Service candidate assessment form). Thermal discharges could negatively impact the Altamaha spinymussel from heat stress, algal blooms, and oxygen depletion in the Altamaha river. These effects would be exacerbated during years of low rainfall, when less water would be available to dissipate the heat of the Plant Hatch effluent. Each of these effects, if severe, could result in increased Altamaha spinymussel mortality downstream of Plant Hatch.

The expansion of operations at Plant Hatch is another threat to the Altamaha spinymussel in this reach of the Altamaha River. On September 14, 2001, the U.S. Fish and Wildlife Service received Joint Public Notice 940003873 from the U.S. Army Corps of Engineers, Savannah District, describing a project to expand Plant Hatch's intake basin within the Altamaha River. Implementation of this permit would re-authorize maintenance dredging of the plant intake basin and would authorize an "L" shaped dredged area that extends 900 feet parallel to the bank and 388 feet channelward. This project will more than double the size of the intake basin and will dredge 44,424 cubic yards of material annually from the intake basin. Dredging of this type and extent is expected to alter flows in the Altamaha River causing stream bed and bank destabilization that would further alter Altamaha spinymussel habitat and potentially result in Altamaha spinymussel mortality and/or loss of populations. Dredging contributes to stream channel instability because flowing water seeks its base level of gravitational flow. The destructive effects of extensive dredging, such as that proposed at Plant Hatch, include accelerated erosion, substratum instability, and the loss of habitat heterogeneity for fishes and benthic invertebrates both immediately upstream and for a greater distance downstream due to alterations in the river's morphology and resulting flow patterns. The Plant Hatch intake basin will likely affect the river in a similar manner as other in-stream operations such as channelization and gravel mining. Channelization impacts a river's physical (e.g., accelerated erosion, reduced depth, decreased habitat diversity, geomorphic instability, riparian canopy loss) and biological (e.g., decreased fish and invertebrate diversity, changed species composition and abundance, decreased biomass and growth rates) characteristics (Stansbery and Stein 1971; Hartfield 1993; Hubbard et al. 1993). Channel maintenance may also result in downstream impacts (Stansbery 1970), such as increases in turbidity and sedimentation, which tend to smother benthic organisms like the Altamaha spinymussel. In-stream gravel mining, which has similar effects to channelization, has been implicated in the destruction of mussel populations (Stansbery 1970; Yokley and Gooch 1976; Grace and Buchanan 1981; Schuster et al. 1989; Hartfield 1993). Negative impacts include stream channel modifications (e.g., geomorphic instability, altered habitat, disrupted flow patterns, sediment transport), water quality modifications (e.g., increased turbidity, reduced light penetration, increased temperature), macroinvertebrate population changes (e.g., from elimination, habitat disruption, increased sedimentation), and changes in fish populations (e.g., impacts to spawning and nursery habitat, food web disruptions) (Lagasse et al. 1980; Kanehl and Lyons 1992). Therefore, if Altamaha spinymussels become eliminated from portions of the Altamaha River due to physical changes caused by dredging and stream channel alterations associated with Plant Hatch, it may be difficult for the species to recolonize the degraded areas.

Studies have shown that once mussels have been eliminated, a decade or more may pass before recolonization occurs (Stansbery 1970; Grace and Buchanan 1981). The low population sizes and disjunct distribution of the species makes recolonization even more unlikely. The Plant Hatch intake basin would also disrupt the natural morphology of the point bars that provide habitat for the Altamaha spinymussel. The intake basin would prevent a portion of the large, coarse sand that is essential for Altamaha spinymussel habitat formation from traveling downstream. In addition, the annual maintenance of the intake basin would release large quantities of fine sediment that could cover the coarse sandy point bars that provide Altamaha spinymussel habitat if transported downstream. In the long term, the effects of this intake basin project could eliminate Altamaha spinymussel habitat in much of the Altamaha River downstream of Plant Hatch. Depending on the extent of the downstream effects of the intake basin, the Altamaha spinymussel may be extirpated from half of its current range, but, at a minimum, it is expected that this project will result in a zone downstream from Plant Hatch where Altamaha spinymussel habitat is destroyed. This would effectively separate the current Altamaha River population into two smaller populations.

Contaminants entering the Altamaha River basin are another factor that negatively impacts the Altamaha spinymussel. In laboratory experiments, mussels suffered mortality when exposed to 2.0 ppm cadmium, 5.0 ppm ammonia, 12.4 ppm chromium, 16 ppm arsenic trioxide, 19 ppm copper, and 66 ppm zinc (Mellinger 1972; Havlik and Marking 1987). Contaminants contained in point and non-point discharges can degrade water and substrate quality and adversely impact, if not destroy, mussel populations (Horne and McIntosh 1979; McCann and Neves 1992; Havlik and Marking 1987). The effects of various contaminants on mussels were reviewed by Havlik and Marking (1987), Naimo (1995), and Keller and Lydy (1997). Mussels appear to be among the most intolerant organisms to heavy metals (Keller and Zam 1991), and several heavy metals are lethal, even at relatively low levels (Havlik and Marking 1987). Most metals are persistent in the environment (Miettinen 1977), remaining available for uptake, transportation, and transformation by organisms for long periods (Hoover 1978). Metals stored in the tissues of freshwater mussels indicate recent or current exposure, while concentrations in shell material indicate past exposure (Imlay 1982; Havlik and Marking 1987). Highly acidic pollutants, such as metals, are capable of contributing to mortality by dissolving mussel shells (Stansbery 1995). Numerous municipal wastewater treatment plants discharge large quantities of effluent into the Altamaha River or its tributaries. For example Bibb County, Georgia, which includes the City of Macon, was permitted to discharge 39.70 million gallons per day (MGD) of domestic waste water into the Ocmulgee River in 1990 (Marella and Fanning 1990). The cumulative effects of this effluent on Altamaha spinymussel habitat have not been quantified, but it is likely that the effluent has degraded the Altamaha spinymussel's habitat through changes in water chemistry and the effects of eutrophication. Furthermore, it is not clear if the effluent discharged into these stream systems can be assimilated. Contaminants associated with industrial and municipal effluents (e.g., heavy metals, ammonia, chlorine, numerous organic compounds) may cause decreased oxygen, increased acidity, and other water chemistry changes that may be lethal to mussels, particularly the highly sensitive early life stages of mussels (Rand and Petrocelli 1985; Sheehan et al. 1989; Keller and Zam 1991; Dimock and Wright 1993; Goudreau et al. 1993; Jacobson et al. 1993; Keller 1993). The adults of certain species may tolerate short-term exposure (Keller 1993), but low levels of some metals may inhibit glochidial attachment in some species (Huebner and Pynnönen 1992). Mussel recruitment may be reduced in habitats with low but chronic heavy metal and other toxicant inputs (Yeager et al. 1994; Naimo 1995; Ahlstedt and Tuberville 1997). Although effluent quality has improved with modern treatment technologies and a ban on phosphate detergents, municipal treatment plants were permitted in 1990 to discharge more than 43 MGD of waste water into the Altamaha River basin below the Fall Line, a geologic land form that separates the Piedmont and Coast Plain physiographic provinces (Marella and Fanning 1990). These discharges are likely to increase as human populations increase, which is expected to have negative long-term effects on the Altamaha spinymussel if contaminant levels within the discharges are not controlled.

