CANDIDATE ASSESSMENT AND LISTING PRIORITY ASSIGNMENT FORM

SCIENTIFIC NAME: *Popenaias popei*

COMMON NAME: Texas hornshell

LEAD REGION: 2

INFORMATION CURRENT AS OF: February 2003

STATUS/ACTION (Check all that apply):
___ New candidate
_X_ Continuing candidate
    _X_ Non-petitioned
    ___ Petitioned - Date petition received: ___
        ___ No finding yet
        ___ 90-day positive - FR date: ___
        ___ 12-month warranted but precluded - FR date: ___
        ___ Recycled (This form serves as new WBP finding)
    ___ Listing priority change
        Former LP: ___
        New LP: ___
Latest date species first became a Candidate: _____
___ Candidate removal: Former LP: ___ (Check only one reason)
    ___ A - Taxon more abundant or widespread than previously believed or not subject to a degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status.
    ___ F - Range is no longer a U.S. territory.
    ___ M - Taxon mistakenly included in past notice of review.
    ___ N - Taxon may not meet the Act=s definition of species.
    ___ X - Taxon believed to be extinct.

ANIMAL/PLANT GROUP AND FAMILY: Clams, Unionidae

HISTORICAL STATES/TERRITORIES/COUNTRIES OF OCCURRENCE: New Mexico, Texas; Mexico

CURRENT STATES/COUNTIES/TERRITORIES/COUNTRIES OF OCCURRENCE: New Mexico, Texas; Mexico

LEAD REGION CONTACT (Name, phone number): Susan Jacobsen, 505/248-6641

LEAD FIELD OFFICE CONTACT (Office, name, phone number): Austin, Texas Field Office, Nathan Allan, 512/490-0057

SUPPORT FIELD OFFICE(S): Albuquerque Field Office

BIOLOGICAL INFORMATION (Describe habitat, historic vs. current range, historic vs. current population estimates (# populations, #individuals/population), etc.):

NOTE: The information in this candidate form is primarily a result of a recently completed, multi year study of the mussels of the Rio Grande, funded by Section 6 as a joint project to the states of Texas and New Mexico. The information is based on the final reports (Lang 2001, Howells 2001) and communications with the principal investigators: Brian Lang, New Mexico Department of Game and Fish (NMGF) and Dr. Robert Howells, Texas Parks and Wildlife Department (TPWD).

Texas hornshell *(Popenaias popei)* (Mollusca: Bivalvia) is a member of the freshwater mussel family Unionidae (Murray and Leonard 1962), which are distinguished from other bivalve families by gross shell characteristics (e.g., large adult size [>60 millimeters (2.34 inches)], elongate shape [shell length > height] and soft anatomy; Burch 1973). The shell of Texas hornshell is subtrapezoidal and elongate (length to height ratio≥1.8), 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.

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). 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, 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), 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 obligatory parasites that typically require a fish host to metamorphose into juvenile mussels. Caudate (with tails) amphibians have been reported as glochidial hosts (i.e., 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 (Gordon et al. *In Review*).

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. These 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 (Lang 2001). 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 (Lang 2001).

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 in the past two decades, to a level of such significance 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 by scientists form Texas Parks and Wildlife Department (TPWD) (Howells et al. 1997). 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.

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). 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 (Howells 2001, Howells and Ansley 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 (Lang 2001). 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 (Lang 2001). Live specimens were 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 (Lang 2001).

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 2001, Howells and Ansley 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 2001).
Historical collections in Mexico are from the Rio Salado (type locality), and was 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 Texas hornshell in Mexico can not be fully determined.

In March 2002, Jose-Luis Egremy of Laredo Community College (LCC) found a living specimen and a number of recently dead shells of Texas Hornshell at a new location in the Rio Grande near Laredo in Webb County, Texas (Robert Howells, Texas Parks and Wildlife Department, *in litt.* 2002). Upon examination of the collection site by Dr. Robert Howells, of

Texas Parks and Wildlife Department, it was apparent the site is a flood-related depositional area and not actual long-term mussel habitat (in other words, mussels are deposited there during high waters, live for a time, then eventually die). Somewhere upriver, a pocket of acceptable mussel habitat must exist to serve as a source of the specimens found. Examination of several sites in April 2003 failed to find it. It is also worth noting that the city of Laredo is doing park construction work at the specimen collection site and U.S. Army Corps of Engineers is initiating similar habitat modification work upstream.

