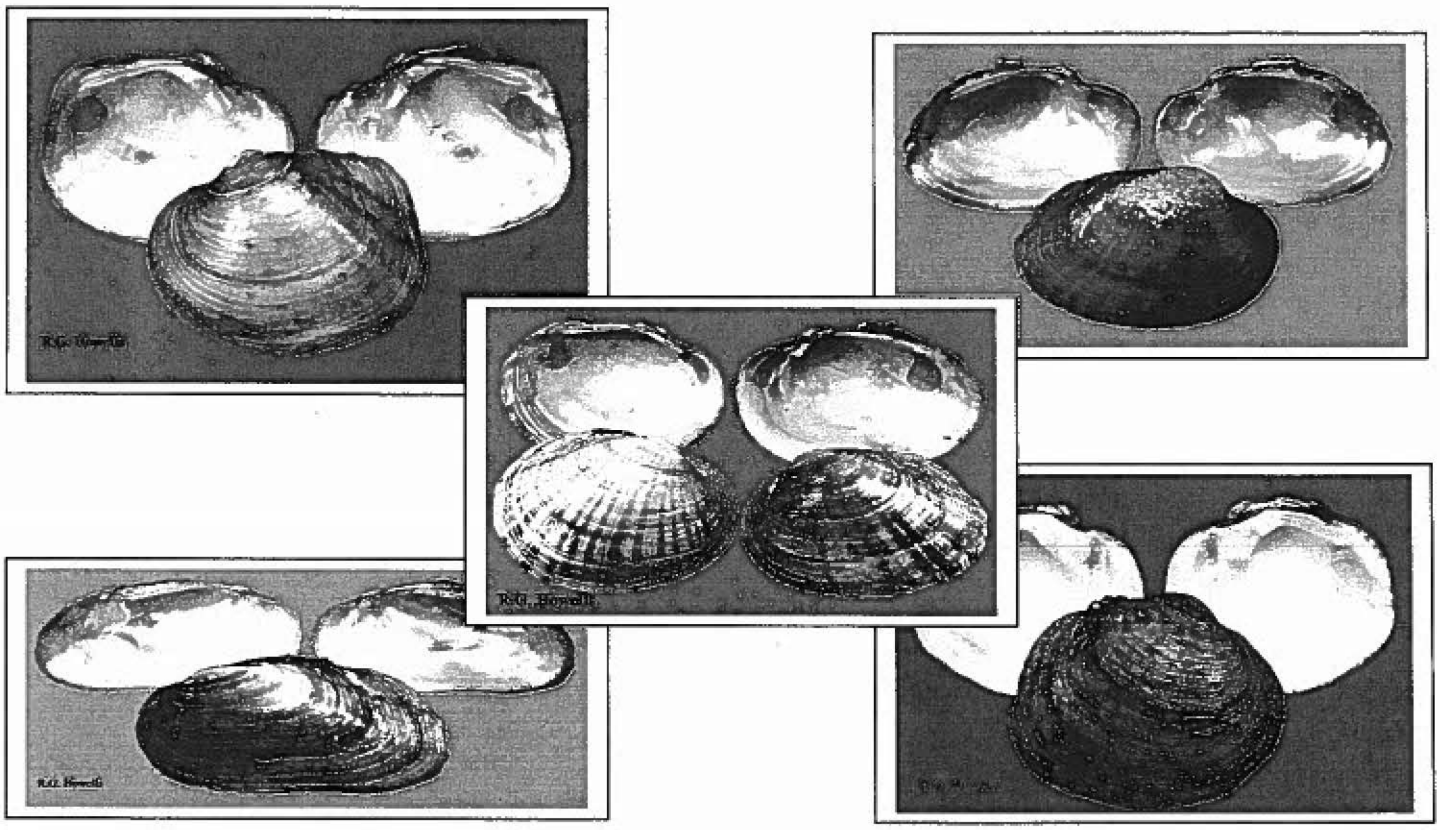
RARE MUSSELS: SUMMARY OF SELECTED BIOLOGICAL AND ECOLOGICAL DATA FOR TEXAS



Prepared by

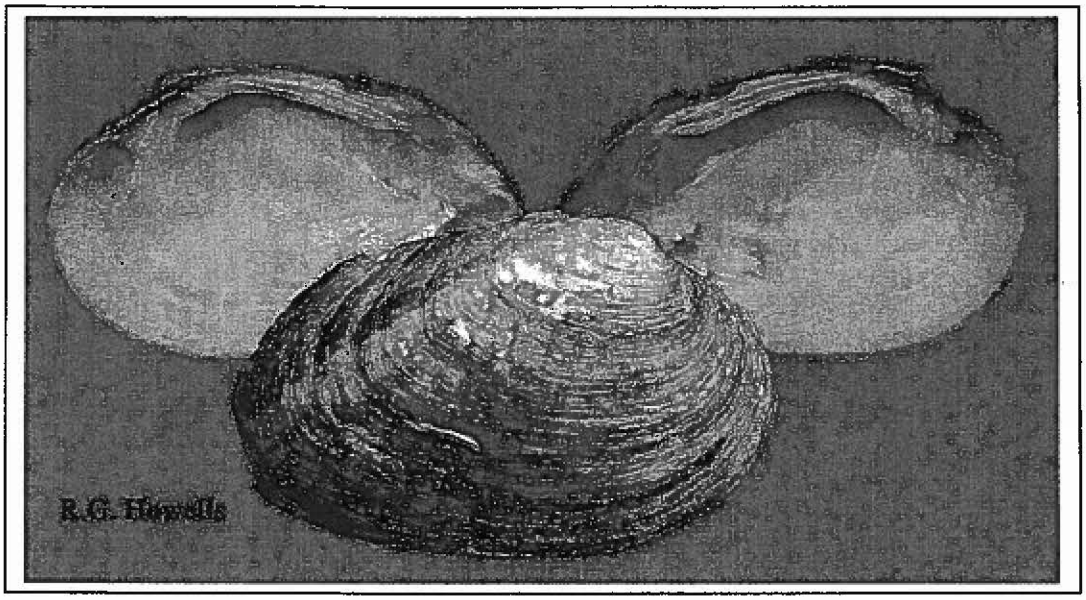
Robert G. Howells

BioStudies
Kerrville, Texas

2010

Six Edwards Plateau Species

FALSE SPIKE (*QUADRULA MITCHELLI*): SUMMARY OF SELECTED BIOLOGICAL AND ECOLOGICAL DATA FOR TEXAS*



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April 2010

*** Not for Internet Distribution**

ABOUT THE AUTHOR

Robert G. Howells is a fisheries scientist and aquatic ecologist. He has conducted research on freshwater mussels in Texas since 1992, in addition to his general fisheries studies and work with exotic species. Howells has served on the staff of the Cleveland Museum of Natural History; conducted environmental studies for 10 years for Ichthyological Associates, Inc., an environmental consulting firm; and spent 22 years with Texas Parks and Wildlife Department's Heart of the Hills Fisheries Science Center. He is the senior author of the book, Freshwater Mussels of Texas, and has written numerous scientific journal articles, symposia proceedings, technical reports, and informational guides. He is a member of the Freshwater Mollusk Conservation Society, American Malacological Society, and is currently working with others with the American Fisheries Society to update the distribution and conservation status of freshwater mussels of the United States, Canada, and Mexico. Howells retired from state employment in 2006, but has continued to study, write, and consult (BioStudies).

FUNDING SUPPORT

Funding support for this report was provided by Save Our Springs Alliance, P.O. Box 684881, Austin, Texas 78768; www.SOSAlliance.org. Individual funding was also provided by the Kirk Mitchell Environmental Law Fund and WildEarth Guardians. Copies of this report can be obtained from SOSA.

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ABOUT THIS REPORT

This report has been primarily drafted as a technical report, but introductory text, a glossary, and labeled shell feature figures have been included to assist non-malacologists with aspects of freshwater mussels. Within this report, shell length is abbreviated "sl" and other shell dimensions are typically written out. From the onset of freshwater mussel studies by Texas Parks and Wildlife Department (TPWD) in 1992, time-since-death estimates were designated for shells, valves, and fragments that were encountered in surveys (e.g., very recently dead = soft tissues still attached to shells and valves). These were defined in TPWD's annual Management Data Series (MDS) mussel survey reports and can be found in Howells (2003) that is available on the Internet. These shell condition designations provided possible status indications ranging from whether living specimens may still occur at a particular site to locations where mussels occurred in the area once, but appear to have been lost long ago. Mussel collection site locations on maps herein sometimes use a single dot to designate two or more collection sites that are in close proximity. Therefore, simply counting dots on these maps may not necessarily represent the total number of collection records or sites. Finally, recent data from several reports that are in preparation or in press may or may not have been included based on availability of these data, and some unconfirmed amateur volunteer records may also have been omitted.

ACKNOWLEDGMENTS

Special appreciation goes to C.M. Mather, J.A.M. Bergmann, and W.H. McCullagh for providing data used in preparation of this report. Thanks also to T.D. Hayes and A.J. Haugen for invaluable editorial input.

INTRODUCTION TO FRESHWATER MUSSELS

Freshwater Bivalves

Many types of bivalve mollusks are called clams or mussels. Neither term is really specific to one group. A number of bivalve groups live in fresh water in Texas. Freshwater mussels, also called pearly freshwater mussels or unionids (Family Unionidae), have over 50 species in Texas and about 300 in North America. A number of tiny fingernailclams (Sphaeriidae) are also present in many waters. Exotic Asian clam (Corbiculidae) invaded Texas in the 1950s and 60s, and exotic zebra mussel (Dreissenidae) was found in Texas in 2009. Several native estuarine clams and mussels can also be found in the lower reaches of coastal rivers.

Native Freshwater Mussels

Freshwater mussels do not attach to solid objects (as adults) like true marine mussels and zebra mussels, but dig into substrates of mud, sand, and gravel. They usually have distinct sexes. Females brood eggs and developing larvae (called glochidia) in marsupial pouches on their gills. Glochidia are parasites on fishes. Upon release from the female, glochidia have only hours to find the appropriate species of host fish that has no immunity to infection and attach to the correct location on that fish or die. After a few weeks or months, the transformed juveniles drop from the host to begin life in the substrate. Generally little harm comes to the host.

Role in the Ecosystem

Freshwater mussels are Mother-Nature's biofilters that feed by removing algae, bacteria, and organics from the water. They remove environmental contaminants and concentrate them in their tissues. Unionids also serve as food for fishes, birds, mammals, and other organisms. They mix water body substrates much as earthworms do in garden soils.

Historic Harvest

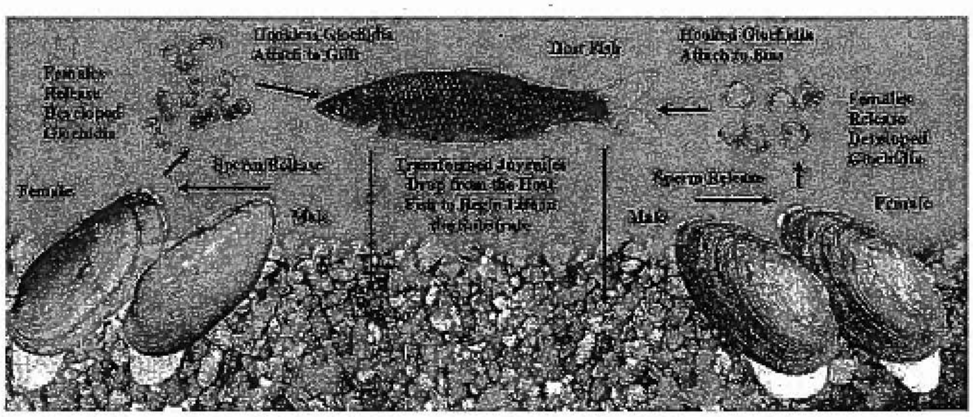
Native Americans harvested freshwater mussels for food, tools, ornament, and natural pearls. In the 1890s, shells of some species became important in button manufacturing (but to a limited extent in Texas). Some Texas mussels produce gem-quality pearls and they have been taken for this purpose since early Spanish times.

Recent Harvest

Limited harvest for pearls continues in Texas. In the late 1900s, some species were taken for their shells that were used to produce implant nuclei needed to create cultured pearls. They are occasionally captured for arts-and-crafts work, bait, and shell collectors. A license is required for any freshwater mussel harvest and some species are legally protected.

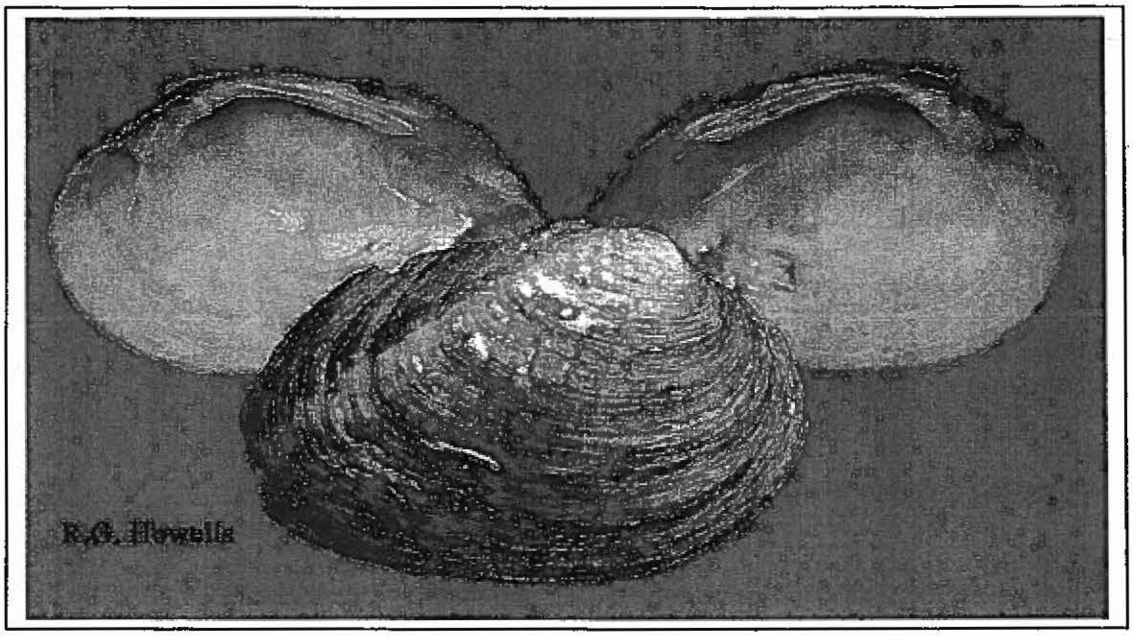
Conservation Status

Freshwater mussels are sensitive indicators of environmental quality. When there is any degradation in the ecosystem, these are usually the first organisms to decline or vanish. As a result, perhaps 80% of North American species are extinct, endangered, threatened, or will be soon. The State of Texas lists 15 species as legally threatened and another as endangered. Many of these are now under consideration for additional federal protection.



Freshwater mussel life cycle.

FALSE SPIKE
Quadrula mitchelli (Simpson 1895)



DESCRIPTION

Descriptions of false spike have been presented by Simpson (1895, 1896, 1914), Wurtz (1950), Howells et al. (1996), Johnson (1999), and Howells (2001a, 2010). Maximum reported shell length reaches 132 mm sl in the Rio Grande, but is usually much less in Central Texas (to 91 mm sl). Shell shape ranges from subrhomboidal to suboval and is only slightly inflated. Shells can be rather thin in some small juveniles, but become solid and moderately thick in large adults. Beaks are somewhat flattened and low, only slightly rising above the hinge line; beak cavities range from relatively shallow to moderately deep. The posterior ridge is low, rounded, and sometimes vaguely double. The posterior slope is flattened to slightly incurved. Pseudocardinal teeth (two left and one right) are only moderately heavy, compressed, with the left teeth clearly divergent and the anterior left tooth leaning forward. Lateral teeth (two left and one right) are straight or nearly so, somewhat short to moderately long (28-41% sl), with a basal flange running the length of the right lateral tooth in most cases. Adductor muscle scars are well impressed. Externally the disk is usually covered with small pustules, a series of dorsal-to-ventral parallel grooves (mid-disk), and often with a series of curving parallel ridges in the posterior field; some individuals may be almost completely free of disk sculpture. External coloration may be tan, olive, greenish-yellow, brown, or black; sometimes obscure green or brown rays are present. Internal coloration is white and iridescent posteriorly.

SPECIES BIOLOGY

Life History

Age and size at maturity
No reports of age or size at maturity were found during preparation of this report.

Brooding season
No reports of brooding seasons were found during preparation of this report.

Fecundity
No reports of fecundity were found during preparation of this report

Glochidia
No descriptions of glochidia were found during preparation of this report.

Hosts
No reports of hosts were found during preparation of this report.

Behavior
No reports of species behavior were found during preparation of this report.

Habitat requirements
Very little has been published regarding habitat requirements or preferences of False Spike. Wurtz (1950) reported specimens from the central Guadalupe River found in waters 61 cm deep in cobble and mud, with waterlilies (Cowlily *Nuphar advena*) present. The elongate-shelled gravel-bar morphs indicate that at least some individuals likely occurred in gravel bars and riffles. The area of the San Marcos River where recently dead material was last found in 2000 (Howells 2001b, 2006) has steep, unstable sand banks with the river cut deeply into the earth. Much of this stretch of the San Marcos River has either deep-shifting sand areas or scoured runs of heavy cobble and rocks. However, the river bends here producing an array of microhabitat areas, including some gravel bars and areas of mud, sand, and finer gravels behind boulders and fallen timber. Other unionids occur in these small pockets of microhabitat (and False Spike may as well if it still persists in the area). False Spike appears to have been a flowing-water species. None are known from impoundments (no natural lakes were present within it range).

Taxonomy and Genetics

Species validity
False spike was originally described by Simpson (1895, in Dall) as *Unio mitchelli*. Other synonyms included *U. iheringi* Wright 1898, *Quadrula* (*Quincuncina*) *guadalupensis* Wurtz 1950, *U. tamaulipasens* Conrad 1855, *Sphenonaias taumilapana* Conrad 1855, *Elliptio tamaulipasensis* (Conrad 1855) (see summaries in Howells et al 1996; Johnson 1999). This is a valid species (Howells et al. 1996; Turgeon et al. 1998); however, its generic status has modified over time. Following initial placement in *Unio,* the species was shifted to *Quadrula*. However,

Ortmann and Walker (1922) erected the genus *Quincuncina* for this and two other species. Biochemical analysis by Serb et al. (2003) demonstrated that *Quincuncina* was invalid, with one species being *Quadrula* and another moved to *Fusconaia*. With the elimination of *Quincuncina* as a valid genus, *Quincuncina mitchelli* was returned to *Quadrula* (albeit without biochemical genetic confirmation due to the absence of available tissue samples).

Metcalf (1982) questioned if the Central Texas and Rio Grande populations represented two distinct taxa. However, given that the Rio Grande population has apparently been extinct for some time and those in Central Texas may also have been lost, biochemical genetic resolution will likely never be accomplished.

Ecophenotypes
An elongate, gravel-bar morph from some sites in Central Texas has historically been given the subspecies name *elongatus*, but this form is not taxonomically significant (Howells et al. 1996).

Biochemical genetics
No biochemical genetic studies were found during preparation of this report.

Range

Historical
False spike has been recognized as two geographically distinct populations, one in the Rio Grande drainage and another in Central Texas (Fig. 1). Rio Grande records are generally based on subfossil and fossil material, with apparently no confirmation of living populations on record (Howells 2001a, 2009). Rio Grande populations seem to have declined prior to major European impacts. Within central Texas, False Spike occurred in the Guadalupe-San Antonio and Colorado drainages and some locations in the Brazos River basin (Strecker 1931; Howells et al. 1996, 1997; R.G. Howells database).