A number of recent illegal effluent discharges into the Altamaha River basin have impacted the Altamaha spinymussel. For instance, the wastewater treatment discharge from Reidsville State Prison enters the Ohoopee River approximately six miles upstream of the largest historical population of Altamaha spinymussels known in the Ohoopee River. The Altamaha Riverkeeper, a watchdog group that works to maintain the quality of the Altamaha River system, reports discharge violations, and sues the violators in court, reported fecal coliform discharges from the prison that exceeded the prison's National Pollutant Discharge Elimination System (NPDES) permit. In addition, the Altamaha Riverkeeper has recently won three court cases for violations of NPDES permits in the Altamaha River basin. In the first, it won a summary judgment against Amercord Inc. for numerous violations of Amercord's NPDES permit at its Lumber City tire plant for discharges into the Ocmulgee River. In this case, Amercord was alleged to discharge quantities of cyanide, copper, zinc and lead in excess of its NPDES permit, and Amercord did not dispute the allegations. The second case was regarding alleged discharges into the Ocmulgee River from Lumber City's waste treatment pond in excess of Lumber City's NPDES permit. The Altamaha Riverkeeper won the case, and Lumber City agreed to implement several short term and long term waste water treatment improvements, which are expected to protect a population of Altamaha spinymussels. In the third case, the Altamaha Riverkeeper won a summary judgement after it disclosed discharges from the City of Cochran's waste treatment pond from July 1995 to August 2000 in excess of the city's NPDES permit. The City of Cochran has been releasing ferris sulfate (used to treat fecal coliform) into Jordan Creek, a tributary of the Ocmulgee River approximately 80 kilometers (50 miles) upstream of known populations of Altamaha spinymussels. Agricultural sources of contaminants in the Altamaha River basin include nutrient enrichment from poultry farms and livestock feedlots, which occur primarily in the Piedmont portion of the basin, and pesticides and fertilizers from row crop agriculture, which occur primarily in the Coastal Plain portion of the basin (Couch et al. 1996; Frick et al. 1998).

Stream ecosystems are negatively impacted when nutrients are added at concentrations that can not be assimilated (Stansbery 1995). The effects of pesticides on mussels may be particularly profound (Fuller 1974; Havlik and Marking 1987; Moulton et al. 1996), and commonly used pesticides have been directly implicated in a North Carolina mussel die-off (Fleming et al. 1995). The Oconee, Ocmulgee, and Ohoopee River systems contain significant acreage in cotton and onion farming. One of the most important pesticides used in cotton farming, malathion, is known to inhibit physiological activities of mussels (Kabeer et al. 1979) that may decrease the ability of mussels to respire and obtain food. The Altamaha Park is a marina on the Altamaha River approximately 10 miles downstream from State Route 301. A number of large houseboats are moored on the river throughout the year and release contaminants, such as fecal coliform, directly into the Altamaha River. The Georgia General Assembly recognized the adverse impacts on water quality that can be caused by recreational boats and recently passed legislation that increased the minimum requirements of boat sanitation systems to include either a holding tank or a U.S. Coast Guard-certified Marine Sanitation Device for all boats. Although this will potentially reduce the quantity of contaminants entering the river, the threat from this contaminant source has not been eliminated, and the Altamaha spinymussel has already been extirpated from this reach of the river (personal communication 2001 cited in U.S Fish and Wildlife Service candidate assessment form).

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

The Altamaha spinymussel is not a commercially valuable species nor are the streams that it inhabits subject to commercial mussel harvesting activities. This species has been actively sought for scientific and private collections. Such activity may increase as the species' rarity increases. Over-collection may have been a localized factor in the decline of this species, particularly in the Ohoopee River where a 1986 collection consisted of at least 30 live individuals (personal communication 2002 cited in U.S Fish and Wildlife Service candidate assessment form). The localized distribution and small size of known populations renders them extremely vulnerable to overzealous recreational or scientific collecting.

C. ***Disease or predation.***

Diseases of freshwater mussels are poorly known. Juvenile and adult mussels are prey items for some invertebrate predators (particularly as newly metamorphosed juveniles) and parasites (e.g., nematodes, trematodes and mites), and provide prey for a few vertebrate species (e.g., otter, raccoon and turtles). Although predation by naturally occurring predators is a normal aspect of the population dynamics of a healthy mussel population, predation may amplify declines in small populations of this species.

D. ***The inadequacy of existing regulatory mechanisms.***

Point source discharges within the range of the Altamaha spinymussel have been reduced since the inception of the Clean Water Act, but this may not provide adequate protection for filter feeding organisms that can be impacted by extremely low levels of contaminants. Several wood processing mills located in the Altamaha River basin discharge effluent directly into the basin's streams. For example, Rayonier's plant in Jesup, Georgia, is permitted to discharge approximately 60 MGD of treated wastewater into the Altamaha River. In addition, municipal wastewater plants continue to discharge large amounts of effluent and, in some circumstances (see section A above), in excess of permitted levels. Although Best Management Practices for sediment and erosion control are often recommended and/or required by local ordinances for construction projects, compliance, monitoring, and enforcement of these recommendations are often poorly implemented. Furthermore, there are currently no requirements within the scope of Federal environmental laws to specifically consider the Altamaha spinymussel during Federal activities, or to ensure that Federal projects will not jeopardize its continued existence.