THREATS (Describe threats in terms of the five factors in section 4 of the ESA providing specific, substantive information.):

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

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 belows 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 in 1968 (Metcalf 1982, Howells et al. 1996, Howells 2001). 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 (Howells 2001).

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 (Howells 2001). 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 (Howells 2001). 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 (Howells 2001). 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 (Lang 2001). 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.

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

Introduction of exotic bivalves, namely the Asian clam (*Corbicula fluminea*), quagga mussel (*Dreissena bugensis*) and the zebra mussel (*D. polymorpha*), 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). 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.

BRIEF SUMMARY OF REASONS FOR REMOVAL OR LISTING PRIORITY CHANGE:
n/a

FOR RECYCLED PETITIONS: n/a

a. Is listing still warranted?
b. To date, has publication of a proposal to list been precluded by other higher priority listing actions?
c. Is a proposal to list the species as threatened or endangered in preparation?
d. If the answer to c. above is no, provide an explanation of why the action is still precluded.

LAND OWNERSHIP (Percentage Federal/state/private, identify nonprivate owners):

Texas hornshell occur 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).

PRELISTING (Describe status of conservation agreements or other conservation activities):

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 is 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.

REFERENCES (Identify primary sources of information (e.g., status reports, petitions, journal publications, unpublished data from species experts) using formal citation format):

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.

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.
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 S. P. Ansley. 1999. Recent freshwater-mussel surveys of the Rio Grande in the Big Bend Region. Triannual Unionid Report (17):7.
Howells, R.G. 2001. Status of freshwater mussels of the Rio Grande, with comments on other bivalves. Texas Parks and Wildlife Department, Inland Fisheries, Austin, Texas. 81 pp.
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. 2001. Status of the Texas hornshell and native freshwater mussels (Unionoidea) in the Rio Grande and Pecos River of New Mexico and Texas. Completion Report, New Mexico Department of Game and Fish, Conservation Services Division, Santa Fe, New Mexico. 13 pp + Appendices.
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.
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.
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 Popeii (Lea, 1857) (Unionoida) from the Black River, New Mexico. The Southwestern Naturalist (*In Press*).
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.

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., 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 (Bethesda) 18: 6-22.

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.

LISTING PRIORITY (place * after number)

THREAT

Magnitude	Immediacy	Taxonomy	Priority
High	Imminent	Monotypic genus	1
		Species	2 *
		Subspecies/population	3
	Non-imminent	Monotypic genus	4
		Species	5
		Subspecies/population	6
Moderate to Low	Imminent	Monotypic genus	7
		Species	8
		Subspecies/population	9
	Non-imminent	Monotypic genus	10
		Species	11
		Subspecies/population	12

Rationale for listing priority number:

Magnitude: The existence of only one confirmed location in New Mexico and one possible new site in Texas makes this species extremely vulnerable to extinction.

Imminence: Past riverine habitat alterations have already occurred to result in the much reduced distribution of this species. Demands for water from the Rio Grande continue to increase and make future habitat degradation likely.

APPROVAL/CONCURRENCE: Lead Regions must obtain written concurrence from all other Regions within the range of the species before recommending changes to the candidate list, including listing priority changes; the Regional Director must approve all such recommendations. The Director must concur on all additions of species to the candidate list, removal of candidates, and listing priority changes.

Approve: Tom Bauer March 14, 2003
Acting Regional Director, Fish and Wildlife Service Date

Concur: _____ _____
Director, Fish and Wildlife Service Date

Do not concur: _____ _____
Director, Fish and Wildlife Service Date

Director's Remarks: _____
_____
_____

Date of annual review: February 2003

Conducted by: Nathan Allan, Austin FWS office

Comments: _____
_____
_____

(rev. 7/02)