Current
No locations of living populations are currently known. Droughts and floods in Central Texas in the late 1970s and early 1980s appear to have largely eliminated this species. None have been found alive since. Indeed, the only suggestion that the species is not already extinct came in 2000 when W.H. McCullagh found two recently dead valves in the lower San Marcos River (Howells 2001b). This location has been reexamined (by W. H. McCullagh, R.G. Howells, A.Y. Karatayev, and L.E. Burlakova) several times since, including at the 2000 collection site, but without any indication of other living or recently dead specimens. No evidence of surviving populations in areas in Texas with historical records was found in surveys conducted by TPWD since 1992, none were located in studies in New Mexico conducted by B.K. Lang (New Mexico Department of Game and Fish, pers. comm.), and none were found by N.E. Strenth (Angelo State University, pers. comm.) in his examinations of Rio Grande tributaries in Mexico during this same time period.

Population levels
No surviving populations are currently known in either the Rio Grande drainage or in Central

Texas rivers. Over the past three decades, two recently dead valves from the lower San Marcos River found in 2000 (Howells 2001b, 2006, 2009) have been the only indication False Spike has not already been lost.

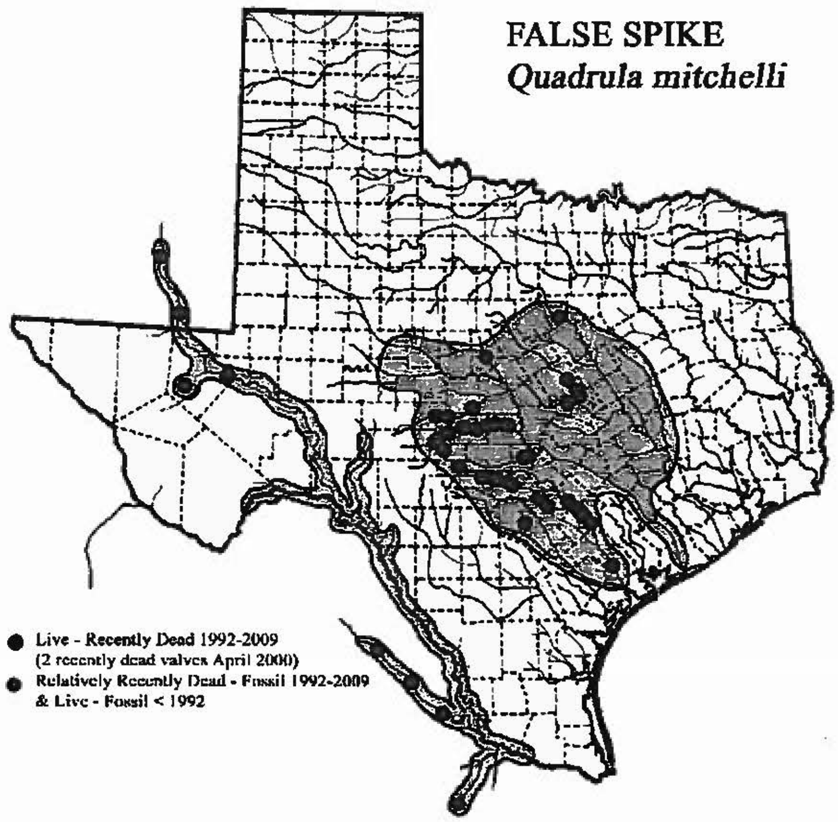


Figure 1. Presumptive historic range of False Spike (*Quadrula mitchelli*) shown in blue in Central Texas and in the Rio Grande drainage. No living specimens have been documented since records prior to 1980.

CONSERVATION MEASURES

When Texas Parks and Wildlife Department (TPWD) created its first freshwater mussel harvest regulations in 1992 and 1993, minimum size limits were established and a series of no-harvest sanctuaries were designated. At that time, minimum harvest sizes focused on commercial shell species of unionids, but the designation of a minimum 63.5 mm sh (2.5 inches sh) in shell height was also designated for "all other species" (including False Spike). This minimum harvest size applied both to living specimens and dead shells and valves and it remains in place today. The largest False Spike measured by the author from Central Texas was well below the minimum legal size. False Spike from the Rio Grande have been reported to 132 mm sl (Metcalf 1982), suggesting some individuals may have exceeded minimum harvest size, but no living or recently dead specimens have been confirmed in this drainage since long before this regulation was enacted.

No locations specifically supporting living False Spike populations were known when TPWD no-harvest sanctuaries were first established. However, because of other rare mussels in the San Marcos River (e.g. Golden Orb *Quadrula* aurea, Texas Pimpleback *Q. petrina*, and Texas Fatmucket *Lampsilis bracteata*) and the general ecological uniqueness of the system, the entire river was designated a no-harvest mussel sanctuary (Howells 2009). In addition to TPWD regulations, Howells et al. (1997) provided a list of the designated TPWD no-harvest mussel sanctuaries. Ultimately in 2006, no-harvest sanctuaries were redefined and were formally passed by the TPW Commission in July 2007 (Texas Parks and Wildlife Department Proclamation 57.156-57.158; Howells 2009). Although no current False Spike population has been confirmed in the San Marcos River, the system has been retained as a mussel sanctuary. Further, several other designated mussel sanctuaries in other drainages are within the historic range of False Spike and could potentially offer protection if it still occurs in those areas.

In December 2009, TPWD moved to list False Spike as a legally threatened species.

LISTING FACTORS

Habitat or Range (Destruction, Modification, Curtailment)

Throughout much of Texas, historic land utilization resulted in modification and elimination of some aquatic habitat critical to False Spike and other unionids. Extensive overgrazing beginning in the mid-1800s resulted in significant loss of vegetative cover and soils, with subsequent increases in runoff causing scouring of many streams and rivers (Howells 1994). Scouring impacts on Texas waters have been further exacerbated by changes in rainfall patterns to fewer light and moderate showers and longer periods of drought punctuated by heavy, damaging floods (http://www.epa.gov/climatechange/science/recentpsc.html; Howells and Power 2004). Additionally, decade-average rainfall has increased over the past century with more rain falling in the early 1990s than fell in 1900-1910 (Howells 1995). Collectively, overgrazing, reduction in vegetative cover and soils, increasing numbers of scouring floods, and general increases in amount of precipitation have combined to dramatically reduce acceptable mussel habitat in many Texas waters. Anthropogenic developments (e.g., impervious surfaces, water flow manipulations) have magnified these impacts.

Central Texas in particular experienced a major drought in the late 1970s followed by several record floods between 1978 and 1981 (Howells et al. 1997; Howells and Power 2004). Some Central Texas mussel population sites that held assemblages of living unionids in the 1970s (including False Spike) no longer supported living mussels when surveyed in the 1980s and 1990s (Howells et al. 1997). These events helped reduce the abundance and distribution of False Spike and other unionids. In addition to past and more-recent negative impacts (that continue), other broad-ranging and site-specific threats exist as well.

Within the San Marcos River, Gonzales County, the last place recently dead specimens were documented, the river is primarily (but not completely) contained within a state park that offers some degree of protection from many potentially negative influences. However, this location has areas of unstable, collapsing sand banks. Deep-shifting sand substrates are unacceptable mussel habitat, as are substrates with constant deposition of material from above (R.G. Howells, unpublished data). Further, the steep banks of the lower San Marcos River do not reduce scouring during high-water periods by allowing flood waters to spread out over adjacent flood plains. Additionally, the Luling oil field area upriver and associated activities (railroads, storage tanks, etc.) pose an additional potential environmental risk to the system.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Because of its small size and shell that has no commercial interest, there has been no noted commercial overutilization problems impacting False Spike populations in Texas waters (Howells 1993; R.G. Howells, unpublished data). No harvest for use as bait has been documented, but most anglers taking unionids for use as bait are not concerned about the identity of the species being harvested (R.G. Howells, unpublished data). Given the last record of recently dead specimens was within a state park with public access, shell-collector harvest as well as deliberate or accidental collection for scientific or educational purposed could be possible.

To date, neither state nor federal resource managers have directed or monitored scientific activities and their impact on False Spike populations. If living populations are found, it is possible multiple researches may survey, sample, and even remove specimens from the same area in relatively narrow windows of time. Volunteer training and sampling programs associated with freshwater mussel research similarly have limited regulated direction and may also potentially conflict with formal scientific research and management activities.

Public release of sensitive population location information has also been problematic regarding the security of some rare unionids in Texas. Some organizations have responded to this informational risk and modified their open releases of potentially harmful information. Unfortunately, even this report contains information that could be potentially misused and could be employed with negative impacts to any False Spike populations that may still survive.

Disease or Predation

No specific diseases have been reported in the published literature (R.G. Howells, unpublished data). Natural predators, like catfishes (Ictaluridae) and freshwater drum (*Aplodinotus grunniens*), no doubt would consume some False Spike, but no confirmation has been documented to date. Neither disease nor predation appear to be problematic issues for this species.

Existing Regulatory Measures

Until December 2009, neither state nor federal regulations offered False Spike threatened or endangered species protections despite its obvious rarity and declining status. Several no-harvest mussel sanctuaries are present within the historic range of this species. The minimum harvest size of 2.5 inches in shell height covered all but possibly some of exceptionally large specimens from the Rio Grande (that were likely lost prior to regulations being drafted). In December 2009, TPWD has listed False Spike as a legally threatened species.

Other Natural or Manmade Factors

Another source of potentially extensive and adverse, yet difficult to quantify, impact involves the increasing human population within the range of False Spike and the resulting increased pumping of aquifer waters for direct and indirect human uses. Flows in many Texas springs have been reduced or eliminated, with subsequent reduction or elimination of spring feeds to streams (Brune 1975, 2002). Historically, water allocation plans in Texas have not focused on preservation of rare mussel resources.

NEEDED INFORMATION

Taxonomy and Genetics

No living specimens have been documented since the 1970s, so no biochemical genetic studies have been conducted on this species. Given that False Spike may already be extinct (Williams et al., American Fisheries Society, in final preparation), the likelihood of obtaining fresh tissue samples appears remote. Biochemical analysis would be useful to confirm it placement in the genus *Quadrula*, but unless tissue samples can be obtained from specimens in existing collections taken years ago or living specimens are found, it may not be possible to develop good biochemical characterizations of this unionid. If living False Spike specimens are ever located, tissue samples (mantle clips or other non-lethal samples) should be taken.

Distribution

Use of historic records and more-recent collections subfossil and fossil material provided a good general indication of historic distribution. Field surveys within the historic range of False Spike should include documentation of shell and valve remains to help further fine tune distributional history.

Although no living populations are currently known, there are areas in the Brazos, Colorado, and Guadalupe-San Antonio rivers and their tributaries between easy access points that have never been surveyed. Efforts should be made to survey these areas, particularly under low-water conditions that could simplify location of any surviving False Spike that may still exist.

Reproductive Biology

If living False Spike are ever found (or museum specimens with preserved soft tissues), it should be noted that spawning and brooding seasons are unknown, glochidia are undescribed, and host fishes have never been identified. If any living specimens are found, it seems apparent that this species is already too rare to encourage sacrificing any specimens to obtain fecundity estimates.

Environmental Aspects of Biology

No reports of physicochemical parameters relative to False Spike were found during preparation of this report. If living specimens are located, efforts should be made to document these environmental variables.

When species are extremely rare, difficult to observe or sample, and sensitive to disturbance, it can be extremely challenging to define critical aspects of species biology that relate to management of the species (e.g., in-stream flow limitations, minimum and maximum lethal temperatures and oxygen levels, critical spawning and incubation temperatures, etc.). Documenting these various elements for False Spike biology on those occasions when opportunity presents can be important, especially when multiple observations can be combined into meaningful summaries. Opportunities to record elements of species biology should not be neglected. It should also be noted that measurements of physicochemical parameters associated with False Spike survival sites need to be documented over long periods of time (years) to be meaningful. Quick snapshot studies in areas often subjected to extensive flood and drought extremes may not provide a good over-all view of the full range of relevant flow rates, water chemistry, and related parameters. Indeed, short snapshot studies can sometimes be more misleading than instructive.

Threats to Continued Survival

Continued human population growth and development in Central Texas are certain to have increasing impacts on native unionid populations. Habitat loss, modification, or disturbance in conjunction with decreasing water supplies can be anticipated.

PERSONAL CONCLUSIONS AND RECOMMENDATIONS

False Spike is a unique unionid within the mapleleaf-pimpleback complex that is (or was) endemic to Central Texas and the Rio Grande. Although apparently not seen alive in over 30 years and not found recently dead in 10 years, False Spike should still be legally listed as an endangered species under both state and federal regulations. Private lands and hard-to access rivers in many areas of its range in Texas make it difficult to absolutely confirm its possible extinction.

Many elements of species biology, including reproductive biology, remain unknown and should be the subject of scientific investigation whenever possible if this unionid is ever found alive again. Failure to initiate preservation activities several decades ago seems may have led to the extreme rarity of this species before such efforts could be successfully employed.

RELEVANT LITERATURE

Brune, G. 1975. Major and historical springs of Texas. Texas Water Development Board, Report 189, Austin.

Brune, G. 2002. Springs of Texas. Volume 1. Springs of Texas. Texas A&M Press, College Station.

Conrad, T.A. 1855. Descriptions of three new species of *Unio*. Proceedings of the Academy of Natural Sciences of Philadelphia 7:256.

Howells, R.G. 1993. Preliminary survey of freshwater mussel harvest in Texas. Texas Parks and Wildlife Department, Management Data Series 100, Austin.

Howells, R.G. 1994. Longhorn cattle and windmills linked to mussel declines. Info-Mussel Newsletter 2(5):5.

Howells, R.G. 1995. Changes in precipitation patterns in Texas. Info-Mussel Newsletter 3(4):6.

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

Howells, R.G. 2001a. Status of freshwater mussels of the Rio Grande, with comments on other bivalves. Texas Parks and Wildlife Department, Austin.

Howells, R.G. 2001b. Distributional surveys of freshwater bivalves in Texas: progress report for 2000. Texas Parks and Wildlife Department, Management Data Series 187, Austin.

Howells, R.G. 2003. Declining status of freshwater mussels of the Rio Grande. Pages 59-73 *in* G.P. Garrett and N.L. Allen, editors. Aquatic fauna of the northern Chihuahuan Desert. Texas Tech University Press, Lubbock. (Initially presented in 2001).

Howells, R.G. 2004. Texas freshwater mussels: species of concern. Texas Parks and Wildlife Department, Wildlife Diversity Conference, San Marcos, Texas. 18-20 August 2004.

Howells, R.G. 2006. Statewide freshwater mussel survey. State Wildlife Grant Final Report T-15-P, Texas Parks and Wildlife Department, Austin.

Howells, R.G. 2009. Biological opinion: conservation status of selected freshwater mussels in Texas. BioStudies, Kerrville, Texas.

Howells, R.G. 2010. Guide to Texas freshwater mussels. BioStudies, Kerrville, 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. Niamo. 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.

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

Howells, R.G., and P. Power. 2004. Freshwater mussels of the San Marcos-Blanco River basin: history and status. 107th Annual Meeting of the Texas Academy of Science, Kerrville, Texas, 6 March 2005

Johnson, R.I. 1999. Unionidae of the Rio Grande (Rio Bravo del Norte) system of Texas and Mexico. Occasional Papers on Mollusks 6(77):1-66.

Metcalf, A.L. 1982. Fossil unionacean bivalves from three tributaries of the Rio Grande. Pages 43-58 *in* J.R. Davis, editor. Proceedings of the symposium on recent benthological investigations in Texas and adjacent states. Texas Academy of Sciences, Austin.

Ortmann, A.E., and B. Walker. 1922. On the nomenclature of certain North American naiades. Occasional Papers of the Museum of Zoology. University of Michigan (112):1-75.

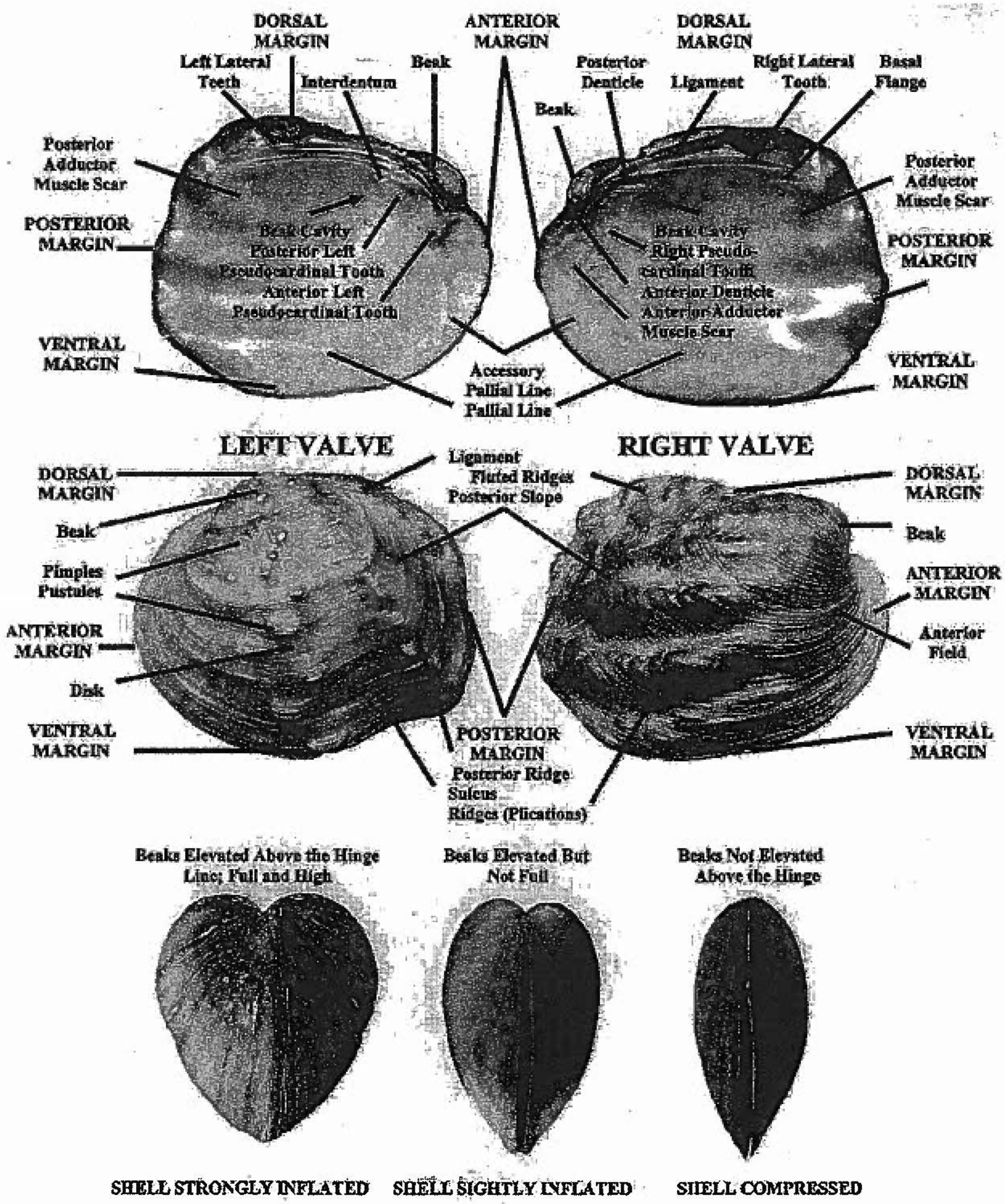
Serb, J.M., J.W. Buhay, and C. Lydeard. 2003. Molecular systematics of the North American bivalve genus *Quadrula* (Unionidae: Ambleminae) based on

mitochondrial ND1 sequences. Molecular Phylogenetics and Evolution 28(2003):1-11.
Simpson, C.T. 1895. Diagnoses of new mollusks from the survey of the Mexican boundary. Proceedings of the United States National Museum 18:1-6.
Simpson, C.T. 1896. Report on the mollusks collected by the International Boundary Commission of the United States and Mexico. Proceedings of the United States National Museum 19:333-378, pls. 21-23.
Simpson, C.T. 1900. Synopsis of the naiads, or pearly fresh-water mussels. Proceedings of the United States National Museum 32:501-1044.
Simpson, C.T. 1914. A descriptive catalogue of the naiades, or pearly fresh-water mussels. Parts I-III. Bryant Walker, Detroit, Michigan.
Strecker, J.K. 1931. The distribution of naiads or pearly fresh-water mussels of Texas. Baylor University Museum Bulletin 2, Waco.
Turgeon, D.D., and 13 co-editors. 1998. Common and scientific names of aquatic invertebrates of the United States and Canada: mollusks. American Fisheries Society Special Publication 26, Bethesda, Maryland.
Wurtz, C.B. 1950. *Quadrula (Quincuncina) mitchelli* sp. Nov. (Unionidae: Pelecypoda). Notulae Naturae 224:1-3.