Current Conservation Efforts: Although few specific activities aimed at protecting the Altamaha spinymussel have been initiated, the U.S. Fish and Wildlife Service works with several organizations, such as TNC, GDNR, and the Altamaha River Keeper, to protect the Altamaha River floodplain and adjacent uplands, which would be beneficial to the Altamaha spinymussel. TNC actively purchases lands within the river basin that exhibit unique biological values and works with landowners to restore and preserve other areas. The Altamaha River Keeper acts as a watchdog group by reporting potential violations of the Clean Water Act to appropriate agencies. Additionally, the U.S. Fish and Wildlife Service, through its Partners for Fish and Wildlife program, has worked with private landowners within the watershed to restore wetlands and adjacent uplands, such as longleaf pine forests. The GDNR has received funds under section 6 of the Endangered Species Act to conduct surveys for the Altamaha spinymussel in the Ocmulgee River and to determine its host fish. Monies have also been awarded to the GDNR to explore the possibility of developing Candidate Conservation Agreements between the State and private landowners to help conserve the imperiled fauna of the Altamaha River.Without the legal protection that would be provided by listing as a Federally endangered species, however, it appears unlikely that it will be possible to reverse the precipitous decline of the Altamaha spinymussel.

E. *Other natural or manmade factors affecting its continued existence.*

Non-indigenous species such as the flathead catfish (*Pylodictis olivaris*) and the Asian clam (*Corbicula fluminea*) have been introduced to the Altamaha Basin and may be having an adverse effect on the Altamaha spinymussel and other native species. Although the host fish or fishes of the Altamaha spinymussel have not been identified, in other native freshwater mussels various centrachids have been identified as hosts of the larvae. Since the introduction of the flathead catfish in the Altamaha River, potential centrachid host fish such as the largemouth bass (*Micropterus salmoides*), redbreast sunfish (*Lepomis auritus*), and bluegill (*L. macrochirus*) have all suffered significant population declines (personal communication 2001 cited in U.S Fish and Wildlife Service candidate assessment form). If one of these species is the host for the Altamaha spinymussel, its breeding success and recruitment could be reduced (E. Keferl, personal communication 2001 cited in U.S Fish and Wildlife Service candidate assessment form), which might help explain the limited evidence of recruitment in recent surveys.

In contrast to the indirect effect of removing the spinymussel's host fish, Asian clams may be a direct threat to native species through competition for available resources (i.e., space, minerals, or food) (Williams et al. 1993). Surveys have found large numbers of Asian clams in the Altamaha Basin for more than 25 years (Gardner et al. 1976; Stringfellow and Gagnon 2001;

personal communication 2001 cited in U.S Fish and Wildlife Service candidate assessment form). Withdrawal of surface water within the Altamaha Basin for thermoelectric power generation, public water supplies, commercial industrial uses, and agriculture has a dramatic effect on flow rates. For example, Laurens County, Georgia, which includes the City of Dublin, withdrew 2.64 MGD for public water supplies, 12.79 MGD for commercial industrial use, and 5.57 MGD for agricultural uses in 1990 (Marella and Fanning 1990). In general, urban counties withdraw more water than rural counties. In 1990, the total amount of surface water withdrawn from the Altamaha River basin was 1315.88 MGD (Marella and Fanning 1990), and development pressures continue to grow which will lead to increased water withdrawals. Currently, the State of Georgia is considering additional water withdrawals from the Oconee River for a golf course (11 MGD) and the City of Greensboro (3 MGD) which would further reduce the amount of water available to the Altamaha spinymussel. No major dams occur on the Altamaha River system within the known historical range of the Altamaha spinymussel. However, the dams that form Sinclair Reservoir on the Oconee River and Jackson and Tobesofkee Reservoirs in the Ocmulgee River basin can influence mussels and their populations through changes in flows that result from electrical power generation and water storage. Such removals can cause drastic flow reductions and alterations that may strand mussels on sandbars resulting in mortality of individuals and harm to populations. Within the Altamaha River basin, 1149 MGD was withdrawn for thermoelectric power generation in 1990 (Marella and Fanning 1990). Drought conditions have persisted in Georgia since 1998 and have likely amplified the threats to the Altamaha spinymussel. Georgia averages 127 centimeters (50 inches) of precipitation annually (U.S. Geological Survey 1986) but has received less than 102 centimeters (40 inches) of precipitation annually since 1998. The Ohoopee River and many other streams in the basin are currently suffering reduced flow rates, and the Ohoopee River was reported to have an estimated average depth of 15 centimeters (6 inches) in the main channel during recent summer surveys (Stringfellow and Gagnon 2001). Normally, mussels will bury themselves in the river bottom as a mechanism to survive a drought, but many mussels may have desiccated (and died) during this prolonged drought (personal communication 2001 cited in U.S Fish and Wildlife Service candidate assessment form). The prolonged drought has resulted in other negative effects to the Altamaha spinymussel as well. For instance, the drought has opened the stream beds to all-terrain and fourwheel drive vehicle access (Stringfellow and Gagnon 2001), so mussels that might have survived the drought are now in danger of being crushed by heavy vehicular traffic in the river bed itself. Additionally, the low flow rates that have resulted provide lower volumes of water to dilute potential contaminants and, therefore, effectively increase the concentrations of contaminants in streams. Federally listed mussels in Spring Creek, which is part of the Flint River basin in southwest Georgia, were severely impacted (e.g., hundreds of mortalities) by drought and low stream flows, and similar impacts may be expected in the smaller tributaries of the Altamaha River basin if they become ephemeral.

REFERENCES

Ahlstedt, S.A., and J.M. Tuberville. 1997. Quantitative reassessment of the freshwater mussel fauna in the Clinch and Powell Rivers, Tennessee and Virginia. Pp. 72-97 *in*

Conservation and Management of Freshwater Mussels II: Initiatives for the Future (K.S. Cummings, A.C. Buchanan, C.A. Mayer, and T.J. Naimo, eds.). Proceedings of a UMRCC symposium, 16-18 October 1995, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Aldridge, D.W., B.S. Payne, and A.C. Miller. 1987. The effects on intermittent exposure to suspended solids and turbulence on three species of freshwater mussels. Environmental Pollution 1987:17-28.

Brim Box, J. and J. Mossa. 1999. Sediment, land use, and freshwater mussels: prospects and problems. Journal of the North American Benthological Society18:99-117.

Burkhead, N.M., and R.E. Jenkins. 1991. Fishes. Pp. 321-409 *in* Virginia's Endangered Species (K. Terwilliger, coordinator). McDonald and Woodward Publishing Co., Blacksburg, Virginia.

Cammack, S.E., C.E. Skelton, and E.E. Van De Genachte. 2000. Altamaha Spinymussel Surveys. Altamaha Riverkeeper Newsletter. Winter 2000-2001.

Clench, W. J. 1962. Collecting freshwater mollusks in south central Georgia. Shells and Their Neighbors, 12:1-7.

Clench, W.J. and R.D. Turner. 1956. Fresh-water mollusks of Alabama, Georgia, and from the Escambia to the Suwannee River. Bulletin of the Florida State Museum 1:97-239.

Coon, T.G., J.W. Eckblad, and P.M. Trygstad. 1977. Relative abundance and growth of mussels (Mollusca: Eulamellibranchia) in pools 8, 9, and 10 of the Mississippi River. Freshwater Biology 7:279-285.

Couch, C.A., E.H. Hopkins, and P.S. Hardy. 1996. Influences of environmental settings on aquatic ecosystems in the Apalachicola-Chattahoochee-Flint River basin. U.S. Geological Survey, National Water Quality Assessment Program. USGS Water Resources Investigations Report 95-4278.

Dennis, S.D. 1985. Distributional analysis of the freshwater mussel fauna of the Tennessee River system, with special reference to possible limiting effects of siltation. Tennessee Wildlife Resources Agency Report No. 85-2, Nashville, Tennessee. 171 pp.

Dennis, S.D. 1984. Distributional analysis of the freshwater mussels of the Tennessee River System, with special reference to possible limiting effects of siltation. Ph.D. Dissertation VPI & SU, Blacksburg, Virginia. 171 pp.

Dimock, R.V., Jr., and A.H. Wright. 1993. Sensitivity of juvenile freshwater mussels to hypoxic thermal and acid stress. Journal of the Elisha Mitchell Scientific Society 109:183-192.

Ellis, M.M. 1931. Some factors affecting the replacement of the commercial fresh-water mussels. U.S. Bureau of Fisheries Circular 7. 10 pp.

Ellis, M.M. 1936. Erosion silt as a factor in aquatic environments. Ecology 17:29-42.

Fleming, W.J., T.P. Augspurger, and J.A. Alderman. 1995. Freshwater mussel die-off attributed to anticholinesterase poisoning. Environmental Toxicology and Chemistry 14:877- 879.

Frick, E.A., D.J. Hippe, G.R. Buell, C.A. Couch, E.H. Hopkins, D.J. Wangsness, and J.W. Garrett. 1998. Water quality in the Apalachicola-Chattahoochee-Flint River basin, Georgia, Alabama, and Florida, 1992-95. U.S. Geological Survey Circular 1164. 38 pp.

Fuller, S.L.H. 1974. Clams and mussels (Mollusca: Bivalvia). Pp.215-273 *in* Pollution ecology of freshwater invertebrates (C.W. Hart and S.L.H. Fuller, eds.). Academic Press, New York.

Grace, T.B., and A.C. Buchanan. 1981. Naiades (mussels) of the Lower Osage River, Tavern Creek, and Maries River, Missouri. Unpublished report, Missouri Department of Conservation, Jefferson City. 147 pp.

Gardner, J.A., Jr., W.R. Woodall, Jr., A.A. Staats, Jr., and J.F. Napoli. 1976. The invasion of the Asian clam (*Corbicula manilensis* Philippi) in the Altamaha River, Georgia. Nautilus, 90:117-125.

Goudreau, S., R.J. Neves, and R.J. Sheehan. 1993. Effects of wastewater treatment plant effluents on freshwater mollusks in the upper Clinch River, Virginia, USA. Hydrobiologia 252:211-230.

Hartfield, P. 1993. Headcuts and their effect on freshwater mussels. Pp. 131-141 *in* Conservation and Management of Freshwater Mussels (A.C. Cummings, A.C. Buchanan, and L.M. Koch, eds.). Proceedings of an UMRCC symposium 12-14 October 1992, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Hartfield, P.D., and E. Hartfield. 1996. Observations on the conglutinates of *Ptychobranchus greeni* (Conrad, 1834) (Mollusca: Bivalvia: Unionoidea). American Midland Naturalist 135:370-375.

Havlik, M. E. and L. Marking. 1987. Effects of contaminants on naiad mollusks (Unionidae): a review. U.S. Fish and Wildl. Serv., Resource. Publ. 164. 20 pp.

Hoover, T.B. 1978. Inorganic species in water: ecological significance and analytical needs. U.S. Environmental Protection Agency, EPA-600/3-78-064.

Horne, F.R., and S. McIntosh. 1979. Factors influencing distribution of mussels in Blanco River, of central Texas. The Nautilus 93:119-133.

Houp, R.E. 1993. Observations on long-term effects of sedimentation on freshwater mussels (Mollusca: Unionidae) in the North Fork of Red River, Kentucky. Transactions of the Kentucky Academy of Science 54:93-97.

Hubbard, W.D., D.C. Jackson, and D.J. Ebert. 1993. Channelization. Pp. 135-155 *in* Impacts on Warmwater Streams: Guidelines for Evaluation (E.F. Bryan and D.A. Rutherford, eds.). Warmwater Stream Committee, Southern Division, American Fisheries Society, Little Rock, Arkansas.

Huebner, J.D., and K.S. Pynnönen. 1992. Viability of glochidia of *Anodonta* exposed to low pH and selected metals. Canadian Journal of Zoology 70:2348-2355.

Imlay, M.J. 1972. Greater adaptability of freshwater mussels to natural rather than to artificial displacement. The Nautilus 86:76-79.

Imlay, M.J. 1982. Use of shells of freshwater mussels in monitoring heavy metals and environmental stresses: a review. Malacological Review 15:1-14.

Jacobson, P.J., J.L. Farris, D.S. Cherry, and R.J. Neves. 1993. Juvenile freshwater mussel (Bivalvia: Unionidae) responses to acute toxicity testing with copper. Environmental Toxicology and Chemistry 12:879-883.