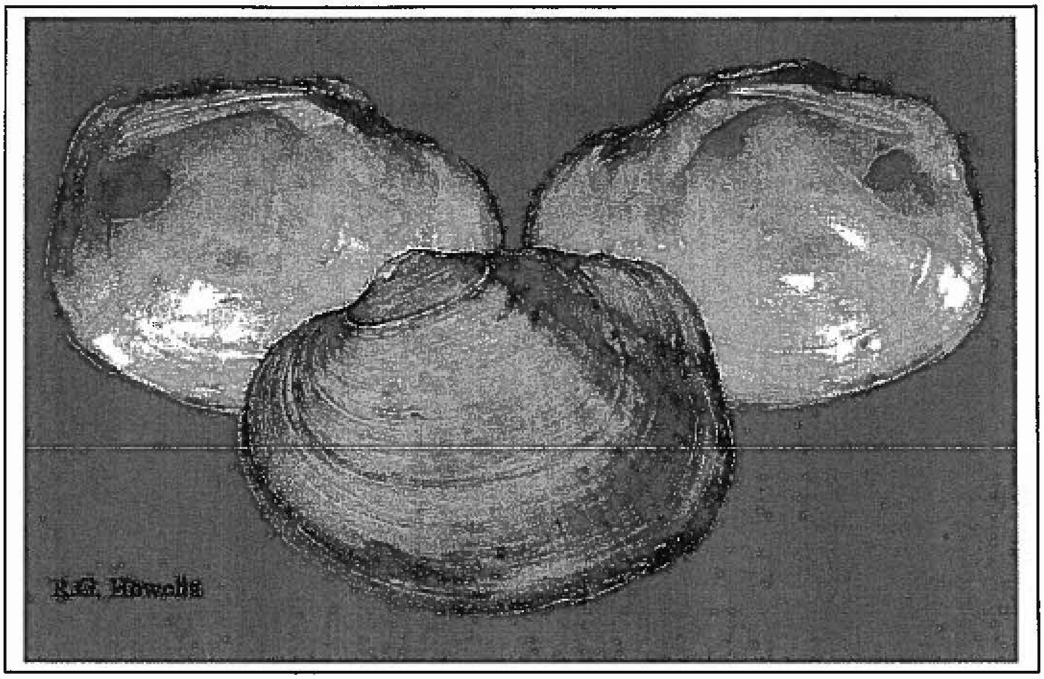
GLOSSARY OF SELECTED TERMS

Ala – a wing-like extension of the dorsal shell margin; usually posterior to the beak, sometimes anterior; "alate" means having a wing.
Beak – the umbo, the elevated (usually) part of the shell on the dorsal edge, anterior to the ligament in freshwater mussels, the oldest part of the shell.
Beak cavity – the inside of the beak within each valve, often forms a pocket or depression.
Beak sculpture – patterns of ridges, loops, and bumps that, like finger prints, can be unique to some species; often eroded and missing.
Chevron – V or arrowhead shaped, sometimes paired into Ws.
Compressed – flattened or pressed together.
Denticle – small (usually) tooth-like structures that may be present anterior and posterior to the right pseudocardinal tooth.
Concentric – circles, rings, or crescents with a common center or origin.
Dimorphic – having two distinct forms.
Ecophenotype – forms of a single species that are physically distinct in different environments.
Elliptical – ellipse shaped or an elongated oval.
Elongate – long or extended.
Endemic – found only in a particular area.
Exfoliated – eroded.
Extirpated – extinct in a particular area.
Fecundity – the number of eggs and/or larvae.
Fluted – grooves and ridges with a ruffle-like appearance.
Growth-rest lines – alternating dark and light concentric lines in a mussel shell indicating periods of slow and fast growth, respectively. In the far north, these may be annuli (formed each year), but in Texas growth may slow during summer droughts or continue over mild winters (therefore growth-rest bands cannot be counted as an indication of age).
Hinge – the area where the right and left valves (shell halves) articulate and are connected by an elastic ligament.
Hinge teeth – lateral and pseudocardinal teeth.
Inflated – swollen, expanded.
Interdentum – the area of the hinge between the lateral and pseudocardinal teeth; absent in some species.
Iridescent – a lustrous, pearly, or rainbow color appearance; only freshwater mussels and marine pearl oysters have iridescent nacre.
Lachrymose – drop-shaped pustules.
Lateral teeth – elongate structures along the hinge in many species located only posterior to the beak in freshwater mussels; absent in some species; these stabilize the hinge and are not true teeth at all.
Lunule – a cavity or depression, also called a sinus.
Nacre – the inner layer of the shell, mother-of-pearl.
Oval (ovate) – egg shaped.
Pallial line – a linear depression inside each valve interior to the shell margin, where the soft mantle tissues were attached.
Periostracum – the outer shell layer, shell epidermis.
Plications – folds, ridges, particularly multiple ridges.
Posterior ridge – a ridge on the posterior half of the shell running from the beak to the margin.
Posterior slope – shell area between the posterior ridge and the dorso-posterior margin.
Pseudocardinal teeth – tooth-like structures located below the beak area, usually two in the left valve and one in the right valve or none at all; may be compressed and leaf-like to heavy and molar-like.
Quadrate – square; often expressed as subquadrate (nearly quadrate).
Pustule – a bump or raised knob on the shell exterior.
Serrated – notched or grooved.
Shell margin – the exterior circumference edge of each valve (sometimes this term excludes the hinge line).
Solid – hard, thick, not soft and chalky.
Striated – with fine lines or grooves.
Truncate – shortened or squared off (sometimes obliquely).
Tubercle – projection from the shell, may be pointed, rounded, or knob-like.
Umbo – beak.
Valve – one half of a bivalve shell.
Wing – ala.

FRESHWATER MUSSEL SHELL FEATURES



GOLDEN ORB (*QUADRULA AUREA*): SUMMARY OF SELECTED BIOLOGICAL AND ECOLOGICAL DATA FOR TEXAS*



Prepared by

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April 2010

*** Not for Internet Distribution**

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Robert G. Howells is a fisheries scientist and aquatic ecologist. He has conducted research on freshwater mussels in Texas since 1992, in addition to his general fisheries studies and work with exotic species. Howells has served on the staff of the Cleveland Museum of Natural History; conducted environmental studies for 10 years for Ichthyological Associates, Inc., an environmental consulting firm; and spent 22 years with Texas Parks and Wildlife Department's Heart of the Hills Fisheries Science Center. He is the senior author of the book, Freshwater Mussels of Texas, and has written numerous scientific journal articles, symposia proceedings, technical reports, and informational guides. He is a member of the Freshwater Mollusk Conservation Society, American Malacological Society, and is currently working with others with the American Fisheries Society to update the distribution and conservation status of freshwater mussels of the United States, Canada, and Mexico. Howells retired from state employment in 2006, but has continued to study, write, and consult (BioStudies).

FUNDING SUPPORT

Funding support for this report was provided by Save Our Springs Alliance, P.O. Box 684881, Austin, Texas 78768; www.SOSAlliance.org. Individual funding was also provided by the Kirk Mitchell Environmental Law Fund and WildEarth Guardians. Copies of this report can be obtained from SOSA.

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CONTENTS

ABOUT THIS REPORT

This report has been primarily drafted as a technical report, but introductory text, a glossary, and labeled shell feature figures have been included to assist non-malacologists with aspects of freshwater mussels. Within this report, shell length is abbreviated "sl" and other shell dimensions are typically written out. From the onset of freshwater mussel studies by Texas Parks and Wildlife Department (TPWD) in 1992, time-since-death estimates were designated for shells, valves, and fragments that were encountered in surveys (e.g., very recently dead = soft tissues still attached to shells and valves). These were defined in TPWD's annual Management Data Series (MDS) mussel survey reports and can be found in Howells (2003) that is available on the Internet. These shell condition designations provided possible status indications ranging from whether living specimens may still occur at a particular site to locations where mussels occurred in the area once, but appear to have been lost long ago. Mussel collection site locations on maps herein sometimes use a single dot to designate two or more collection sites that are in close proximity. Therefore, simply counting dots on these maps may not necessarily represent the total number of collection records or sites. Finally, recent data from several reports that are in preparation or in press may or may not have been included based on availability of these data, and some unconfirmed amateur volunteer records may also have been omitted.

ACKNOWLEDGMENTS

Special appreciation goes to N.A. Johnson, C.M. Mather, J.A.M. Bergmann, and W.H. McCullagh for providing data used in preparation of this report. Thanks also to T.D. Hayes and A.J. Haugen for invaluable editorial input.

INTRODUCTION TO FRESHWATER MUSSELS

Freshwater Bivalves

Many types of bivalve mollusks are called clams or mussels. Neither term is really specific to one group. A number of bivalve groups live in fresh water in Texas. Freshwater mussels, also called pearly freshwater mussels or unionids (Family Unionidae), have over 50 species in Texas and about 300 in North America. A number of tiny fingernailclams (Sphaeriidae) are also present in many waters. Exotic Asian clam (Corbiculidae) invaded Texas in the 1950s and 60s, and exotic zebra mussel (Dreissenidae) was found in Texas in 2009. Several native estuarine clams and mussels can also be found in the lower reaches of coastal rivers.

Native Freshwater Mussels

Freshwater mussels do not attach to solid objects (as adults) like true marine mussels and zebra mussels, but dig into substrates of mud, sand, and gravel. They usually have distinct sexes. Females brood eggs and developing larvae (called glochidia) in marsupial pouches on their gills. Glochidia are parasites on fishes. Upon release from the female, glochidia have only hours to find the appropriate species of host fish that has no immunity to infection and attach to the correct location on that fish or die. After a few weeks or months, the transformed juveniles drop from the host to begin life in the substrate. Generally little harm comes to the host.

Role in the Ecosystem

Freshwater mussels are Mother-Nature's biofilters that feed by removing algae, bacteria, and organics from the water. They remove environmental contaminants and concentrate them in their tissues. Unionids also serve as food for fishes, birds, mammals, and other organisms. They mix water body substrates much as earthworms do in garden soils.

Historic Harvest

Native Americans harvested freshwater mussels for food, tools, ornament, and natural pearls. In the 1890s, shells of some species became important in button manufacturing (but to a limited extent in Texas). Some Texas mussels produce gem-quality pearls and they have been taken for this purpose since early Spanish times.

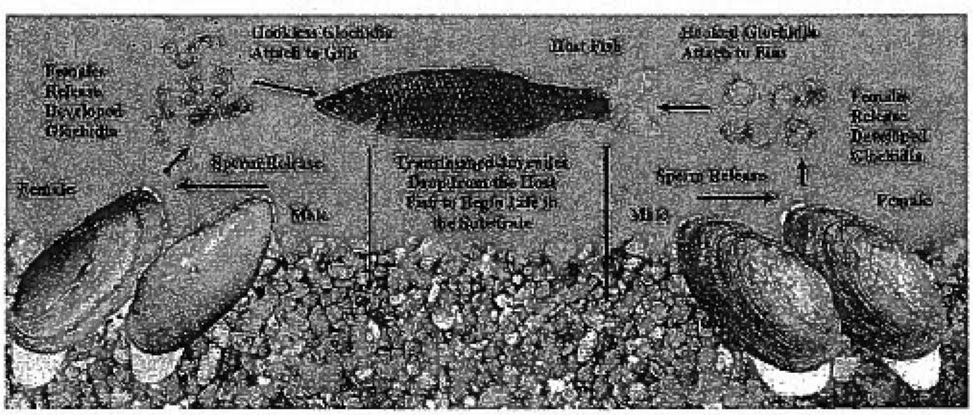
Recent Harvest

Limited harvest for pearls continues in Texas. In the late 1900s, some species were taken for their shells that were used to produce implant nuclei needed to create cultured pearls. They are occasionally captured for arts-and-crafts work, bait, and shell collectors. A license is required for any freshwater mussel harvest and some species are legally protected.

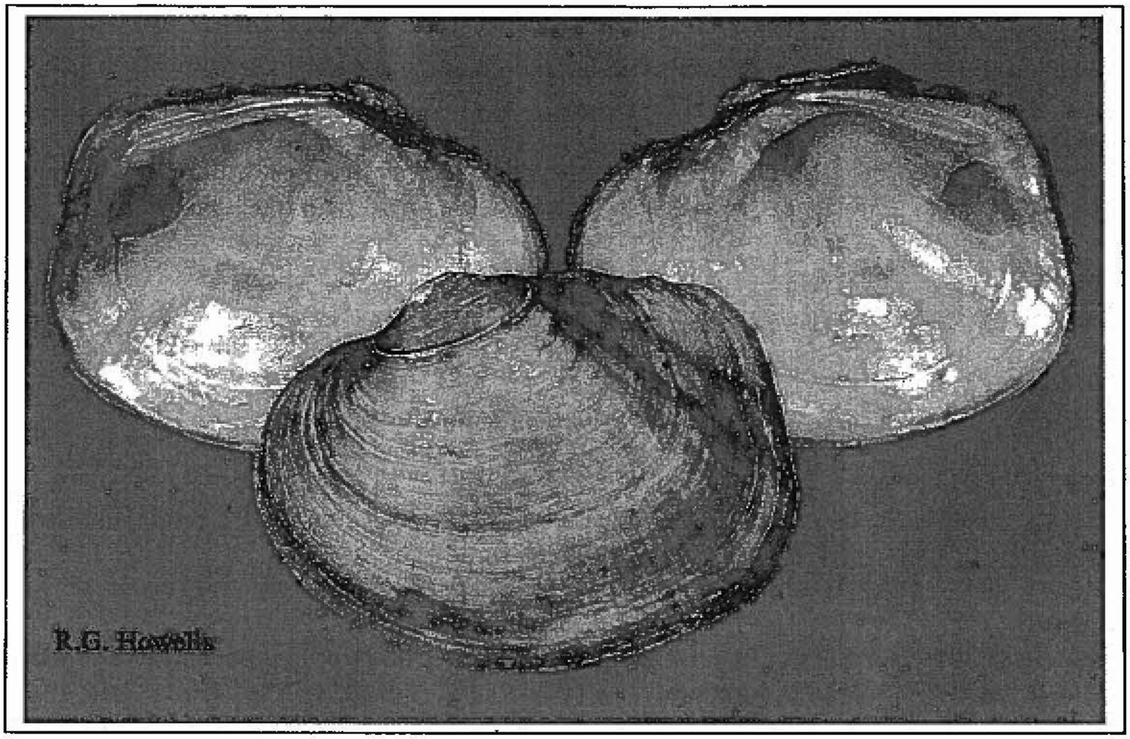
Conservation Status

Freshwater mussels are sensitive indicators of environmental quality. When there is any degradation in the ecosystem, these are usually the first organisms to decline or vanish. As a result, perhaps 80% of North American species are extinct, endangered, threatened, or will be soon. The State of Texas lists 15 species as legally threatened and another as endangered. Many of these are now under consideration for additional federal protection.

Freshwater mussel life cycle.



GOLDEN ORB
Quadrula aurea (Lea 1859)



DESCRIPTION

Descriptions of golden orb have been presented by Simpson (1914), Howells et al. (1996), and Howells (2002, 2010). Shell length reaches at least 82 mm sl, but is usually much less. Shape ranges from oval to nearly round, subquadrate, and somewhat subrectangular (but always longer than high) and is moderately compressed (much less inflated than other pimpleback-type quadrulids in Texas) and solid, but only moderately thick. Beaks are raised above the hinge line, but are not high or extremely full; the beak cavity is moderately deep. The posterior ridge is broad and rounded and is sometimes double. Adductor muscle scars are impressed. Pseudocardinal teeth (two left and one right) are not massive or strongly three-dimensional; the right valve usually has a thin anterior denticle and an obscure posterior denticle. Lateral teeth (two left and one right) are relatively short, only slightly thickened, and straight to very slightly curved; the right tooth usually has a basal flange most of its length. The disk usually shows no external sculpturing, but very rarely has a suggestion of pustules on the central disk. A few specimens may display rows of ridges or pustules above the posterior ridge, but most are unsculptured in this area. External coloration yellowish- or orangish-tan or brown, occasionally dark brown or black; some specimens may show faint greenish rays. Internally, white to bluish-white, iridescent posteriorly (an old report of purple tinted nacre is inconsistent with modern specimens). Soft tissues are white to off-white.

SPECIES BIOLOGY

Life History

Age and size at maturity
No data on age or size at maturity were found during preparation of this report.

Brooding season
Howells (2000) reported finding females with marsupial eggs from May through August, but noted that no living females taken earlier in the year were found with glochidia.

Fecundity
No data on fecundity were found during preparation of this report.

Glochidia
No descriptions of glochidia were found during preparation of this report.

Hosts
No hosts have been identified for Golden Orb. However, other quadrulids use catfishes (Ictaluridae) as hosts and Golden Orb may do so as well.

Behavior
No published observations of Golden Orb behavior were found during preparation of this report. Specimens held in flow-through raceways at TPWD's Heart of the Hills Fisheries Science Center and in the author's aquaria were observed to move relatively little and to partially bury into gravel substrates (R.G. Howells, unpublished data). Calcium deposition on shells of many Guadalupe River specimens also indicates Golden Orb typically buries about 60-70% its shell length into the substrate and remains in that position long enough for significant calcium deposits to develop on exposed shell surfaces (R.G. Howells, unpublished data).

Habitat requirements
Habitat requirements were discussed by Howells et al. (1996) and Howells (2002). Generally, Golden Orb has been found almost exclusively in flowing waters in moderate-size streams and rivers. No natural lakes occur within its range and it has not been found in reservoirs (even those impoundments associated with flowing waters where Golden Orb populations occur), with a single exception. A population of Golden Orb established in Lake Corpus Christi (lower Nueces River drainage), but is usually associated with wind-swept points where wave action may simulate flowing-water conditions. It has not been confirmed in the more-recently built Choke Canyon Reservoir upstream in the same drainage basin. However, Choke Canyon Reservoir is positioned east-west along its long axis, but Choke Canyon Reservoir's main axis is north-south and perpendicular to prevailing winds (R.G. Howells, unpublished data).

Kerr County - Guadalupe River, Kerrville:
Much of this area is scoured bedrock and cobble, with little high-quality mussel habitat apparent. One site accumulates heavy deposits of silt and detritus from a tributary stream (R.G. Howells, unpublished data).

Gonzales County – San Marcos River:
This stretch of the San Marcos River has high, collapsing, sandy banks and is deeply cut into the earth. Gravel bars occur at scattered sites and some sand and mud areas develop behind larger boulders and fallen trees. Mussels are largely restricted to a limited number of sites of micro-habitat at protected locations. Most of the area supporting Golden Orb is within a state park with wooded areas adjacent to the river (R.G. Howells, unpublished data).