Johnson, R. I. 1970. The systematics and zoogeography of the Unionidae (Mollusca: Bivalvia) of the Southern Atlantic Slope Region. Bulletin of the Museum of Comparative Zoology 140:263-449.

Kanehl, P., and J. Lyons. 1992. Impacts of in-stream sand and gravel mining on stream habitat and fish communities, including a survey on the Big Rib River, Marathon County, Wisconsin. Wisconsin Department of Natural Resources Research Report 155. 32 pp.

Kat, P.W. 1982. Effects of population density and substratum type on growth and migration of Elliptio complanata (Bivalvia: Unionidae). Malacological Review 15:119-127.

Keller, A.E. 1993. Acute toxicity of several pesticides, organic compounds and a wastewater effluent to the freshwater mussels *Anodonta imbecillis*, *Ceriodaphnia dubia* and *Pimephales promelas*. Bulletin of Environmental Contamination and Toxicology 51:696-702.

Keller, A.E., and M. Lydy. 1997. Biomonitoring and the hazards of contaminants to freshwater mollusks. Unpublished report *in* Freshwater mollusks as indicators of water quality: a workshop. U.S. Geological Survey, Biological Resources Division and National Water Quality Assessment Program. 55 pp.

Keller, A.E., and S.G. Zam. 1991. The acute toxicity of selected metals to the freshwater mussel *Anodonta imbecilis* (sic). Environmental Toxicology and Chemistry 10:539-546.

Lagasse, P.F., B.R. Winkley, and D.B. Simons. 1980. Impact of gravel mining on river system instability. Journal of the Waterway, Port, Coastal, and Ocean Division 13:389-404.

Marking, L.L., and T.D. Bills. 1979. Acute effects of silt and sand sedimentation on freshwater mussels. Pp. 204-211 *in* Proceedings of the UMRCC Symposium on Upper Mississippi River Bivalve Mollusks (J.R. Rasmussen, ed.). Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Kabeer, A. I., M. Sethuraman, M.R. Begum, and R.K. Ramana. 1979. Effect of malathion on ciliary activity of fresh water mussel, *Lamellidens marginalis* (Lamarck). Comparative Physiology and Ecology 4:71-73.

Keferl, E. P. 1993. The status of freshwater mussels in some Georgia, South Carolina, and North Carolina waters. Pp. 298-302 *in* Proceedings of the 1993 Georgia Water Resources conference (K. J. Hatcher, ed.). Institute of Ecology, University of Georgia, Athens.

Keferl, E. P. 1981. A survey of the naiades of the Ohoopee River, Georgia. The Bulletin of the American Malacological Union, Inc. 11-15.

Marella, R. L., and J.L. Fanning.1990. National Water Quality Assessment of the Georgia-Florida Coastal Plain Study Unit-Water Withdrawals and Treated wastewater Discharges. U. S. Geological Survey. 76 pp.

McCann, M.T., and R.J. Neves. 1992. Toxicity of coal-related contaminants to early life stages of freshwater mussels in the Powell River, Virginia. Unpublished report, U.S. Fish and Wildlife Service, Asheville, North Carolina. 92 pp.

Meeks, G., and L.C. Runyon, 1990, Wetland Protection and the States, National Conference of State Legislatures, Denver Colo., 26 pp.

Mellinger, P. J. 1972. The comparative metabolism of cadmium, mercury, and zinc as environmental contaminants in the freshwater mussel *Margaritifera margaritifera*. Ph.D. thesis, Oregon State University, Corvallis. 129 pp.

Moulton, C.A., W.J. Fleming, and C.E. Purnell. 1996. Effects of two cholinesterase-inhibiting pesticides on freshwater mussels. Environmental Toxicology and Chemistry 15:131-137.

Naimo, T.J. 1995. A review of the effects of heavy metals on freshwater mussels. Ecotoxicology 4:341-362

Neves, R.J. 1997. A national strategy for the conservation of native freshwater mussels. Pp. 1-10 *in* Conservation and Management of Freshwater Mussels II: Initiatives for the Future (K.S. Cummings, A.C. Buchanan, C.A. Mayer, and T.J. Naimo, eds.). Proceedings of the UMRCC symposium, 16-18 October 1995, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

O'Brien, C.A. and J. Brim Box. in prep.[?]. Status survey of the Altamaha spinymussel (*Elliptio spinosa*) in the Altamaha River. Final Report for Georgia Department of Natural Resources.

Rand, G.M., and S.R. Petrocelli. 1985. Fundamentals of Aquatic Toxicology. Hemisphere Publishing Corporation, New York.

Richter, B.R., D.P. Braun, M.A. Mendelson, and L.L. Master. 1997. Threats to imperilled freshwater fauna. Conservation Biology 11:1081-1093.

Salomons, W., N.M. de Rooij, H. Kerdijk, and J. Bril. 1987. Sediments as a source for contaminants? Hydobiologia 149:13-30.

Schuster, G.A., R.S. Butler, and D.H. Stansbery. 1989. A survey of the unionids (Bivalvia: Unionidae) of Buck Creek, Pulaski County, Kentucky. Transactions of the Kentucky Academy of Science 50:79-85.

Sheehan, R.J., R.J. Neves, and H.E. Kitchel. 1989. Fate of freshwater mussels transplanted to formerly polluted reaches of the Clinch and North Fork Holston rivers, Virginia. Journal of Freshwater Ecology 5:139-149.

Sickel, J. B. 1980. Correlation of unionid mussels with bottom sediment composition in the Altamaha River, Georgia. The Bulletin of the American Malacological Society. 10-13 pp.

Stansbery, D.H. 1970. Eastern freshwater mollusks (I): the Mississippi and St. Lawrence River systems. [Proceedings of the American Malacological Union Symposium on Rare and Endangered Mollusks (A.H. Clarke, ed.)]. Malacologia 10: 9-22.

Stansbery, D.H. 1971. Rare and endangered molluscs in the eastern United States. Pp. 5-18 *in* Proceedings of a symposium on rare and endangered mollusks (naiads) of the United States (S.E. Jorgensen and R.W. Sharpe, eds.). U.S. Fish and Wildlife Service, Twin Cities, Minnesota.

Stringfellow, C. and P. Gagnon. 2001. Final Report of the Altamaha Spiny Mussel Survey in the lower Ohoopee River. Submitted to U.S. Fish and Wildlife Service. 10 pp.

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P.M. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione, and J.D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks, 2nd edition. American Fisheries Society, Special Publication 26, Bethesda, Maryland.

van der Schalie, H. 1938. Contributing factors in the depletion of naiades in eastern United States. Basteria 3:51-57.

Want, W.L., 1990, Law of Wetland Regulation (release #1/7/90), Clark-Boardman Company, Ltd, New York.

Wegert, R.G., J.O. Blanto, M. Alber, and A.G. Chalmers, 1999, Human impacts on the Salinity Regimes of Coastal Georgia Estuaries, Final Report, Dept. Of Marine Sciences, University of Georgia, Athens, GA. 13 pp.

Wilber, C.G. 1983. Turbidity in the Aquatic Environment: An Environmental Factor in Fresh and Oceanic Waters. C.C. Thomas, Springfield, Illinois.

Williams, J. D., M. L. Warren, Jr., K. S. Cummings, J. L. Harris, and R. J. Neves. 1992. Conservation Status of freshwater mussels of the United States and Canada. Fisheries 18:6-22.

Wolcott, L.T., and R.J. Neves. 1991. Impacts of siltation on mussel fauna of the Powell River. Unpublished report, U.S. Fish and Wildlife Service, Asheville, North Carolina. 7 pp.

U.S. Geological Survey. 1986. National water summary 1985-Hydrologic events and surfacewater resources: U.S. Geological Survey Water-Supply Paper 2300, 506 pp.

Yeager, B.L. 1994. Impacts of reservoirs on the aquatic environment of regulated rivers. Tennessee Valley Authority, Resource Group Water Management, TVA/WR-93/1.

Yokley, P., Jr., and C.H. Gooch. 1976. The effect of gravel dredging on reservoir primary production, invertebrate production, and mussel production, July 1, 1974 - June 30, 1976. Tennessee Wildlife Resources Agency Technical Report 76-56. 32 pp.

PETITION TO LIST

elongate mud meadows pyrg
(*Pyrgulopsis notidicola*)

AS A FEDERALLY ENDANGERED SPECIES

CANDIDATE HISTORY

CNOR 6/13/02: C

TAXONOMY

The hydrobiid snail *Pyrgulopsis notidicola*, the elongate mud meadows pyrg, was originally described by Hershler in 1998. It is distinguished from three other sympatric species by its more elongate shell with short spire; larger and more disjunct aperture; well-developed columellar shelf; smaller, globose bursa copulatrix; penis with larger terminal gland; and very weak ventral gland.

NATURAL HISTORY

Although few studies have been conducted on species within the genus *Pyrgulopsis* (springsnails) in the Great Basin, their basic natural history is known. Springsnails are small (usually less than 5 millimeters (0.2 inches (in.)) high, are tightly linked with their aquatic habitat, and often are endemic to single bodies of water (particularly springs), or local drainage features (Hershler 1998). Springsnails are widely distributed within the Great Basin, where they occur in a variety of relatively small, usually fishless, spring-fed water bodies. This genus also occurred historically in a few Great Basin lakes; none have been found in rivers. Springsnails occupy only permanent springs because they cannot survive outside an aquatic environment. Therefore, extant populations are in aquatic habitats that have persisted for long periods of geological time (Taylor 1985). It is uncommon for a spring to be occupied by more than one species of springsnail.

Springsnails often decline dramatically in density downstream from spring sources, presumably reflecting their requirement for the well-known stable temperature, chemistry, and flow regime characterized by headsprings (Deacon and Minkley 1974). They feed on algae gleaned from the substrate and aquatic vegetation, and they occupy habitats with good water quality. Although they may occupy a number of different substrates, most species prefer either sand, gravel, or cobble. There have been no studies on the life history of the Great Basin species.

The elongate mud meadows pyrg is endemic to Soldier Meadow, which is located at the northern extreme of the western arm of the Black Rock Desert in the transition zone between the Basin and Range Physiographic Province and the Columbia Plateau Province, Humboldt County, Nevada. This region is characterized by cold, dry winters influenced primarily by cool, polar air masses, and by hot, dry summers influenced primarily by warm, tropical air masses (Nachlinger 1991). Soldier Meadow lies between the Calico Mountains to the west and the Black Rock Range to the east, and encompasses a province of approximately 50 thermal, connected and isolated springs in an alluvial basin at the northwestern terminus of the Black Rock Desert about 121 kilometers (km) (75 miles (mi)) north of Gerlach, Nevada and 16 km (10 mi) south of the Summit Lake Paiute Indian Reservation. The vegetation is broadly classified into four wetland communities and three upland communities, one of which is considered transitional. The wetland communities support a tremendous diversity of plants, with over 60 different species identified in the marshes, seeps, and meadows. Thermal springs occur in the area at elevations ranging from 1,320 and 1,393 m (4,330 and 4,570 ft) (Nachlinger 1991). Some of the springs provide the only known habitat for the desert dace (*Eremichthys acros*), a federally-listed species endemic to approximately 20 springs in Soldier Meadow (Knight 1990).

The only ecological data compiled on the elongate mud meadows pyrg were collected by Donald W. Sada, Associate Research Professor, Desert Research Institute (personal communication 1996 cited in U.S. Fish and Wildlife Service candidate assessment form) and Sada and Powell (2001). This species occupies two basic habitat types. The first type is near the source of springs with temperatures greater than 45° C) (113° F). In this habitat, the species occupies the splash zone on rocks and riparian grasses. It occupies habitats occurring only in wetted areas within 1 centimeter (0.4 in.) of the water. In these high temperatures, it is semiaquatic and not submerged. The second type of habitat occurs where the temperature decreases down stream from spring sources. In this habitat, the species disappears from the splash zone and becomes submerged, limiting itself to gravel substrate in riffles. It does not occupy sites with low current velocity or habitats with fine substrates. Total amount of occupied habitat includes one spring providing less than 300 meters (m) (984 feet (ft)) of habitat. Sada and Powell (2001) estimated that the density of snails per 25 square centimeters (cm^2) (4 square inches (in^2) ranged from 0 to 27 (mean 2.7 to 13.0/25 cm^2 (4 in^2) in riffle habitats with gravel substrate. They were absent from ponded areas with fine substrate.