Gonzales County – Guadalupe River, downstream of Lake Gonzales:
From Lake Gonzales downstream to Lake Wood, the Guadalupe River has moderately steep banks, most of which are moderately stable and vegetated along their riparian zones. Substrates range from mud, sand, and gravel to heavier cobble, and vary from site to site. Bank areas are private lands with very little public access (a fact that has limited scientific access and study of this area) (R.G. Howells, unpublished data).

Gonzales County – Guadalupe River, downstream of Lake Wood:
This stretch of the Guadalupe River between Lake Wood and the confluence of the San Marcos River is similar to the area described above downstream of Lake Gonzales. When studied by TPWD in the 1990s, the Guadalupe-Blanco River Authority often withheld water at upstream areas over night, then released it rather rapidly in the early morning to generate electricity during peak demand periods. This created dramatic fluctuations in water level and flow rate. It is unclear at this writing if this flow manipulation has continued (R.G. Howells, unpublished data).

Victoria County – Guadalupe River, near Victoria:
Golden Orb was found a this location was found in September 2009 by N.A. Johnson (University of Florida, pers. comm.) and was reported just below a small bridge, but without other site descriptors.

Goliad County – San Antonio River, Goliad and upstream of Goliad:
Golden Orb was found at these locations when they were sampled by Karatayev and Burlakova (2007) in 2007, but no detailed site descriptions were included in their report. These sites were alluded to in Burlakova and Karatayev (2008), but without site descriptions. These locations were not previously surveyed by the author.

Goliad County – San Antonio River, south-southwest of Victoria:
In September 2009, N.A. Johnson (University of Florida, pers. comm.) found a single living Golden Orb specimen here and indicted only that the site had deeply incised banks that were difficult to survey.

Live Oak and San Patrico counties – Lake Corpus Christi:
Only this reservoir has been found to support an impounded Golden Orb population. Deep embayments at some locations have very soft silt bottoms with emergent macrophytes in their inner reaches, this graduates into firm mud, then to sand and gravel, with heavy cobble on the outer tips of points. Golden Orb typically position themselves along the mud, sand, and gravel areas and avoid soft silt and mud in the inner embayments and cobble areas near the points. Wind and wave actions in association with appropriate substrates appear to sufficiently resemble flowing water conditions to permit survival (R.G. Howells, unpublished data).

Taxonomy and Genetics

Species validity
Golden Orb is considered to be a valid mussel species (Howells et al. 1996; Turgeon et al. 1998). It was originally described as *Unio aureus* by Lea in 1859 and later moved to *Quadrula* by Simpson 1900.

Ecophenotypes
Like a number of other Central Texas unionids, Golden Orb occasionally produces elongate gravel-bar or riffle morphs. However, these are not recognized as taxonomically distinct. *Unio bolli* of Call (1881) is likely only an elongate form of this species.

Biochemical genetics
Howells (2002) reported basic electrophoretic analysis of Golden Orb and other pimpleback species in Texas and other Gulf states. Serb et al. (2003) included this species in their DNA work with the genus *Quadrula*. Curiously, Serb et al. (2003) demonstrated the species status of Western Pimpleback (*Q. mortoni*), but did not resolve genetic similarities between Golden Orb and Pimpleback (*Q. pustulosa*), two morphologically-distinct species located in widely separated areas of the state and which are separated by several drainage basins and other pimpleback species. Serb et al. (2003) indicated additional work was needed and also did not comparatively include Smooth Pimpleback (*Q. houstonensis*).

Range

Historical
Golden orb is endemic to Central Texas with its historic range including the Guadalupe-San Antonio River basin and Nueces-Frio River basin (Howells 2002) (Fig. 1). Strecker (1931) also included four sites in the Central Brazos River drainage; however, these almost certainly represent misidentified Smooth Pimpleback (*Q. houstonensis*) (Howells 2002). Numerous unionid surveys throughout the Brazos River system from the 1970s through 2009 have failed to find any Golden Orb specimens in this drainage basin (R.G. Howells, unpublished database), including studies that documented even long-dead and subfossil shells and valves (see Howells annual Management Data Series reports 1994-2006 produced by Texas Parks and Wildlife Department, TPWD). Studies of archaeological specimens from the Brazos River drainage also failed to produce any Golden Orb specimens (e.g., Howells et al. 2003). Additionally, reports in Howells et al. (1996) of Golden Orb from three locations in the upper Colorado River drainage have been found to be referable to misidentified Texas Pimpleback (*Q. petrina*) specimens. Here too, no confirmed Golden Orb specimens appear to have been present in the Colorado River drainage. It should be noted that until quite recently, pimpleback species in Central Texas (Golden Orb, Smooth Pimpleback, and Texas Pimpleback) were not known to be abundant and the full range of morphological variation and geographic distribution was imperfectly known. As a result, even many authorities misidentified some specimens creating confusion with both identification and distribution in older literature. Biochemical genetic studies and expanded knowledge of morphology and distribution have significantly improved understanding of all three pimpleback species in recent years.

Current

Presently known populations of Golden Orb have been restricted to only nine locations, several of which have only been recently located. Among these, moderate-size populations may survive at six sites, one appears to contain only a small number of individuals, one recently produced only a single specimen, and the remaining population may have been eliminated in recent years. Other areas with reported collection records have been examined by TPWD since 1992, but no additional populations were found. Those confirmed with living or recently dead specimens since 2004 (Figure 2) include:

Kerr County - Guadalupe River, Kerrville: This was an extremely small population that has been impacted by construction work and dewatering and it may no longer be extant.
Gonzales County – San Marcos River: presumed still present
Gonzales County – Guadalupe River, downstream of Lake Gonzales: presumed still present
Gonzales County – Guadalupe River, downstream of Lake Wood: presumed still present
Victoria County – Guadalupe River, near Victoria: presumed still present
Goliad County – San Antonio River, Goliad and upstream of Goliad: presumed still present
Goliad County – San Antonio River, south-southwest of Victoria: based on only a single specimen found in September 2009
Live Oak and San Patrico counties – Lake Corpus Christi: presumed still present

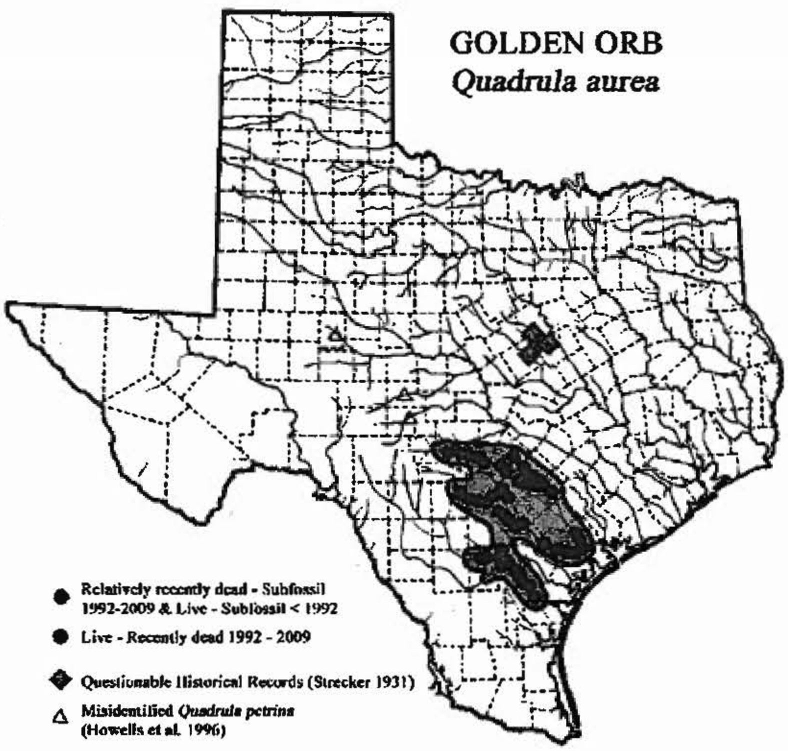


Figure 1. Presumptive historic range of Golden Orb (*Quadrula aurea*) shown in blue in Central Texas.

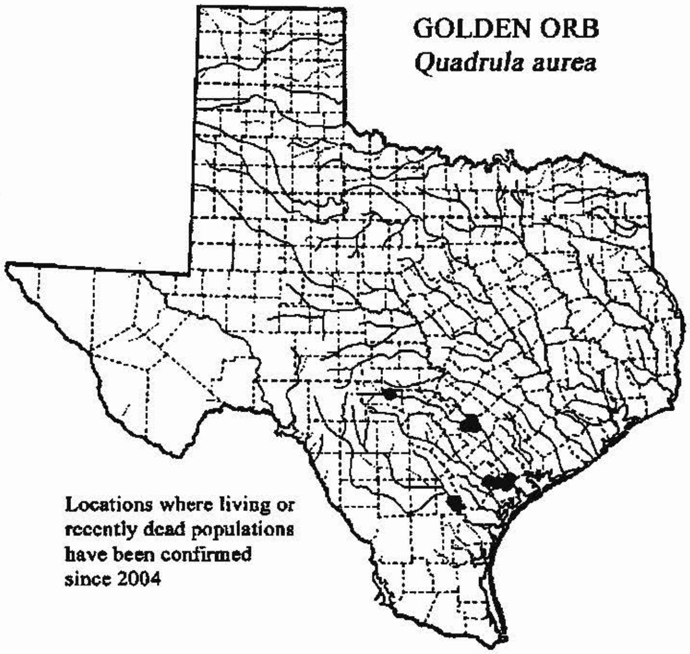


Figure 2. Populations of Golden Orb (*Quadrula aurea*) confirmed since 2004.

Population levels

Historically, Golden Orb remained rare to uncommon throughout its range and early collections generally included limited numbers. From the 1960s through the 1990s, malacologists working in Central Texas (e.g., H.D. Murray, R.W. Neck, C.M. Mather, J.A.M. Bergmann, R.G. Howells) continued to find few specimens and fewer population locations (Howells 2004, 2009). In the 1990s, noteworthy numbers were found in the Guadalupe River downstream of Lake Wood and in Lake Corpus Christi, but the species continued to appear rather rare (see summaries in Howells et al. 1997; Howells 2004, 2009). However, in 2006, 2007, and 2008, Karatayev and Burlakova (2007) and Burlakova and Karatayev (2008) reported finding additional specimens in the lower San Marcos River, Guadalupe River below Lake Wood, and at two new sites in the San Antonio River in Goliad County. In 2009, N.A. Johnson (University of Florida, pers. comm.) also found another population in the Guadalupe River near Victoria and a single individual in the lower San Antonio River. It is interesting that despite numerous survey efforts in previous decades by knowledgeable individuals significant new discoveries occurred in recent years. Some of these new locations had not been previously examined. However, 2007 was an extremely wet year. One upriver site in the Guadalupe drainage recorded 129 cm of rainfall in 2007. Then, subsequent years were very dry. The same upriver site had only 30 cm in 2008 and 31 cm from January through August in 2009 (R.G. Howells, unpublished data). It is possible very high-water conditions displaced Golden Orb specimens from scattered established sites and concentrated numbers of them in depositional areas in 2007. These, then, were more easily located in 2008 and early 2009 when river levels were very low. If so, densities reported may be artificially inflated and whether these "populations" continue to endure over a long period of time remains to be determined.

Kerr County - Guadalupe River, Kerrville:
No living Golden Orb had been found in this area in recent surveys until February 1997 when three specimens (some very recently dead) were found following high waters (Howells 1998). In June 1998, the City of Kerrville lowered the level of the Guadalupe River to simplify construction of a foot bridge in a local park; at that time a single very-recently dead specimen was recovered (Howells 1999; 2006). Because the river drainage in 1998 was so extensive, lasted an extended period of time, and no mussel trails indicating survivors had crawled to areas that had not dewatered were found, it appeared likely that this small population may have been eliminated. However, in July 2005, A.Y. Karatayev and L.E. Burlakova examined this area again for TPWD and found two additional living individuals that had survived (Howells 2006). No living specimens have been documented in this stretch of the Guadalupe River since July 2005 and building and bridge-construction projects in this area in subsequent years, including some that are ongoing at present (March 2010), cast doubts on the survival of Golden Orb at this site.

Gonzales County – San Marcos River:
This population appears to be rather small and is limited by restricted available habitat (R.G. Howells, unpublished data). Burlakova and Karatayev (2008) described this population as "large" and "very abundant", but their estimate appears to be based on a small number of specimens.

Gonzales County – Guadalupe River, downstream of Lake Gonzales:
This stretch of river appears to have been last studied in 2006 when only three living Golden Orb were discovered between Lake Gonzales and Lake Wood (Howells 2006). This population may or may not be as large as that found downstream below Lake Wood, but this area is also more difficult to access and survey.

Gonzales County – Guadalupe River, downstream of Lake Wood:
This area was first sampled in 1993, but with more-detailed efforts in 1996, 2002, and 2006 (summaries in Howells 2006). Living Golden Orb specimens were located in each of the last three surveys. Burlakova and Karatayev (2008) reported finding 91 living Golden Orb here in 2006 and another 33 living specimens in a subsequent survey (date unstated, presumably in 2008); they provided density estimates for this location and considered the Guadalupe River population to be "large".

Victoria County – Guadalupe River, near Victoria:
Over 100 living Golden Orb were documented here in September 2009 by N.A. Johnson (University of Florida, pers. comm.). No population size estimates were generated.

Goliad County – San Antonio River, Goliad and upstream of Goliad:
Burlakova and Karatayev (2008) reported living Golden Orb at both these locations and indicate 285 living specimens were found in 2008 for both sites combined.

Goliad County – San Antonio River, south-southwest of Victoria:
A single living specimen was found here in September 2009 (N.A. Johnson, University of Florida, pers. comm.), but the location was reportedly particularly difficult to sample.

Live Oak and San Patrico counties – Lake Corpus Christi:
A moderately large Golden Orb population was present here in the early 1990s, but in July 1996, the reservoir was largely drained to provide water to reduce salinity levels in coastal bays and large numbers of mussels were stranded (Howells 2006). When examined in 2005, no living Golden Orb specimens were found, but additional living specimens were located when reexamined in 2006 (Howells 2006). The Lake Corpus Christ Golden Orb population was clearly reduced in 1996 and its current level remains uncertain, but the species is presumably still present.

It should be noted that Karatayev and Burlakova (2007, 2008) and Burlakova and Karatayev (2008) report both catch-per-unit-area (density; N/m^2) and catch-per-unit-effort (CPUE; *N*/hour) as density. Further, they indicated that timing of CPUE calculations was not initiated until the first living specimen was found. This technique could produce CPUE values higher than those of other researchers that began counting effort at the initiation of sampling rather than some time later when a living specimen is located. This technique methodology could account for differences in findings between those of Karatayev and Burlakova and data from other researchers.

CONSERVATION MEASURES

When Texas Parks and Wildlife Department (TPWD) created its first freshwater mussel harvest regulations in 1992 and 1993, minimum size limits were established and a series of no-harvest sanctuaries were designated. At that time, minimum harvest sizes focused on commercial shell species of unionids, but the designation of a minimum 63.5 mm sh (2.5 inches sh) in shell height was also designated for "all other species" (including Golden Orb). This minimum harvest size applied both to living specimens and dead shells and valves and it remains in place today. The largest Golden Orb specimen apparently documented (82 mm sl) would have been greater than minimum legal size, but very few Golden Orb ever grow large enough to be legally taken (except under permit from TPWD) and all are too compressed to be of interest to most musselers.

No locations specifically supporting living Golden Orb populations were known when TPWD no-harvest sanctuaries were first established. However, when living populations were confirmed, efforts were made to add these sites to the list of protective sanctuaries (Howells 2009). In addition to TPWD regulations, Howells et al. (1997) provided a list of the designated TPWD no-harvest mussel sanctuaries. Ultimately in 2006, no-harvest sanctuaries were redefined and were formally passed by the TPW Commission in July 2007 (Texas Parks and Wildlife Department Proclamation 57.156-57.158; Howells 2009). Present or previously observed Golden Orb populations at three locations are now in no-harvest sanctuaries including:

Kerr County - Guadalupe River, Kerrville,
Gonzales County – San Marcos River,

Gonzales County – Guadalupe River, downstream of Lake Wood:

Populations not currently in sanctuaries and reasons for omission include:

Gonzales County – Guadalupe River, downstream of Lake Gonzales:
Population is apparently rather small, but should now be included.
Victoria County – Guadalupe River, near Victoria:
Only discovered in 2009 after the current regulation was passed; should be added.
Goliad County – San Antonio River, Goliad and upstream of Goliad:
Only discovered in 2008 after the regulation was passed; should be added.
Goliad County – San Antonio River, south-southwest of Victoria:
Based on only one animal in 2009.
Live Oak and San Patrico counties – Lake Corpus Christi:
Other legal mussel harvest occurs in this reservoir; this location could be designated a sanctuary if sufficient numbers of Golden Orb are demonstrated to persist. Additionally, consideration would need to be given to the existing mussel fishery and possible impact on water management practices in this reservoir.

It should be noted that TPWD no-harvest sanctuaries only legally preclude harvest of mussels from those designated waters and their tributaries. Mussel sanctuaries do not prohibit other area activities that could potentially have negative impacts on local unionids however.

In December 2009, TPWD moved to list Golden Orb as a legally threatened species.

LISTING FACTORS

Habitat or Range (Destruction, Modification, Curtailment)

Throughout much of Texas, historic land utilization resulted in modification and elimination of some aquatic habitat critical to Golden Orb and other unionids. Extensive overgrazing beginning in the mid-1800s resulted in significant loss of vegetative cover and soils, with subsequent increases in runoff causing scouring of many streams and rivers (Howells 1994). Scouring impacts on Texas waters have been further exacerbated by changes in rainfall patterns to fewer light and moderate showers and longer periods of drought punctuated by heavy, damaging floods (http://www.epa.gov/climatechange/science/recentpsc.html; Howells and Power 2004). Additionally, decade-average rainfall has increased over the past century with more rain falling in the early 1990s than fell in 1900-1910 (Howells 1995). Collectively, overgrazing, reduction in vegetative cover and soils, increasing numbers of scouring floods, and general increases in amount of precipitation have combined to dramatically reduce acceptable mussel habitat in many Texas waters. Anthropogenic developments (e.g., impervious surfaces, water flow manipulations) have magnified these impacts.

Central Texas in particular experienced a major drought in the late 1970s followed by several record floods between 1978 and 1981 (Howells et al. 1997; Howells and Power 2004). Some Central Texas mussel population sites that held assemblages of living unionids in the 1970s (including Golden Orb) no longer supported living mussels when surveyed in the 1980s and 1990s (Howells et al. 1997). These events helped reduce the abundance and distribution Golden orb and other unionids.

In addition to past and more-recent negative impacts (that continue), other broad-ranging and site-specific threats exist as well. By population site, these include:

Kerr County - Guadalupe River, Kerrville:
The small Golden Orb population in the Guadalupe River in Kerr County was thought to have been lost in 1998 when the city of Kerrville drained a section of the river to expedite construction of a park foot-bridge in the area (Howells 2009). However, in 2005, A.Y. Karatayev and L.E. Burlakova found two living individuals had survived (Howells 2006). Since this time, several building projects along the banks of the Guadalupe River and replacement of a bridge over the river have occurred between the upstream and downstream specimen collection locations. Despite several annual examinations of this stretch of river, no additional living Golden Orb specimens have been documented in the area since 2005 (Howells 2009). Building and bridge construction in the area are continuing at this time (March 2010).

Gonzales County – San Marcos River:
The San Marcos River Golden Orb population is primarily (but not completely) contained within a state park that offers some degree of protection from many potentially negative influences. However, this location has areas of unstable, collapsing sand banks. Deep-shifting sand substrates are unacceptable mussel habitat, as are substrates with constant deposition of material from above (R.G. Howells, unpublished data). Further, the steep banks of the lower San Marcos River do not reduce scouring damage during high waters by allow flood waters to spread out over adjacent flood plains. Additionally, the Luling oil field area upriver and associated activities (railroads, storage tanks, etc.) pose an additional potential environmental risk to the system.