POPULATION STATUS

The elongate mud meadows pyrg was first collected by J.J. Landye in Soldier Meadow in 1978 (Hershler 1998) and populations he collected were still extant during 1996 surveys by D. Sada (personal communication 1996 cited in U.S. Fish and Wildlife Service candidate assessment form). The type locality, and the only known locality for the species, is an unnamed spring in the Mud Meadow drainage within the Soldier Meadow complex. This area is the northernmost of a large series of thermal springs having broad outflows. Extensive surveys in the Soldier Meadow region have not recorded any observations outside its restricted range (personal communication 1996 cited in candidate assessment form; Hershler 1998), although several springs in the region are occupied by other *Pyrgulopsis* species. The absence of early distributional surveys makes it impossible to determine how current distribution and abundance of the elongate mud meadows pyrg compares with historical conditions.

The elongate mud meadows pyrg occurs only in a stretch of thermal aquatic habitat that is approximately 300 m (984 ft) long and 2 m (6.7 ft) wide. Water depths in unaltered portions of the spring brook do not exceed 15 cm (6 in.) and substrate composition includes sand, gravel, and cobble. Current velocity varies from 0 (along the banks) to 40 cm/sec (16 in./sec) in mid-channel. All substrate in bathing impoundments along this spring brook is composed of silt and sand. Water depth in these impoundments is usually greater than 50 cm (20 in.) and current velocity is 0 cm/sec. Riparian vegetation along the spring brook is dominated by sedges and rushes. Woody vegetation is absent. Water temperature decreases downstream from the spring source and the elongate mud meadows pyrg becomes decreasingly abundant where temperatures drop below 32° C (90° F) degrees.

The Nevada Natural Heritage Program ranks the elongate mud meadows pyrg as Critically Imperiled.

The U.S. Fish and Wildlife Service classifies the elongate mud meadows pyrg as a candidate for Endangered Species Act protection with a listing priority number of 2.

LISTING CRITERIA

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.*

Historical range:	Nevada.
Current range:	A single spring in the Mud Meadow drainage in the Soldier Meadow complex (Humboldt County, Nevada).
Land ownership:	All habitat is on public lands under the management authority of BLM.

The springs inhabited by the elongate mud meadows pyrg are on public lands managed by the U.S Bureau of Land Management (BLM). The top four recreational uses of Soldier Meadow listed are, in order: bathing in hot springs, camping, all-terrain vehicle travel, and four wheel driving. This area has some of the most desirable campsites in the entire Black Rock Desert National Conservation Area (NCA). People are drawn to the area by the hot springs, several of which are at an ideal temperature for bathing, and by the quiet and solitude of the area. Most visitors to the area have little or no knowledge of the occurrence of springsnails. The sites used for bathing are highly disturbed. Because the spring brook is relatively shallow, bathers have constructed impoundments to increase the depths to a point suitable for bathing (BLM 1998). Between 1994 and 1995, visitor use increased by 4,000 12-hour visitor days (BLM 1998). Today, the area is becoming a well-known recreation area due to the highly popular Burning Man Festival held yearly about 48 km (30 mi) south of Soldier Meadow and drawing some 45,000 visitors from all over the world. The visibility of the area has also increased due to the designation of the Black Rock Desert NCA in 2000 (personal communication 2002 cited in U.S. Fish and Wildlife Service candidate assessment form). On Labor Day weekend, 2001, over 400 dispersed campers were observed within the vicinity of the spring occupied by the elongate mud meadows pyrg (personal communication 2002 cited in U.S. Fish and Wildlife Service candidate assessment form).

Sada and Powell (2001) found the elongate mud meadows pyrg only in shallow, flowing water on gravel substrate. The species does not occur in deep water (i.e. impoundments) where water velocity is low, gravel substrate is absent, and sediment levels are high. Deep water habitats do not occur naturally in elongate mud meadows pyrg habitat. Examination of its habitat use along its 300 m (984 ft) range, showed that the species is absent from impoundments that have been constructed for recreational bathing. The fact that the elongate mud meadows pyrg is found above and below these constructed impoundments suggests that their construction is eliminating habitat for this species and reducing its historic range. In the last 10 years, the number of impoundments have doubled to over a dozen. Bathers also adversely impact habitat by increasing sedimentation through stream bank trampling and removal of vegetation. The placement of various materials to increase the comfort of the bathers (e.g., carpet) in the spring brook and on its banks also adversely impacts the elongate mud meadows pyrg and its habitat. Post-Burning Man event cleanup by BLM staff in 2000, resulted in the removal of impoundments, large pieces of carpet which had been placed on the banks and in the spring brook, and various other materials which had been left behind in the spring brook by recreationalists (personal communication 2000 cited in U.S. Fish and Wildlife Service candidate assessment form). Concentrated, overnight use of the area, and the lack of sanitary facilities may also be resulting in impacts to water quality.

The Soldier Meadow area was subject to intensive geothermal exploration in the 1970s. The maximum temperature of the aquifer was deemed insufficient to support economic development at that time; however, future exploration and resource development of this type could affect the groundwater system supplying the thermal spring habitat in this area (U.S. Fish and Wildlife Service 1997). Soldier Meadow is designated as a Known Geothermal Resource Area and its springs are vulnerable to development of its ground water resources for energy development. Although there are no pending permits for new projects, increased interest in geothermal resources for their energy potential indicates that all species occupying thermal springs in Soldier Meadow are vulnerable to impacts of reduced spring discharge. Some portions of the species' habitat are protected from exploration and development activities through the ACEC/RNA designation for the desert dace (U.S. Fish and Wildlife Service 1997).

B. ***Overutilization for commercial, recreational, scientific, or educational purposes.***

Not known to be a threat to the elongate mud meadows pyrg at this time.

C. ***Disease or predation.***

Not known to be a threat to the elongate mud meadows pyrg at this time.