Gonzales County – Guadalupe River, downstream of Lake Gonzales and
Gonzales County – Guadalupe River, downstream of Lake Wood:
Both stretches of river have wooded banks, with private homes and farmlands, with the typical associated potential threats (e.g., use of pesticides, nutrient input, etc.). However, no dramatically significant threats are particularly apparent. Within these two regions of the Guadalupe River, water level and flow manipulation by the local river authority are topics that need to be considered. Golden Orb has survived in these areas even during extreme low-water periods and rapid water releases. It may be reasonable to assume that if extraordinary extremes are avoided, the species should continue to endure.

Victoria County – Guadalupe River, near Victoria:
This location was not examined by the author and details of the river and surrounding environment have apparently not been published. Urban, residential, agricultural, and industrial activities in the area suggest a number of topics that deserve more-detailed consideration.

Goliad County – San Antonio River, Goliad and upstream of Goliad:

Karatayev and Burlakova (2007) and Burlakova and Karatayev (2008) did not elaborate on habitat status or threats at these sites; however, one site is within a state park. Neither site has been examined by the author and more-detailed study of both is warranted.

Goliad County – San Antonio River, south-southwest of Victoria:
This location was described as deeply incised into the ground, with steep banks (N.A. Johnson, University of Florida, pers. comm.), but no detailed habitat descriptions or threats are available. More information about this location is needed; however, given that only a single living specimen was documented here, other areas should be considered higher-priority sites if time and monies are limited.

Live Oak and San Patrico counties – Lake Corpus Christi:
This reservoir is surrounded by residential and ranch lands typical of Texas coastal plain areas. The reservoir shorelines include private homes, marinas, and a state park with associated environmental considerations. Probably the greatest concern for the Golden Orb population here is dramatic fluctuation in water level. Drought periods can result in reservoir levels falling significantly. Also, particularly during drought periods, waters from this impoundment may be needed for an array of human uses and to provide reduced salinities in receiving bays downstream. At such times, impact on Golden Orb may need to be weighed against human needs or potential fish kills and environmental damage in coastal bays.

Except for the Kerr County population (that may no longer exist) and that in Lake Corpus Christi, all of the other locations where living Golden Orb are known to occur are within about a 65 km radius and occur within the same drainage basin. The Kerr County site is about 150 km to the northwest of the San Marcos River site and Lake Corpus Christi is about 55 km southwest of the lower-most San Antonio River site (and the only location outside the Guadalupe-San Antonio drainage basin). Even if some Golden Orb populations are of moderate size, such close proximity within the same drainage area suggests a single catastrophic event (e.g., hurricane) could potentially badly damage or eliminate them.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Because of its small size and shell that has no commercial interest, there has been no noted overutilization problems impacting Golden Orb populations in Texas waters (Howells 1993; R.G. Howells, unpublished data). Golden Orb has not been harvested in Texas as a commercial mussel species or pearl mussel (Howells 1993). Although minimum harvest sizes under TPWD regulations prohibit take of any unionid species less than 2.5 inches in shell height, anglers collecting mussels for use as bait are less discriminatory than commercial shell musselers and might take any species at any size (R.G. Howells, unpublished data). However, TPWD regulations do not specifically restrict mussel harvest for use as bait and the extent of possible impact by anglers is undocumented.

To date, neither state nor federal resource managers have directed or monitored scientific activities and their impact on Golden Orb populations. It is possible multiple researches may survey, sample, and even remove specimens from the same area in relatively narrow windows of time. It remains undetermined if this activity has been problematic at known population sites. Volunteer training and sampling programs associated with freshwater mussel research similarly have limited time and place focus and may also potentially conflict with formal scientific research and management activities.

Public release of sensitive population location information has also been problematic regarding the security of some rare unionids in Texas. Some organizations have responded to this informational risk and modified their open releases of potentially harmful information. Unfortunately, even this report contains information that could be potentially misused and could be employed with negative impacts to surviving Golden Orb populations.

Disease or Predation

No specific diseases have been reported in the published literature or observed during recent studies of Golden Orb (R.G. Howells, unpublished data). Natural predators, like catfishes (Ictaluridae) and freshwater drum (*Aplodinotus grunniens*), no doubt consume some Golden Orb, but no confirmation has been documented to date. Neither disease nor predation appear to be problematic issues for this species.

Existing Regulatory Measures

Until December 2009, neither state nor federal regulations offered Golden Orb threatened or endangered species protections despite its obvious rarity and declining status. Several no-harvest mussel sanctuaries did include some populations and the minimum harvest size of 2.5 inches in shell height covered all but a small number of exceptionally large specimens. In December 2009, TPWD listed Golden Orb as a legally threatened species. Some populations remain in no-harvest sanctuaries, but others are present in non-sanctuary areas.

Other Natural or Manmade Factors

Another source of potentially extensive and adverse, yet difficult to quantify, impact involves the increasing human population within the range of Golden Orb and the resulting increased pumping of aquifer waters for direct and indirect human uses. Flows in many Texas springs have been reduced or eliminated, with subsequent reduction or elimination of spring feeds to streams (Brune 1975, 2002). Historically, water allocation plans in Texas have not focused on preservation of rare mussel resources.

NEEDED INFORMATION

Taxonomy and Genetics

Basic electrophoretic and DNA analyses have been performed on Golden Orb and confirmed its taxonomic status. Other biochemical genetic studies, such as DNA barcoding, could still contribute to helping to define this species. Probably many such activities can be conducted with mantle clips or other non-lethal sampling methods. Genetic studies to compare Golden Orb to

Smooth Pimpleback need to be completed. Additionally, no studies have genetically compared existing Golden Orb populations.

Distribution

Distribution of Golden Orb is relatively well reported. However, it is possible additional populations may exist in areas that have not yet been surveyed. For example, areas of the central San Antonio River, stretches of the Guadalupe River from the City of Gonzales downriver to the Goliad County line, and in the Nueces River up- and downstream of Lake Corpus Christi need increased survey efforts. Additionally, existing populations (most located in rather close proximity) could be easily lost within a short time window. Several sites have not been examined in a number of years. The known population sites should be periodically monitored to confirm their status and document potential threats. However, some level of regulatory control should be exercised to prevent excessive or disruptive monitoring activities. Several populations reported to be abundant in 2007 and 2008 need to be reexamined in future years to determine if those populations persist or not.

Reproductive Biology

Spawning and brooding periods are almost unknown and need to be much better defined. Glochidia remain undescribed and hosts are still unknown. No efforts directed at captive culture appear to have been attempted and no captive populations are being held as protection against catastrophic losses of natural populations.

Environmental Aspects of Biology

No reports of physicochemical parameters relative to Golden Orb were found during preparation of this report. Karatayev and Burlakova (2007) did in-stream flow studies in the San Antonio River, including areas that contained Golden Orb. However, their analyses combined mussel species and sites, and produced results that were not specific to Golden Orb and are not necessarily directly applicable to a single rare species or population site.

When species are very rare, difficult to observe or sample, and sensitive to disturbance, it can be extremely challenging to define critical aspects of species biology that relate to management of the species (e.g., in-stream flow limitations, minimum and maximum lethal temperatures and oxygen levels, critical spawning and incubation temperatures, etc.). Documenting these various elements for Golden Orb biology on those occasions when opportunity presents can be important, especially when multiple observations can be combined into meaningful summaries. Opportunities to record elements of species biology should not be neglected. It should also be noted that measurements of physicochemical parameters associated with Golden Orb population sites need to be documented over long periods of time (years) to be meaningful. Quick snapshot studies in areas often subjected to extensive flood and drought extremes may not provide a good over-all view of the full range of relevant flow rates, water chemistry, and related parameters. Indeed, short snapshot studies can sometimes be more misleading than instructive.

Threats to Continued Survival

Continued human population growth and development in Central Texas are certain to have increasing impacts on native unionid populations. Habitat loss, modification, or disturbance in conjunction with decreasing water supplies can be anticipated.

PERSONAL CONCLUSIONS AND RECOMMENDATIONS

Golden Orb is a unique unionid within the pimpleback complex that is endemic to Central Texas. Although several newly discovered populations have been located in recent years, all but one occur in the same drainage basin and exist within a relatively small geographic area. Though more numerous than historically thought, Golden Orb should still be legally listed as a threatened species under both state and federal regulations.

Many elements of species biology, including reproductive biology, remain unknown and should be the subject of scientific investigation before this unionid becomes too rare to allow intense study.

RELEVANT LITERATURE

Brune, G. 1975. Major and historical springs of Texas. Texas Water Development Board, Report 189, Austin.

Brune, G. 2002. Springs of Texas. Volume 1. Springs of Texas. Texas A&M Press, College Station.

Burlakova, L.E., and A.Y. Karatayev. 2008. Statewide assessment of unionid diversity in Texas. Performance Report. State Wildlife Grant report to Texas Parks and Wildlife Department, Austin.

Howells, R.G. 1993. Preliminary survey of freshwater mussel harvest in Texas. Texas Parks and Wildlife Department, Management Data Series 100, Austin.

Howells, R.G. 1994. Longhorn cattle and windmills linked to mussel declines. Info-Mussel Newsletter 2(5):5.

Howells, R.G. 1995. Changes in precipitation patterns in Texas. Info-Mussel Newsletter 3(4):6.

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

Howells, R.G. 1998. Distributional surveys of freshwater bivalves in Texas: progress report for 1997. Texas Parks and Wildlife Department, Management Data Series 147, Austin.

Howells, R.G. 1999. Distributional surveys of freshwater bivalves in Texas: progress report for 1998. Texas Parks and Wildlife Department, Management Data Series 161, Austin.

Howells, R.G. 2000. Reproductive seasonality of freshwater mussels (Unionidae) in Texas. Pages 35-48 *in* R.A. Tankersley and five coeditors. Freshwater mollusk symposia proceedings. Ohio Biological Survey Special Publication, Columbus.

Howells, R.G. 2002. Freshwater mussels (Unionidae) of the pimpleback complex (*Quadrula* spp.) in Texas. Texas Parks and Wildlife Department, Management Data Series 197, Austin.

Howells, R.G. 2003. Declining status of freshwater mussels of the Rio Grande. Pages 59-73 *in* G.P. Garrett and N.L. Allen, editors. Aquatic fauna of the northern Chihuahuan Desert. Texas Tech University Press, Lubbock. (Initially presented in 2001).

Howells, R.G. 2004. Texas freshwater mussels: species of concern. Texas Parks and Wildlife Department, Wildlife Diversity Conference, San Marcos, Texas. 18-20 August 2004.

Howells, R.G. 2006. Statewide freshwater mussel survey. State Wildlife Grant Final Report T-15-P, Texas Parks and Wildlife Department, Austin.

Howells, R.G. 2009. Biological opinion: conservation status of selected freshwater mussels in Texas. BioStudies, Kerrville, Texas.

Howells, R.G. 2010. Guide to Texas freshwater mussels. BioStudies, Kerrville, 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. Niamo. 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.

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

Howells, R.G., J. Neel-Hartman, and S.A. Wagner. 2003. Appendix G. Freshwater mussel shell from 41MM340. Pages 246-270 *in* R.B. Mahoney and six coauthors. Data recovery excavations at 41MM340: a Late Archaic site along Little River, Milam County, Texas. Center for Archaeological Research, The University of Texas at San Antonio. Archaeological Survey Report 340.

Howells, R.G., and P. Power. 2004. Freshwater mussels of the San Marcos-Blanco River basin: history and status. 107th Annual Meeting of the Texas Academy of Science, Kerrville, Texas, 6 March 2005

Karatayev, A.Y., and L.E. Burlakova. 2007. Distributional surveys and habitat utilization of freshwater mussels. Final report. Buffalo State College, Buffalo, New York. Prepared for the Texas Water Development Board, Austin.

Karatayev, A.Y., and L.E. Burlakova. 2007. Distributional surveys and habitat utilization of freshwater mussels. Final report. Buffalo State College, Buffalo, New York. Prepared for the Texas Water Development Board, Austin. [This report was issued in December 2007 and January 2008].

Simpson, C.T. 1900. Synopsis of the naiads, or pearly fresh-water mussels. Proceedings of the United States National Museum 22(1205):501-1044.

Simpson, C.T. 1914. A descriptive catalogue of the naiades, or pearly fresh-water mussels. Parts I-III. Bryant Walker, Detroit, Michigan.

Serb, J.M., J.W. Buhay, and C. Lydeard. 2003. Molecular systematics of the North American bivalve genus *Quadrula* (Unionidae: Ambleminae) based on mitochondrial ND1 sequences. Molecular Phylogenetics and Evolution 28(2003):1-11.

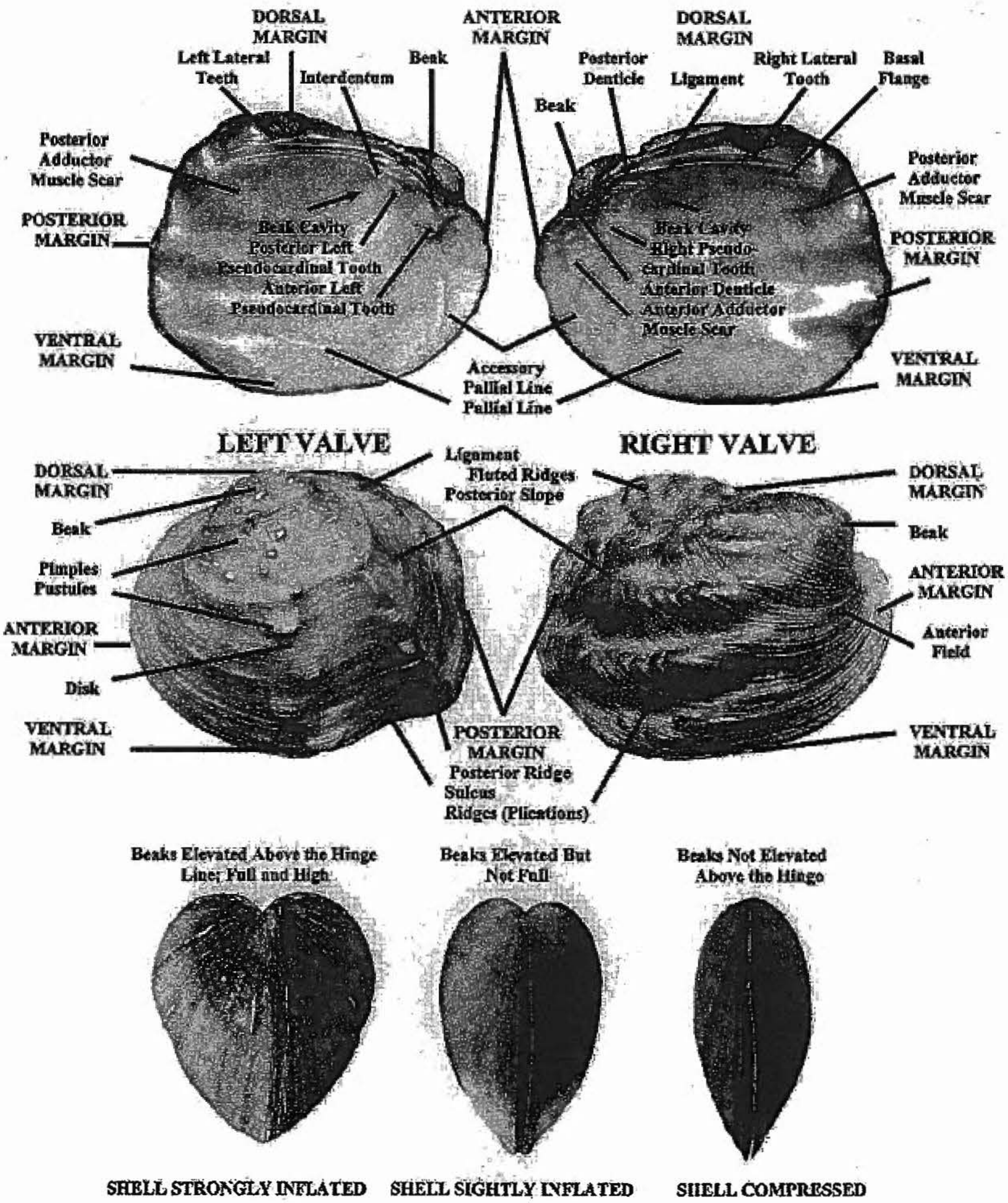
Strecker, J.K. 1931. The distribution of naiads or pearly fresh-water mussels of Texas. Baylor University Museum Bulletin 2, Waco.

Turgeon, D.D., and 13 co-editors. 1998. Common and scientific names of aquatic invertebrates of the United States and Canada: mollusks. American Fisheries Society Special Publication 26, Bethesda, Maryland.

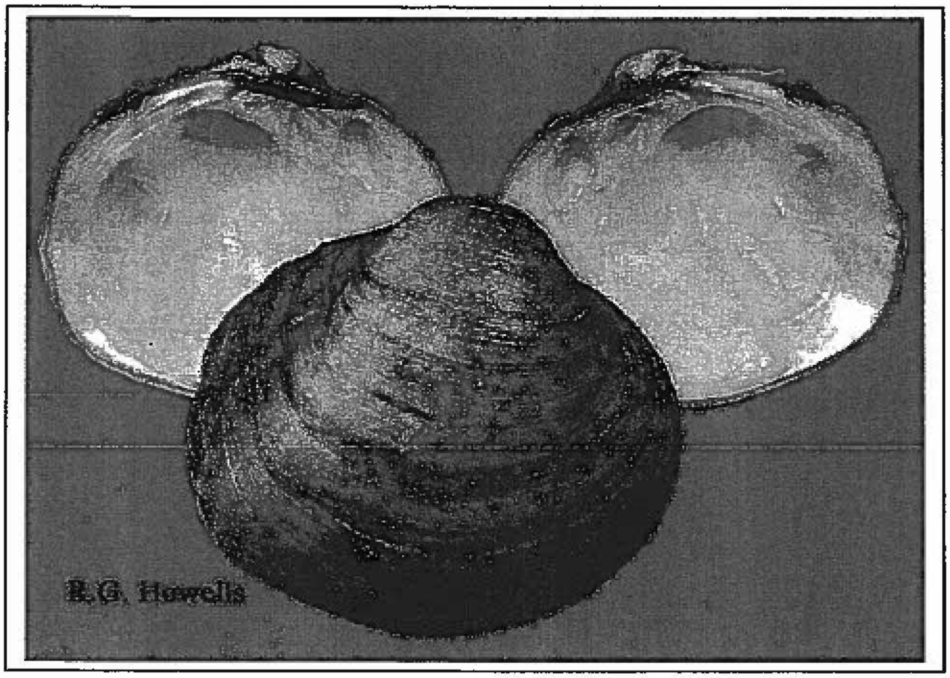
GLOSSARY OF SELECTED TERMS

Ala – a wing-like extension of the dorsal shell margin; usually posterior to the beak, sometimes anterior; "alate" means having a wing.
Beak – the umbo, the elevated (usually) part of the shell on the dorsal edge, anterior to the ligament in freshwater mussels, the oldest part of the shell.
Beak cavity – the inside of the beak within each valve, often forms a pocket or depression.
Beak sculpture – patterns of ridges, loops, and bumps that, like finger prints, can be unique to some species; often eroded and missing.
Chevron – V or arrowhead shaped, sometimes paired into Ws.
Compressed – flattened or pressed together.
Denticle – small (usually) tooth-like structures that may be present anterior and posterior to the right pseudocardinal tooth.
Concentric – circles, rings, or crescents with a common center or origin.
Dimorphic – having two distinct forms.
Ecophenotype – forms of a single species that are physically distinct in different environments.
Elliptical – ellipse shaped or an elongated oval.
Elongate – long or extended.
Endemic – found only in a particular area.
Exfoliated – eroded.
Extirpated – extinct in a particular area.
Fecundity – the number of eggs and/or larvae.
Fluted – grooves and ridges with a ruffle-like appearance.
Growth-rest lines – alternating dark and light concentric lines in a mussel shell indicating periods of slow and fast growth, respectively. In the far north, these may be annuli (formed each year), but in Texas growth may slow during summer droughts or continue over mild winters (therefore growth-rest bands cannot be counted as an indication of age).
Hinge – the area where the right and left valves (shell halves) articulate and are connected by an elastic ligament.
Hinge teeth – lateral and pseudocardinal teeth.
Inflated – swollen, expanded.
Interdentum – the area of the hinge between the lateral and pseudocardinal teeth; absent in some species.
Iridescent – a lustrous, pearly, or rainbow color appearance; only freshwater mussels and marine pearl oysters have iridescent nacre.
Lachrymose – drop-shaped pustules.
Lateral teeth – elongate structures along the hinge in many species located only posterior to the beak in freshwater mussels; absent in some species; these stabilize the hinge and are not true teeth at all.
Lunule – a cavity or depression, also called a sinus.
Nacre – the inner layer of the shell, mother-of-pearl.
Oval (ovate) – egg shaped.
Pallial line – a linear depression inside each valve interior to the shell margin, where the soft mantle tissues were attached.
Periostracum – the outer shell layer, shell epidermis.
Plications – folds, ridges, particularly multiple ridges.
Posterior ridge – a ridge on the posterior half of the shell running from the beak to the margin.
Posterior slope – shell area between the posterior ridge and the dorso-posterior margin.
Pseudocardinal teeth – tooth-like structures located below the beak area, usually two in the left valve and one in the right valve or none at all; may be compressed and leaf-like to heavy and molar-like.
Quadrate – square; often expressed as subquadrate (nearly quadrate).
Pustule – a bump or raised knob on the shell exterior.
Serrated – notched or grooved.
Shell margin – the exterior circumference edge of each valve (sometimes this term excludes the hinge line).
Solid – hard, thick, not soft and chalky.
Striated – with fine lines or grooves.
Truncate – shortened or squared off (sometimes obliquely).
Tubercle – projection from the shell, may be pointed, rounded, or knob-like.
Umbo – beak.
Valve – one half of a bivalve shell.
Wing – ala.

FRESHWATER MUSSEL SHELL FEATURES



SMOOTH PIMPLEBACK (*QUADRULA HOUSTONENSIS*): SUMMARY OF SELECTED BIOLOGICAL AND ECOLOGICAL DATA FOR TEXAS*



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April 2010

*** Not for Internet Distribution**

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Robert G. Howells is a fisheries scientist and aquatic ecologist. He has conducted research on freshwater mussels in Texas since 1992, in addition to his general fisheries studies and work with exotic species. Howells has served on the staff of the Cleveland Museum of Natural History; conducted environmental studies for 10 years for Ichthyological Associates, Inc., an environmental consulting firm; and spent 22 years with Texas Parks and Wildlife Department's Heart of the Hills Fisheries Science Center. He is the senior author of the book, Freshwater Mussels of Texas, and has written numerous scientific journal articles, symposia proceedings, technical reports, and informational guides. He is a member of the Freshwater Mollusk Conservation Society, American Malacological Society, and is currently working with others with the American Fisheries Society to update the distribution and conservation status of freshwater mussels of the United States, Canada, and Mexico. Howells retired from state employment in 2006, but has continued to study, write, and consult (BioStudies).

FUNDING SUPPORT

Funding support for this report was provided by Save Our Springs Alliance, P.O. Box 684881, Austin, Texas 78768; www.SOSAlliance.org. Individual funding was also provided by the Kirk Mitchell Environmental Law Fund and WildEarth Guardians. Copies of this report can be obtained from SOSA.

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ABOUT THIS REPORT

This report has been primarily drafted as a technical report, but introductory text, a glossary, and labeled shell feature figures have been included to assist non-malacologists with aspects of freshwater mussels. Within this report, shell length is abbreviated "sl" and other shell dimensions are typically written out. From the onset of freshwater mussel studies by Texas Parks and Wildlife Department (TPWD) in 1992, time-since-death estimates were designated for shells, valves, and fragments that were encountered in surveys (e.g., very recently dead = soft tissues still attached to shells and valves). These were defined in TPWD's annual Management Data Series (MDS) mussel survey reports and can be found in Howells (2003) that is available on the Internet. These shell condition designations provided possible status indications ranging from whether living specimens may still occur at a particular site to locations where mussels occurred in the area once, but appear to have been lost long ago. Mussel collection site locations on maps herein sometimes use a single dot to designate two or more collection sites that are in close proximity. Therefore, simply counting dots on these maps may not necessarily represent the total number of collection records or sites. Finally, recent data from several reports that are in preparation or in press may or may not have been included based on availability of these data, and some unconfirmed amateur volunteer records may also have been omitted.

ACKNOWLEDGMENTS

Special appreciation goes to Neil B. Ford, N.A. Johnson, C.M. Mather, J.A.M. Bergmann, W.H. McCullagh, and M.E. May for providing data used in preparation of this report. Thanks also to T.D. Hayes and A.J. Haugen for invaluable editorial input.

INTRODUCTION TO FRESHWATER MUSSELS

Freshwater Bivalves

Many types of bivalve mollusks are called clams or mussels. Neither term is really specific to one group. A number of bivalve groups live in fresh water in Texas. Freshwater mussels, also called pearly freshwater mussels or unionids (Family Unionidae), have over 50 species in Texas and about 300 in North America. A number of tiny fingernailclams (Sphaeriidae) are also present in many waters. Exotic Asian clam (Corbiculidae) invaded Texas in the 1950s and 60s, and exotic zebra mussel (Dreissenidae) was found in Texas in 2009. Several native estuarine clams and mussels can also be found in the lower reaches of coastal rivers.

Native Freshwater Mussels

Freshwater mussels do not attach to solid objects (as adults) like true marine mussels and zebra mussels, but dig into substrates of mud, sand, and gravel. They usually have distinct sexes. Females brood eggs and developing larvae (called glochidia) in marsupial pouches on their gills. Glochidia are parasites on fishes. Upon release from the female, glochidia have only hours to find the appropriate species of host fish that has no immunity to infection and attach to the correct location on that fish or die. After a few weeks or months, the transformed juveniles drop from the host to begin life in the substrate. Generally little harm comes to the host.

Role in the Ecosystem

Freshwater mussels are Mother-Nature's biofilters that feed by removing algae, bacteria, and organics from the water. They remove environmental contaminants and concentrate them in their tissues. Unionids also serve as food for fishes, birds, mammals, and other organisms. They mix water body substrates much as earthworms do in garden soils.

Historic Harvest

Native Americans harvested freshwater mussels for food, tools, ornament, and natural pearls. In the 1890s, shells of some species became important in button manufacturing (but to a limited extent in Texas). Some Texas mussels produce gem-quality pearls and they have been taken for this purpose since early Spanish times.

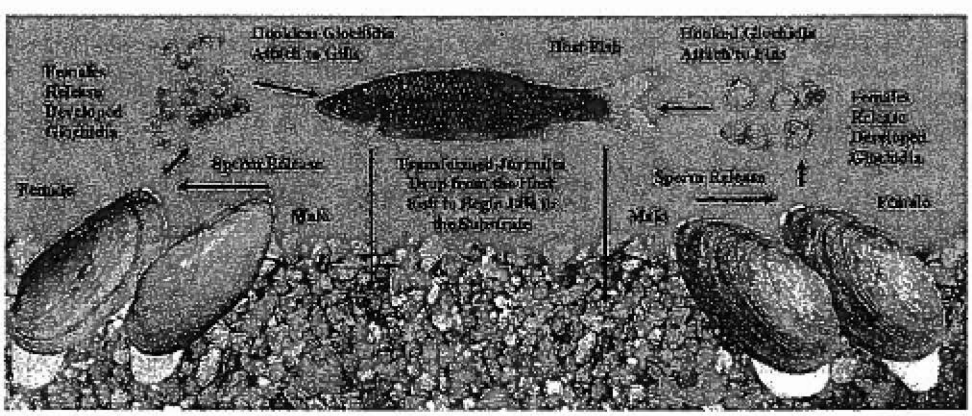
Recent Harvest

Limited harvest for pearls continues in Texas. In the late 1900s, some species were taken for their shells that were used to produce implant nuclei needed to create cultured pearls. They are occasionally captured for arts-and-crafts work, bait, and shell collectors. A license is required for any freshwater mussel harvest and some species are legally protected.

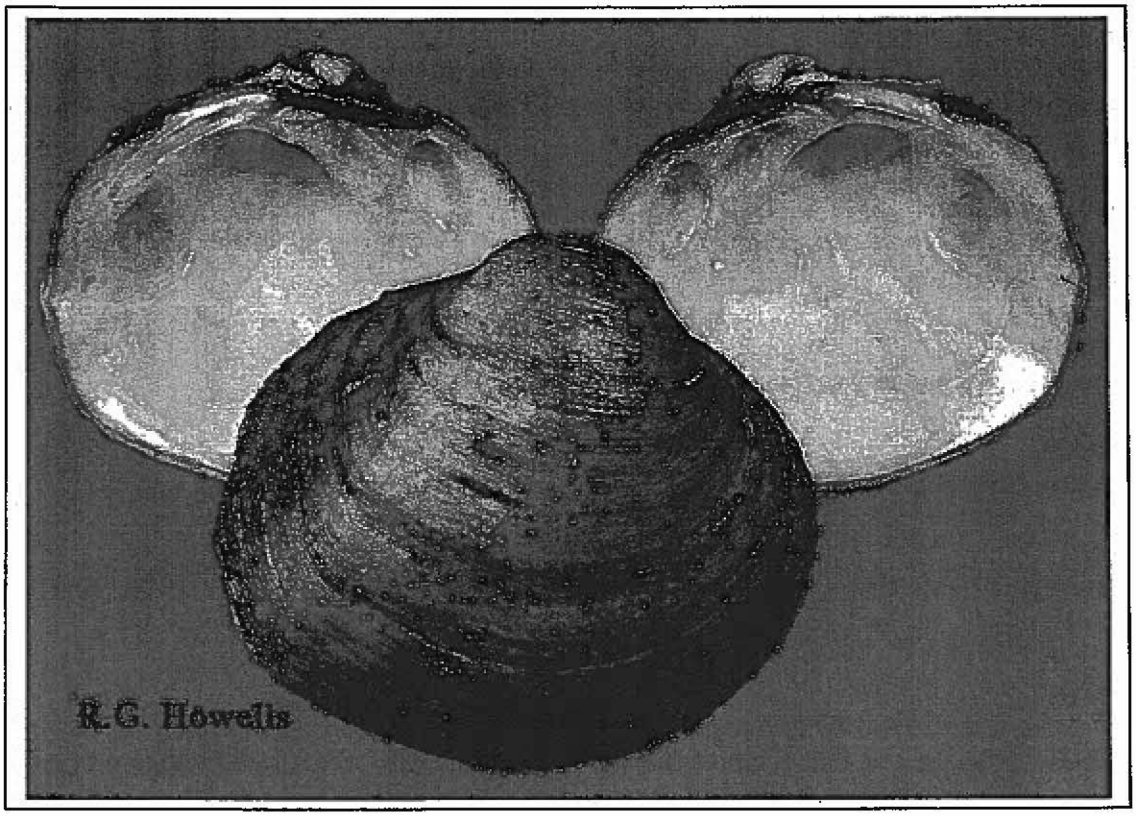
Conservation Status

Freshwater mussels are sensitive indicators of environmental quality. When there is any degradation in the ecosystem, these are usually the first organisms to decline or vanish. As a result, perhaps 80% of North American species are extinct, endangered, threatened, or will be soon. The State of Texas lists 15 species as legally threatened and another as endangered. Many of these are now under consideration for additional federal protection.

Freshwater mussel life cycle.



SMOOTH PIMPLEBACK
Quadrula houstonensis (Lea 1859)



DESCRIPTION

Smooth Pimpleback has been described by Simpson (1914), Howells et al. (1996), and Howells (2002, 2010). Shell length reaches at least 60 mm sl. Shell shape ranges from subquadrate to subrhomboidal and nearly round; it is moderately thick, solid, and inflated (significantly more inflated than Golden Orb *Quadrula aurea*). Beaks are full, high, elevated well above the hinge line and turned forward over a lunule; beak cavities are deep. The posterior ridge is broadly rounded; often with a minor second or third ridge. Pseudocardinal teeth (two left and one right) are heavy to massive; the posterior left tooth smaller and the anterior left tooth often squared and chisel-like; the right valve generally has anterior and posterior denticles. Lateral teeth (two left and one right) are usually relatively short, heavy, and straight or slightly curved; the right lateral tooth usually has a well-defined basal flange. Externally, Smooth Pimpleback lack disk sculpturing both on the central disk and dorsal to the posterior ridge. Although museum specimens presumed to be this species have been described as having pustules, these identifications preceded biochemical DNA analysis and may well refer to other pimpleback species. Externally, the shell epidermis ranges from tan to light brown, dark brown, and black, and without rays. Internally, the nacre is white and iridescent posteriorly. Soft tissues are white to off-white.

SPECIES BIOLOGY

Life History

Age and size at maturity
No reports of age or size at maturity were found during preparation of this report. Particularly small, presumptive juveniles were rare during TPWD mussel surveys conducted 1992-2006 (R.G. Howells, unpublished data).

Brooding season
Howells (2000a) reported examining 30 specimens from 1992 through 1997, but neither eggs nor glochidia were found.

Fecundity
No reports of fecundity were found during preparation of this report.

Glochidia
No descriptions of glochidia were found during preparation of this report.

Hosts
No reports of host fishes were found during preparation of this report. Given that other quadrulid species use catfishes (Ictaluridae), Smooth Pimpleback likely does so as well.

Behavior
No descriptions of behavior of Smooth Pimpleback were found during preparation of this report. A number of living specimens removed from the wild and placed in flow-through raceways at TPWD's Heart of the Hills Fisheries Science Center were observed to move very little during confinement.

Habitat requirements
Smooth Pimpleback has been collected in mixed mud, sand, and finer gravels in moderate to large streams, rivers, and some reservoirs. Karatayev and Burlakova (2007, 2008) examined habitat utilization by unionids in the Central and Lower Brazos River, and discussed unionid associations in general, but did not produce results specific to Smooth Pimpleback.

Habitat characteristics of generalized current population areas:

Central Colorado River – Highland Lakes:
Unlike other Central Texas pimpleback species, Texas Pimpleback (*Q. petrina*) and most Golden Orb (*Q. aurea*) populations, Smooth Pimpleback does occur in some reservoirs, but not in others. It has been taken alive in recent years in Lake LBJ and Lake Marble Falls, with repeated collections of shells in Inks Lake, but seems currently absent upstream in Lake Buchanan or downstream in lakes Travis, Austin, and Town (Lady Bird Johnson). Lake Travis is rocky and fluctuates dramatically (undesirable features for mussel habitat), Lake Austin receives cold water discharges from Lake Travis, and both Austin and Town lakes are in urban areas with associated urban impacts. Upstream, Lake Buchanan has mud, sand, and gravel substrates that are

acceptable to a number of other unionid species, but fluctuates dramatically at times. Inks Lake is subject to a 3-m drawdown every other winter and relatively few living unionids persist about this level; living Smooth Pimpleback may occur in deeper areas that are not regularly dewatered and have not been efficiently surveyed to date.

Lower Colorado River:
None of the lower Colorado River collection sites have been examined by the author, but this area generally has areas of mud, sand, and gravel, with banks of varying height and stability. Access and subsequent sampling effort has been limited in this area.

Central Brazos River and associated tributaries:
Much of the central and lower Brazos River has steep, unstable sandy banks and deep-shifting sand substrates (undesirable mussel habitat), but with scattered areas of mud and gravel bars and some rocky outcroppings. Access can be difficult and sampling challenging in many areas. Some tributary streams (e.g., Navasota River, Little Brazos River, Yegua Creek) have low to moderate height banks, but these are sometimes more heavily vegetated and generally stable. Substrate areas of mud, sand, and gravel that provide mussel habitat are present in certain areas. Water depths vary in these tributaries, but are typically less then 2 m and often less than 1 m.

Taxonomy and Genetics

Species validity
Species synonymy has been given by Simpson (1914) and Howells et al. (1996). Smooth Pimpleback was originally described by Lea in 1859 as *Unio houstonensis*, later placed in the genus *Margaron*, but ultimately moved to *Quadrula* by Simpson (1900). The American Fisheries Society (Turgeon et al. 1998) continues to maintain Smooth Pimpleback as a valid taxon.

Ecophenotypes
No specific ecophenotypes have been designated for Smooth Pimpleback.

Biochemical genetics
Electrophoretic comparison to other pimpleback species in Texas and the Gulf Coast was presented by Howells (2002). Serb et al. (2003) produced DNA analyses of many quadrulid species, but did not include Smooth Pimpleback. To date, this species appears not to have been otherwise subjected to more-advanced biochemical studies.

Range

Historical
Smooth Pimpleback was restricted to the central and lower reaches of the Brazos and Colorado rivers and their tributaries in Central Texas (Strecker 1931; Howells et al. 1996, 1997).

Smooth Pimpleback has been reported from other drainages in Texas, including the Trinity River (Strecker 1931). It has also been listed for areas outside Texas including southern Arkansas and the Verdigris River, Kansas (Simpson 1914). These reports appear to be misidentifications of apustulose forms of other pimpleback species that can sometimes closely resemble Smooth Pimpleback. This species was historically uncommon and therefore its full range of morphological variation and geographic distribution were imperfectly known, even among authorities in the field. This has resulted in numerous past and ongoing misidentifications.

Current

Until very recently, Smooth Pimpleback appeared to have been dramatically reduced in both abundance and distribution throughout its range. Recent field survey work by Karatayev and Burlakova (2007, 2008) and Randklev and Kennedy (2008) found it more common at some sites in the central Brazos River drainage than previously recognized. Locations where living and recently dead specimens have been documented since 2004 include:

Central Colorado River drainage – Highland Lakes:
Lake Marble Falls, Burnet County - The species was found alive in Lake Marble Falls in 1995 during a drawdown (Howells 1996a), but a subsequent survey in 1996 failed to find any additional living animals (Howells 1997). A living Smooth Pimpleback was confirmed in Lake Marble Falls in June 2005 (Howells 2006). This suggests a small population may still persist in this impoundment. It should be noted that a single living Smooth Pimpleback was also taken just upstream in Lake LBJ in 2001 (Howells 2002b), but no living specimens were found during subsequent surveys in 2005 (Howells 2006).

Lower Colorado River drainage:
Colorado River, Colorado County - Living specimens were found in the Colorado River near Garwood in September 2009 (N.A. Johnson, University of Florida, pers. comm.). Several other living individuals were also taken just upstream in 1999 (Howells 2000b).

Central Brazos River and its tributaries:
Lake Brazos, Waco, McLennan County – N.B. Ford (University of Texas at Tyler, pers. comm.) located living Smooth Pimpleback at this site in June 2005 during a low-water period.

Leon River, Hamilton County area – Living Smooth Pimpleback specimens were found at two locations in the Hamilton (city) area in 2006 (Howells 2006), with other living or recently dead found in this general area in earlier TPWD surveys.

Little River, Milam County – Karatayev and Burlakova (2007, 2008) reported finding living specimens in the lower reaches of this river in 2006.

Little Brazos River, Robertson County – Recently dead and living specimens were found in this area in the early 1992 during surveys by TPWD (Howells 1994), with relatively recently dead specimens found in 1993 (Howells 1995) and 1994 (Howells 1996b). A report by Karatayev and Burlakova (2007, 2008) of living specimens from the Little Brazos River in 2006 may have referred to this same area as well, but their exact collection site was not identified.