D. ***The inadequacy of existing regulatory mechanisms.***

Approximately 124 hectares (307 acres) of public land surrounding some of the habitat of the desert dace has been designated by the BLM as the Soldier Meadow Desert Dace Area of Critical Environmental Concern (ACEC). It is also designated as a BLM Research Natural Area (RNA). The ACEC was designated to highlight the area where special management attention is needed to protect and prevent irreparable damage to important biological, cultural, and historic resources. An RNA is an area which contains natural resource values of scientific interest and is managed primarily for research and educational purposes. In 1998, BLM completed the Soldier Meadow Activity Plan and Environmental Assessment (Plan). The preferred alternative within the Plan is designed to: 1) address impacts to special status species and cultural resources from increased recreation, livestock, wild horse and burro grazing, and potential geothermal and mineral development; 2) implement management actions to provide favorable habitat conditions for desert dace that will enable the U.S. Fish and Wildlife Service to delist the species; 3) implement management actions to protect habitat for Soldier Meadow cinquefoil (*P. basaltica*), a rare plant species known only from Soldier Meadow and an area in northeast California, so the U.S. Fish and Wildlife Service will not need to list the species; and 4) implement management actions to protect cultural resources in the area from further degradation. Specific actions identified in the Plan include: monitoring area use, increasing law enforcement, designating visitor use areas, designating specific bathing pools with walk-in access, limiting camping, limiting vehicle parking and camping within 61 m (200 ft) of the spring brook, developing interpretive signs, and dismantling impoundments in nondesignated bathing areas. These actions could help conserve the elongate mud meadows pyrg and its habitat. Some portions of this Plan have been implemented, including increased recreational area use monitoring and enforcement. This occurs mainly during holiday weekends or major events, such as the Burning Man Festival. However, limited resources and the remote nature of the site have made it difficult to implement most of the specific actions so the impact of the Plan has been minimal. Four years have passed since the Plan was finalized, yet visitor use bathing areas have still not been designated, allowing for continued dispersed use of the area, which negatively impacts the elongate mud meadows pyrg and its habitat.

Current Conservation Efforts: The Recovery Plan for the Rare Species of Soldier Meadows (U.S. Fish and Wildlife Service 1997) and BLM Soldier Meadow Activity Plan (BLM 1998) describe management actions that would provide conservation benefits to the species. To date, few of these actions have been undertaken.

E. ***Other natural or manmade factors affecting its continued existence.***

Spring-dwelling species in the western U.S. are vulnerable to unpredictable events, which have led to the decline and extirpation of many populations (Sada and Vinyard 2002). Habitats occupied by springsnails are often small, unique habitats where environmental conditions are predictable and stochastic events are rare. However, the small size of their habitats and their limited range (many are endemic) makes them highly susceptible to any factors that negatively impact their habitat. Other spring-dwelling species have been particularly vulnerable to habitat alteration by water diversion and to introduction of predaceous and competitive non-native species (Williams et al. 1985; Sada and Vinyard 2002). Because of its extremely limited range (less than 300 m (984 ft) of spring brook), the elongate mud meadows pyrg is highly susceptible to extinction if factors in its environment become unfavorable. The elongate mud meadows pyrg cannot withstand dessication for more than a few hours and does not have the ability to migrate to other suitable habitats. Its inability to withstand dessication also means that any impacts, such as water diversions that would result in drying of its habitat, could result in extinction. This is possible even if the impact is temporary.

A serious potential threat is posed by introductions of non-native species, which may result from intended management actions or accidental introduction by fisherman and recreational bathers. The red-rimmed thiara (*Melanoides tuberculata*) and New Zealand mudsnail (*Potamopyrgus antipodarum*) are two species in western Nevada and eastern California that may be introduced into Soldier Meadow in the future. Both of these species are hardy, tolerant of surviving dry conditions of extended periods, and both are known to have been transported in moist clothing or footwear. Hershler and Sada (1987) observed decreased springsnail abundance in habitats occupied by the thiara in other areas, and the mudsnail was recently established in nearby California where it has rapidly dominated the macroinvertebrate community. Continued use of elongate mud meadows pyrg habitat by bathers provides a continuing threat that these species may be accidentally introduced.

REFERENCES

Deacon, J. E. and W. L. Minckley. 1974. Desert fishes. Pp. 385-487 *in* Desert Biology (G. W. Brown, Jr., ed.). Special Topics on the Physical and Biological Aspects of Arid Regions vol. II. Academic Press, New York.

Hershler, R. 1998. A systematic review of the hydrobiid snails (Gastropoda: Rissoidea) of the Great Basin, western United States. Part I. Genus *Pyrgulopsis*. The Veliger 41:1-132.

Hershler, R. and D.W. Sada. 1987. Springsnails (Gastropoda: Hydrobiidae) of Ash Meadows, Amargosa basin, California-Nevada. Proceedings of the Biological Society of Washington 100:776-843.

Knight, T.A. 1990. Status report: *Potentilla basaltica* Tiehm and Ertter. Unpublished report prepared for the U.S. Fish and Wildlife Service, Reno, Nevada. 25 pp.

Nachlinger, J. 1991. Ecological survey of Soldier Meadow, Humboldt County, Nevada. Unpublished report prepared for the Bureau of Land Management, Winnemucca, Nevada. 26 pp.

Sada, D.W. and H. Powell. 2001. Distribution, abundance, and habitat use of Soldier Meadow springsnails (Family Hydrobiidae). Unpublished report to U.S. Bureau of Land Management, Winnemucca, NV.

Sada, D.W. and G.L. Vinyard. 2002. Anthropogenic changes in historical biogeography of Great Basin aquatic biota. Smithsonian Contributions to Earth Science. In press.

Taylor, D. W. 1985. Evolution of freshwater drainages and molluscs in Western North America. Pages 265-321 *in* Late Cenozoic History of the Pacific Northwest (C.J. Hocutt and A.B. Leviton, eds.). American Association for the Advancement of Science and California Academy of Science, San Francisco.

U.S. Bureau of Land Management. 1998. Soldier Meadow Activity Plan and Environmental Assessment. Bureau of Land Management, Winnemucca District, Winnemucca, Nevada.

U.S. Fish and Wildlife Service. 1997. Recovery Plan for the Rare Species of Soldier Meadows. Portland, Oregon. 50 pp.

Williams, J.E., D.B. Bowman, J.E. Brooks, A.A. Echelle, R.J. Edwards, D.A. Hendrickson, and J.J. Landye. 1985. Endangered aquatic ecosystems of North American deserts with a list of vanishing fishes of the region. Arizona-Nevada Academy of Science 20:1-62.