Navasota River, Brazos/Grimes counties – Living Smooth Pimpleback specimens were located by Randklev and Kennedy (2008) in the lower reaches of the Navasota River in 2008. Karatayev and Burlakova (2007, 2008) surveyed this same area of the Navasota River drainage in 2006 and found living Smooth Pimpleback in the same area of this river.

Yegua Creek, Burleson/Washington counties – Living Smooth Pimpleback specimens were located by Randklev and Kennedy (2008) in the lower reaches of Yegua Creek in 2008. Karatayev and Burlakova (2007, 2008) surveyed this creek drainage in 2006 and found living Smooth Pimpleback at the same location.

Brazos River, Milam/Robertson counties - Living Smooth Pimpleback specimens were located by Randklev and Kennedy (2008) at a site in the central Brazos River in 2008. Karatayev and Burlakova (2007, 2008) surveyed a number of sites in the Brazos River drainage in 2006 and 2007 and found living Smooth Pimpleback, but did not specify which of their sites supported populations and which did not.

Generally, Smooth Pimpleback appears to be maintaining small populations in (1) some of the Highland Lakes of the central Colorado River drainage, (2) the lower Colorado River in Colorado County, and (3) the central Leon River in Hamilton County, and may occur more numerously at some scattered sites in (4) the central Brazos basin between Little River in Milam County and the Navasota River (Grimes County), including the lower reaches of some tributaries including lower Little River, lower Little Brazos River, lower Navasota River, and lower Yegua Creek, with the current status of an additional population (5) in Lake Brazos in McLennan County uncertain at present. Areas of historic records throughout its historic range examined by TPWD and others since 1992 failed to produce other existing populations.

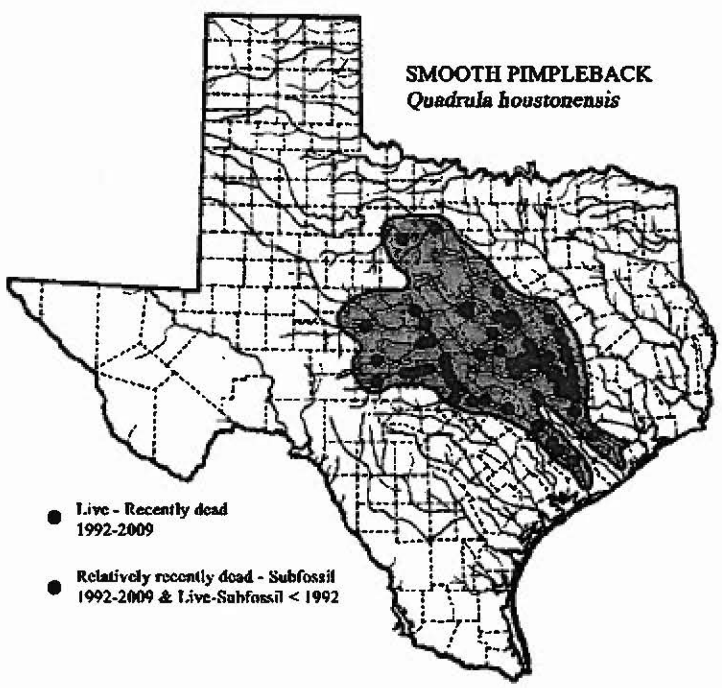


Figure 1. Presumptive historic range of Smooth Pimpleback (*Quadrula houstonensis*) shown in blue in Central Texas.

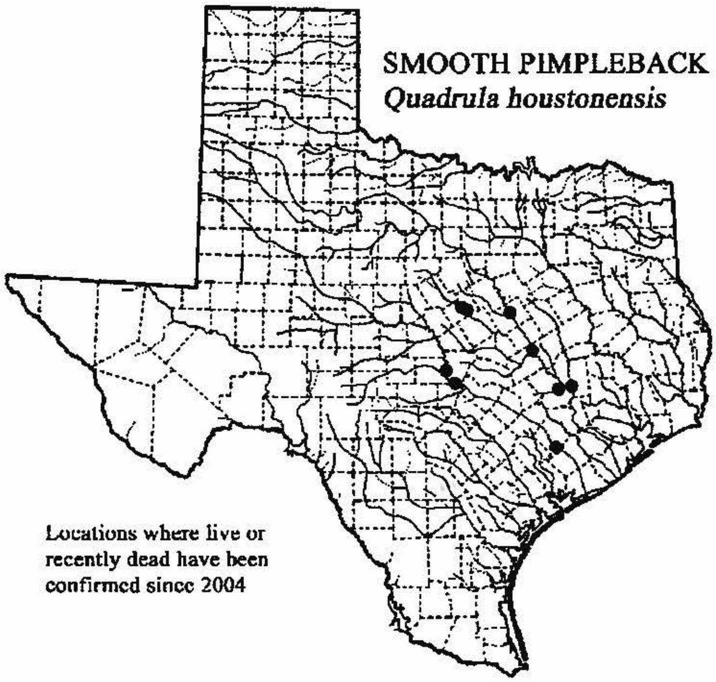


Figure 2. Populations of Smooth Pimpleback (*Quadrula houstonensis*) confirmed since 2004.

Population levels

Historically, Smooth Pimpleback remained rare to uncommon throughout its range and early collections generally included limited numbers. From the 1960s through the 1990s, malacologists working in Central Texas (e.g., H.D. Murray, R.W. Neck, C.M. Mather, J.A.M. Bergmann, R.G. Howells) continued to find few specimens and fewer population locations (Howells 2002a, 2006, 2009). In 2006, 2007, and 2008, Howells (2006), Karatayev and Burlakova (2007, 2008), and Randklev and Kennedy (2008) reported finding additional specimens in the Central Brazos River and its associated tributaries. In 2009, N.A. Johnson (University of Florida, pers. comm.) also found living specimens at another site in the lower Colorado River. It is interesting that despite numerous survey efforts in previous decades by knowledgeable individuals significant new discoveries occurred in recent years. Some of these new locations had not been previously examined. However, 2007 was an extremely wet year. One upriver site in the Guadalupe drainage recorded 129 cm of rainfall in 2007. Then, subsequent years were very dry. The same upriver site had only 30 cm in 2008 and 31 cm from January through August in 2009 (R.G. Howells, unpublished data). It is possible very high-water conditions displaced Smooth Pimpleback specimens from scattered established sites and concentrated numbers of them in depositional areas in 2007. These, then, were more easily located in late 2007, 2008 and early 2009 when river levels were very low. If so, densities reported may be artificially inflated and whether these "populations" continue to endure over a long period of time remains to be determined. Apparent status at recent individual locations includes:

Central Colorado River drainage – Highland Lakes:
Lake Marble Falls, Burnet County – Lake Marble Falls produced 13 living specimens in 1995 (Howells 1996a), none were found alive in 1996 (Howells 1997), and only a single living Smooth Pimpleback was confirmed in 2005 (Howells 2006). This suggests that the species may still persist in this impoundment, but the population is likely rather small. Upstream in Lake LBJ, a single living Smooth Pimpleback was taken in 2001 (Howells 2002b), but no living specimens were found during subsequent surveys in 2005 (Howells 2006). Again, the species may still be present in this impoundment, but the population here too is likely small.

Lower Colorado River drainage:
Colorado River, Colorado County – Three living specimens were found in the Colorado River near Garwood in September 2009 (N.A. Johnson, University of Florida, pers. comm.). Several other living individuals were also taken just upstream in 1999 (Howells 2000). Sampling effort here appears too limited to provide a good indication of population size.

Central Brazos River and its tributaries:
Lake Brazos, Waco, McLennan County – N.B. Ford (University of Texas at Tyler, pers. comm.) located living Smooth Pimpleback at this site in June 2005 during a low-water period. He indicated they were moderately common only at a single site at that time. Current status here is unreported.

Leon River, Hamilton County area – Living Smooth Pimpleback specimens were found at two locations in the Hamilton (city) area in 2006 (Howells 2006), with other living or recently dead found in this general area in earlier TPWD surveys. Sampling effort and areas examined were too limited in 2006 to provide a good assessment of population size.

Little River, Milam County – Karatayev and Burlakova (2007, 2008) reported finding living specimens in the lower reaches of this river in 2006. They reported a catch-per-unit-effort (CPUE) of living specimens of 0.40/hour.

Little Brazos River, Robertson County – Recently dead and living specimens were found in this area in the early 1992 during surveys by TPWD (Howells 1994), with relatively recently dead specimens found in 1993 (Howells 1995) and 1994 (Howells 1996b). A report by Karatayev and Burlakova (2007, 2008) of living specimens from the Little Brazos River in 2006 may have come from this same area as well, but their exact collection site was not identified; they reported a CPUE of living specimens of 0.67/hour.

Navasota River, Brazos/Grimes counties – Living Smooth Pimpleback specimens were located by Randklev and Kennedy (2008) in the lower reaches of the Navasota River in 2008. They documented 117 specimens found in a 14-m x 3-m transect (or $2.79/m^2$). Karatayev and Burlakova (2007, 2008) surveyed this same area of the Navasota River drainage in 2006 and also found living Smooth Pimpleback; they reported CPUE of living specimens of 1.76/hour.

Yegua Creek, Burleson/Washington counties – Living Smooth Pimpleback specimens were located by Randklev and Kennedy (2008) in the lower reaches of Yegua Creek in 2008. They documented 31 specimens in a 14-m x 3-m transect (or 0.74/m^2). Karatayev and Burlakova (2007, 2008) surveyed this creek drainage in 2006 and found living Smooth Pimpleback at the same location and reported CPUE of living specimens of 4.00/hour.

Brazos River, Milam/Robertson counties - Living Smooth Pimpleback specimens were located by Randklev and Kennedy (2008) at a site in the central Brazos River in 2008. They documented 12 specimens in a 1-hour timed search of 168 m of river bank and a 10-m x 10-m transect. Karatayev and Burlakova (2007, 2008) surveyed a number of sites (in these and other counties) in the Brazos River drainage in 2006 and 2007 and found living Smooth Pimpleback, but did not specify which of their sites supported populations; they reported a collective CPUE of living specimens of 2.20/hour.

Karatayev and Burlakova (2007, 2008) described Smooth Pimpleback as "very abundant" and "quite abundant" in the Brazos River drainage. They reported a CPUE of 6.5/hour (listed as average relative density); however, this number exceeds their CPUE values (listed as relative abundance) for the various water body sites examined within the Brazos River drainage. In general, Smooth Pimpleback appears somewhat more numerous within the Brazos River basin than earlier studies indicated, but concerns about apparent density increases due to depositional concentration by flood waters, ease of sampling during drought conditions, and an apparent die-off in this system suggest there are still valid concerns about the conservation status of this species here. Within the Colorado River, population numbers appear extremely low.

It should be note that Karatayev and Burlakova (2007, 2008) report both catch-per-unit-area (density; N/m^2) and catch-per-unit-effort (CPUE; N/hour) as density. Further, they indicated that timing of CPUE calculations was not initiated until the first living specimen was found. This technique could produce CPUE values higher than those of other researchers that began counting effort at the initiation of sampling rather than some time later when a living specimen is located. This technique methodology could account for differences in findings between those of Karatayev and Burlakova and data from other researchers.

CONSERVATION MEASURES

When Texas Parks and Wildlife Department (TPWD) created its first freshwater mussel harvest regulations in 1992 and 1993, minimum size limits were established and a series of no-harvest sanctuaries were designated. At that time, minimum harvest sizes focused on commercial shell species of unionids, including 69.9 mm (2.75 inches) in shell height for all pimpleback species. The largest Smooth Pimpleback specimen measured by the author to date was 60 mm shell height (R.G. Howells, unpublished data) and less than legally harvestable size (see measurements presented in Howells 2002a). Because Smooth Pimpleback shells are solid, thick, and white-nacred, they could be taken incidentally by shell musselers in Texas (R.G. Howells, unpublished data; Howells 1993); however, their sub-legal sizes discouraged such harvest. Now, listing by TPWD in December 2009 as a legally threatened species prohibits such harvest.

No locations specifically supporting living Smooth Pimpleback populations were known when TPWD no-harvest sanctuaries were first established. Howells et al. (1997) provided a list of the designated TPWD no-harvest mussel sanctuaries. Ultimately in 2006, no-harvest sanctuaries were redefined and were formally passed by the TPW Commission in July 2007 (Texas Parks and Wildlife Department Proclamation 57.156-57.158; Howells 2009). Unfortunately, none of the currently known Smooth Pimpleback populations are within specific no-harvest sanctuaries, but several sanctuary areas of the Colorado and Brazos drainage could potentially still include this species.

It should be noted that TPWD no-harvest sanctuaries only legally preclude harvest of mussels from those designated waters and their tributaries. Mussel sanctuaries do not prohibit other area activities that could potentially have negative impacts on local unionids however.

In December 2009, TPWD moved to list Smooth Pimpleback as a legally threatened species.

LISTING FACTORS

Habitat or Range (Destruction, Modification, Curtailment)

Throughout much of Texas, historic land utilization resulted in modification and elimination of some aquatic habitat critical to Smooth Pimpleback and other unionids. Extensive overgrazing beginning in the mid-1800s resulted in significant loss of vegetative cover and soils, with subsequent increases in runoff causing scouring of many streams and rivers (Howells 1994b). Scouring impacts on Texas waters have been further exacerbated by changes in rainfall patterns to fewer light and moderate showers and longer periods of drought punctuated by heavy, damaging floods (http://www.epa.gov/climatechange/science/recentpsc.html; Howells and Power 2004). Additionally, decade-average rainfall has increased over the past century with more rain falling in the early 1990s than fell in 1900-1910 (Howells 1995). Collectively, overgrazing, reduction in vegetative cover and soils, increasing numbers of scouring floods, and general increases in amount of precipitation have combined to dramatically reduce acceptable mussel habitat in many Texas waters. Anthropogenic developments (e.g., impervious surfaces, water flow manipulations) have magnified these impacts.

Central Texas in particular experienced a major drought in the late 1970s followed by several record floods between 1978 and 1981 (Howells et al. 1997; Howells and Power 2004). Some Central Texas mussel population sites that held assemblages of living unionids in the 1970s (including Smooth Pimpleback) no longer supported living mussels when surveyed in the 1980s and 1990s (Howells et al. 1997). These events helped reduce the abundance and distribution Smooth Pimpleback and other unionids.

In addition to past and more-recent negative impacts (that continue), other broad-ranging and site-specific threats exist as well. By population site, these include:

Central Colorado River drainage – Highland Lakes:
Lake Marble Falls, Burnet County – This reservoir, and Lake LBJ upstream are extensively surrounded by urban, residential, and recreational areas, including some older established sites and extensive, new and ongoing development at some locations. Impacts typical of urban, residential, and recreational sites are an ongoing risk. Perhaps one of the most threatening

negative impacts is the periodic reduction in reservoir level and associated dewatering that have not considered potential impact on area unionids. A proposal to release treated wastewater into the Highland Lakes has been rejected by the Texas Commission for Environmental Quality; however, several limited-volume releases have been grandfathered under existing regulations. If future proposals related to release of wastewaters into the Highland Lakes develop, impact on Smooth Pimpleback needs to be considered.

Lower Colorado River drainage:
Colorado River, Colorado County - This location has not been examined by the author. Generally, this stretch of the lower Colorado River includes surrounding agricultural lands, a few smaller urban areas, and some industrial sites as well as a number of highway and railroad crossing. No specific impact threats to Smooth Pimpleback have been evaluated at this time.

Central Brazos River and its tributaries:
Lake Brazos, Waco, McLennan County – This population was found during a low-water period (N.B. Ford, University of Texas at Tyler, pers. comm.) and no reports evaluating status or impact threats to Smooth Pimpleback appear to have been reported. Association with the Waco urban setting suggests an array of possible concerns.

Leon River, Hamilton County area – The two locations where living Smooth Pimpleback was found in 2006 (Howells 2006) are generally within ranch lands and agricultural areas. Stream banks are moderately high, but fairly stable. Ranching, farming, and bridge construction activities in this area have not historically focused on mussel impact concerns; however, Smooth Pimpleback has endured here.

Little Brazos River, Robertson County – The run of the Little Brazos River in Robertson County near Hearne, Texas, supported an abundant and diverse unionid assemblage, including Smooth Pimpleback, when surveyed by TPWD in 1992 (Howells 1994). However, when examined in August 1993, a massive unionid die-off was found to have occurred (Howells 1995). However, when examined again in 1994, 55-gallon drums and 5-gallon buckets were found to have been dumped into the river upstream in the Calvert area, but more unionids were found to have survived in the Hearne area than initially thought (Howells 1996b). Much of the Little Brazos River runs through agricultural areas, but generally maintains wooded streamside areas and banks. At Hearne, railroad yards and tracks and major trucking facilities are located adjacent to the river. Potential impacts from agricultural activities as well as transportation facilities present potential concerns.

Little River, Milam County – Karatayev and Burlakova (2007, 2008) reported finding living specimens in the lower reaches of this river in 2006, but did not discuss specific habitat threats. The cities of Georgetown, Belton, Killeen, and Temple, in addition to the Fort Hood military reservation, located upstream in this same drainage basin suggest sources of possible environmental impacts.

Navasota River, Brazos/Grimes counties – No details related to possible impacts to the Smooth Pimpleback population in this area were available during the preparation of this report.

Yegua Creek, Burleson/Washington counties – No details related to possible impacts to the Smooth Pimpleback population in this area were available during the preparation of this report.

Brazos River, Milam/Robertson counties - Randklev and Kennedy (2008) reported finding living Smooth Pimpleback specimens at this site in the central Brazos River in 2008, but noted recent mortality of a large portion of the population (one of three Smooth Pimpleback populations in the central Brazos River system was in obvious decline). Karatayev and Burlakova (2007, 2008) reported on a number of survey sites in the Brazos River, including the same location examined by Randklev and Kennedy (2008), but only reported living specimens, without comment on population status at this site or others.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Because of its small size and shell that has no particular commercial interest, there has been no noted overutilization problems impacting Smooth Pimpleback populations in Texas waters (Howells 1993; R.G. Howells, unpublished data). None of the Smooth Pimpleback specimens measured by the author to date have exceeded the minimum harvest size of 2.75 inches and no records of commercial shell harvest of this species were found (R.G. Howells, unpublished data). Occasional collection for use as live bait may occur, but has not been documented to date, and no record of excessive impact from scientific or educational harvest has been reported.

To date, neither state nor federal resource managers have directed or monitored scientific activities and their impact on Smooth Pimpleback populations. It is possible multiple researches may survey, sample, and even remove specimens from the same area in relatively narrow windows of time. It remains undetermined if this activity has been problematic at known population sites. Volunteer training and sampling programs associated with freshwater mussel research similarly have limited time and place focus and may also potentially conflict with formal scientific research and management activities.

Public release of sensitive population location information has also been problematic regarding the security of some rare unionids in Texas. Some organizations have responded to this informational risk and modified their open releases of potentially harmful information. Unfortunately, even this report contains information that could be potentially misused and could be employed with negative impacts to surviving Smooth Pimpleback populations.

Disease or Predation

No specific diseases have been reported in the published literature or observed during recent studies of Smooth Pimpleback (R.G. Howells, unpublished data). Natural predators, like catfishes (Ictaluridae) and freshwater drum (*Aplodinotus grunniens*), no doubt consume some Smooth Pimpleback, but no confirmation has been documented to date. Neither disease nor predation appears to be problematic issues for this species.

Existing Regulatory Measures

Until December 2009, neither state nor federal regulations offered Smooth Pimpleback threatened or endangered species protections despite its apparent rarity and declining status. Several no-harvest mussel sanctuaries might include this species, but otherwise, none of the exiting populations are confirmed to be present in designated mussel sanctuaries. The minimum harvest size of 2.75 inches in shell height precluded legal harvest from the earliest TPWD mussel regulations. In December 2009, TPWD has listed Smooth Pimpleback as a legally threatened species, blocking all legal harvest (except under special permits).

Other Natural or Manmade Factors

Another source of potentially extensive and adverse, yet difficult to quantify, impact involves the increasing human population within the range of Smooth Pimpleback and the resulting increased pumping of aquifer waters for direct and indirect human uses. Flows in many Texas springs have been reduced or eliminated, with subsequent reduction or elimination of spring feeds to streams (Brune 1975, 2002). In addition to reduction in stream flows due to natural droughts and high-water use demand, proposals to release treated sewage effluent into waters containing Smooth Pimpleback further confounds water quality issues for this species. Historically, water allocation plans in Texas have not focused on preservation of rare mussel resources.

NEEDED INFORMATION

Taxonomy and Genetics

Howells (2002a) presented electrophoretic comparison of Smooth Pimpleback to other pimpleback species in Texas and the Gulf Coast. However, no basic DNA analyses have been performed on Smooth Pimpleback to confirm its taxonomic status. Other biochemical genetic studies, such as DNA barcoding, could still contribute to helping in defining this species. Probably many such activities can be conducted with mantle clips or other non-lethal sampling methods. Additionally, no studies have genetically compared existing Smooth Pimpleback populations, some of which are isolated with no genetic exchange.

Distribution

Genetic studies have helped provide a reasonably good insight into Smooth Pimpleback distribution in Texas. However, the discovery of several noteworthy populations in recent years that had not been previously reported highlights the need to additional field survey work. Recently identified populations need repeated future study to determine if they are stable and enduring or only represent temporary clustering due to deposition by flood waters. Additionally, most reports of Smooth Pimpleback populations reflect surveys at highway crossings and other easy access points. Surveys to examine river reaches between access points are critically needed in both the Brazos and Colorado basins. Further, deeper water surveys are needed in the Highland Lakes of the central Colorado River drainage, and probably other reservoirs as well.

Many such reservoirs have periodic water-level fluctuations that could limit Smooth Pimpleback populations in shallow, fluctuation zones.

Reproductive Biology

Spawning and brooding seasons remain unknown, glochidia are undescribed, and host fishes have yet to be determined for Smooth Pimpleback. All are critical elements necessary for good species management efforts. If recent abundance estimates of Karatayev and Burlakova (2007, 2008) and corresponding population die-offs found by Randklev and Kennedy (2008) are correct, these aspects of species biology, including fecundity estimates, should be examined while specimens of Smooth Pimpleback are still available and sufficiently numerous to be studied without putting the species at risk.

Environmental Aspects of Biology

Physical habitat and critical physicochemical parameters associated with Smooth Pimpleback have been very poorly reported in the scientific literature and need to be better defined. These issues need to be examined repeatedly over an extended period of time rather than simply as snapshot views that can be more misleading than instructive. Further, habitat and physicochemical measurements need to be applied specifically to Smooth Pimpleback and not collectively to broad unionid assemblages of mixed species.

Threats to Continued Survival

Continued human population growth and development in Central Texas are certain to have increasing impacts on native unionid populations. Habitat loss, modification, or disturbance in conjunction with decreasing water supplies can be anticipated. Central Colorado River survivors appear to be confined to one or more reservoirs challenged by limited water availability and quality. Threats to those in the lower Colorado River remain largely undocumented. Threats to populations in the central Brazos River drainage are potentially many, but here too, are generally unstudied and unreported. The populations considered "abundant" by Karatayev and Burlakova (2007, 2008) are located within only about a 40-km radius and within the same drainage basin in the central Brazos River and several of its lower tributaries. Other known populations are either apparently quite small or are of uncertain size. A single catastrophic event (e.g., severe drought or hurricane) could negatively impact the greatest currently-recognized concentrations of Smooth Pimpleback.

PERSONAL CONCLUSIONS AND RECOMMENDATIONS

Smooth Pimpleback is a unique unionid within the pimpleback complex that is endemic to Central Texas. Although several newly discovered populations have been located in recent years, all that are reported to be abundant occur in the same drainage basin and exist within a relatively small geographic area. Though more numerous than historically thought, Smooth Pimpleback should still be legally listed as a threatened species under both state and federal regulations.

Many elements of species biology, including reproductive biology, remain unknown and should be the subject of scientific investigation before this unionid becomes too rare to allow intense study.

RELEVANT LITERATURE

Brune, G. 1975. Major and historical springs of Texas. Texas Water Development Board, Report 189, Austin.

Brune, G. 2002. Springs of Texas. Volume 1. Springs of Texas. Texas A&M Press, College Station.

Howells, R.G. 1993. Preliminary survey of freshwater mussel harvest in Texas. Texas Parks and Wildlife Department, Management Data Series 100, Austin.

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

Howells, R.G. 1994b. Longhorn cattle and windmills linked to mussel declines. Info-Mussel Newsletter 2(5):5.

Howells, R.G. 1995a. Distributional surveys of freshwater bivalves in Texas: progress report for 1993. Texas Parks and Wildlife Department, Management Data Series 119, Austin.

Howells, R.G. 1995b. Changes in precipitation patterns in Texas. Info-Mussel Newsletter 3(4):6.

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

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

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.

Howells, R.G. 2000a. Reproductive seasonality of freshwater mussels (Unionidae) in Texas. Pages 35-48 *in* R.A. Tankersley and five coeditors. Freshwater mollusk symposia proceedings. Ohio Biological Survey Special Publication, Columbus.

Howells, R.G. 2000b. Distributional surveys of freshwater bivalves in Texas: progress report for 1999. Texas Parks and Wildlife Department, Management Data Series 170, Austin.

Howells, R.G. 2002a. Freshwater mussels of the pimpleback-complex (*Quadrula* spp.) in Texas. Texas Parks and Wildlife Department, Management Data Series 197, Austin.

Howells, R.G. 2002b. Distributional surveys of freshwater bivalves in Texas: progress report for 2001. Texas Parks and Wildlife Department, Management Data Series 200, Austin.

Howells, R.G. 2003. Declining status of freshwater mussels of the Rio Grande. Pages 59-73 *in* G.P. Garrett and N.L. Allen, editors. Aquatic fauna of the northern Chihuahuan Desert. Texas Tech University Press, Lubbock. (Initially presented in 2001).

Howells, R.G. 2006. Statewide freshwater mussel survey. State Wildlife Grant Final Report T-15-P, Texas Parks and Wildlife Department, Austin.

Howells, R.G. 2009. Biological opinion: conservation status of selected freshwater mussels in Texas. BioStudies, Kerrville, Texas.

Howells, R.G. 2010. Guide to Texas freshwater mussels. BioStudies, Kerrville, 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. Niamo. 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.

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

Howells, R.G., and P. Power. 2004. Freshwater mussels of the San Marcos-Blanco River basin: history and status. 107th Annual Meeting of the Texas Academy of Science, Kerrville, Texas, 6 March 2005

Karatayev, A.Y., and L.E. Burlakova. 2007. Distributional surveys and habitat utilization of freshwater mussels. Final report. Buffalo State College, Buffalo, New York. Prepared for the Texas Water Development Board, Austin.

Karatayev, A.Y., and L.E. Burlakova. 2008. Distributional surveys and habitat utilization of freshwater mussels. Final report. Buffalo State College, Buffalo, New York. Prepared for the Texas Water Development Board, Austin. [This report was issued both in December 2007 and January 2008].

Lea, I. 1859. Descriptions of seven new uniones from South Carolina, Florida, Alabama and Texas. Proceedings of the Philadelphia Academy of Sciences 11:154-155.

Randklev, C.R., and J.H. Kennedy. 2008. Preliminary summary report on Brazos River mussel survey performed 15-18 July. University of North Texas, Denton.

Serb, J.M., J.W. Buhay, and C. Lydeard. 2003. Molecular systematics of the North American bivalve genus *Quadrula* (Unionidae: Ambleminae) based on mitochondrial ND1 sequences. Molecular Phylogenetics and Evolution 28(2003):1-11.

Simpson, C.T. 1900. Synopsis of the naiads, or pearly fresh-water mussels. Proceedings of the United States National Museum 22(1205):501-1044.

Simpson, C.T. 1914. A descriptive catalogue of the naiades, or pearly fresh-water mussels. Parts I-III. Bryant Walker, Detroit, Michigan.

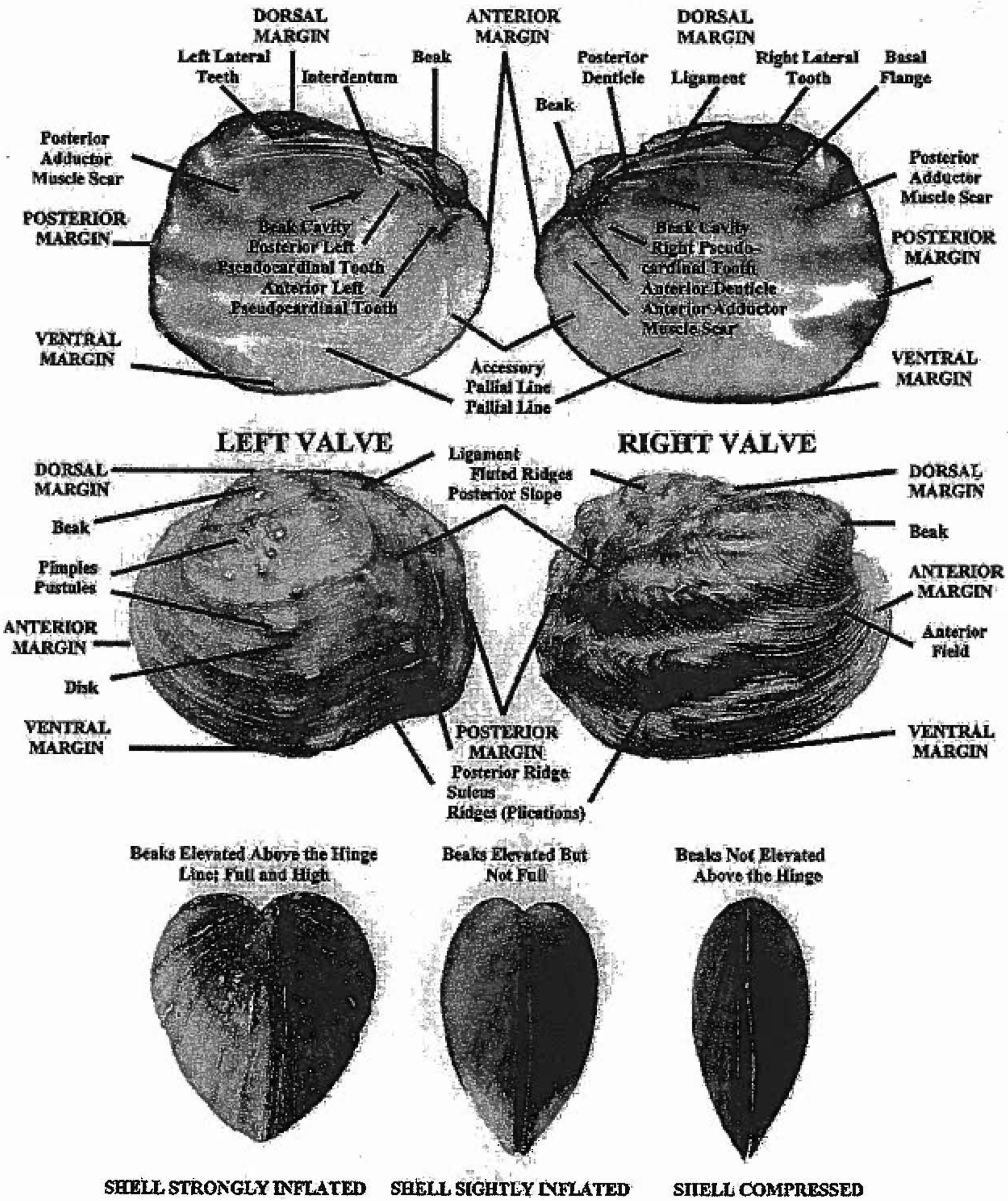
Strecker, J.K. 1931. The distribution of naiads or pearly fresh-water mussels of Texas. Baylor University Museum Bulletin 2, Waco.

Turgeon, D.D., and 13 co-editors. 1998. Common and scientific names of aquatic invertebrates of the United States and Canada: mollusks. American Fisheries Society Special Publication 26, Bethesda, Maryland.

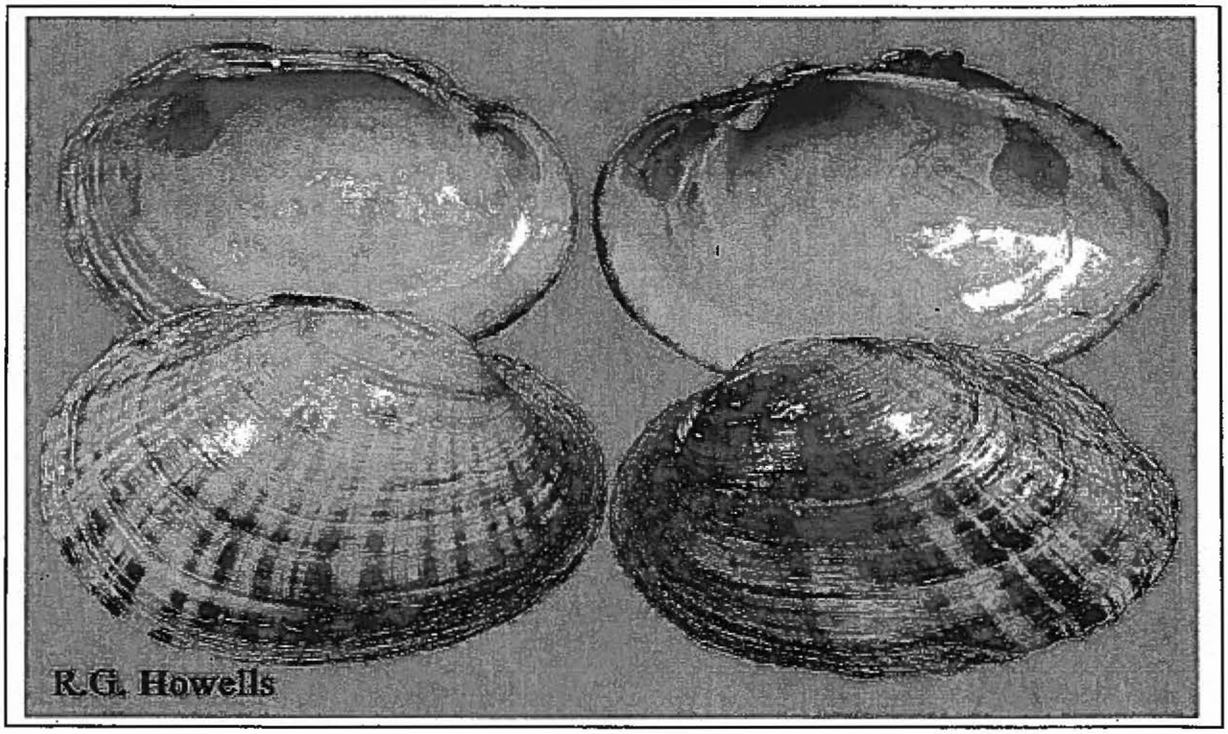
GLOSSARY OF SELECTED TERMS

Ala – a wing-like extension of the dorsal shell margin; usually posterior to the beak, sometimes anterior; "alate" means having a wing.
Beak – the umbo, the elevated (usually) part of the shell on the dorsal edge, anterior to the ligament in freshwater mussels, the oldest part of the shell.
Beak cavity – the inside of the beak within each valve, often forms a pocket or depression.
Beak sculpture – patterns of ridges, loops, and bumps that, like finger prints, can be unique to some species; often eroded and missing.
Chevron – V or arrowhead shaped, sometimes paired into Ws.
Compressed – flattened or pressed together.
Denticle – small (usually) tooth-like structures that may be present anterior and posterior to the right pseudocardinal tooth.
Concentric – circles, rings, or crescents with a common center or origin.
Dimorphic – having two distinct forms.
Ecophenotype – forms of a single species that are physically distinct in different environments.
Elliptical – ellipse shaped or an elongated oval.
Elongate – long or extended.
Endemic – found only in a particular area.
Exfoliated – eroded.
Extirpated – extinct in a particular area.
Fecundity – the number of eggs and/or larvae.
Fluted – grooves and ridges with a ruffle-like appearance.
Growth-rest lines – alternating dark and light concentric lines in a mussel shell indicating periods of slow and fast growth, respectively. In the far north, these may be annuli (formed each year), but in Texas growth may slow during summer droughts or continue over mild winters (therefore growth-rest bands cannot be counted as an indication of age).
Hinge – the area where the right and left valves (shell halves) articulate and are connected by an elastic ligament.
Hinge teeth – lateral and pseudocardinal teeth.
Inflated – swollen, expanded.
Interdentum – the area of the hinge between the lateral and pseudocardinal teeth; absent in some species.
Iridescent – a lustrous, pearly, or rainbow color appearance; only freshwater mussels and marine pearl oysters have iridescent nacre.
Lachrymose – drop-shaped pustules.
Lateral teeth – elongate structures along the hinge in many species located only posterior to the beak in freshwater mussels; absent in some species; these stabilize the hinge and are not true teeth at all.
Lunule – a cavity or depression, also called a sinus.
Nacre – the inner layer of the shell, mother-of-pearl.
Oval (ovate) – egg shaped.
Pallial line – a linear depression inside each valve interior to the shell margin, where the soft mantle tissues were attached.
Periostracum – the outer shell layer, shell epidermis.
Plications – folds, ridges, particularly multiple ridges.
Posterior ridge – a ridge on the posterior half of the shell running from the beak to the margin.
Posterior slope – shell area between the posterior ridge and the dorso-posterior margin.
Pseudocardinal teeth – tooth-like structures located below the beak area, usually two in the left valve and one in the right valve or none at all; may be compressed and leaf-like to heavy and molar-like.
Quadrate – square; often expressed as subquadrate (nearly quadrate).
Pustule – a bump or raised knob on the shell exterior.
Serrated – notched or grooved.
Shell margin – the exterior circumference edge of each valve (sometimes this term excludes the hinge line).
Solid – hard, thick, not soft and chalky.
Striated – with fine lines or grooves.
Truncate – shortened or squared off (sometimes obliquely).
Tubercle – projection from the shell, may be pointed, rounded, or knob-like.
Umbo – beak.
Valve – one half of a bivalve shell.
Wing – ala.

FRESHWATER MUSSEL SHELL FEATURES



TEXAS FATMUCKET
Lampsilis bracteata (Gould 1855)
SUMMARY OF SELECTED BIOLOGICAL AND ECOLOGICAL DATA FOR TEXAS*



Prepared by

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BioStudies
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April 2010

*** Not for Internet Distribution**

ABOUT THE AUTHOR

Robert G. Howells is a fisheries scientist and aquatic ecologist. He has conducted research on freshwater mussels in Texas since 1992, in addition to his general fisheries studies and work with exotic species. Howells has served on the staff of the Cleveland Museum of Natural History; conducted environmental studies for 10 years for Ichthyological Associates, Inc., an environmental consulting firm; and spent 22 years with Texas Parks and Wildlife Department's Heart of the Hills Fisheries Science Center. He is the senior author of the book, Freshwater Mussels of Texas, and has written numerous scientific journal articles, symposia proceedings, technical reports, and informational guides. He is a member of the Freshwater Mollusk Conservation Society, American Malacological Society, and is currently working with others with the American Fisheries Society to update the distribution and conservation status of freshwater mussels of the United States, Canada, and Mexico. Howells retired from state employment in 2006, but has continued to study, write, and consult (BioStudies).

FUNDING SUPPORT

Funding support for this report was provided by Save Our Springs Alliance, P.O. Box 684881, Austin, Texas 78768; www.SOSAlliance.org. Individual funding was also provided by the Kirk Mitchell Environmental Law Fund and WildEarth Guardians. Copies of this report can be obtained from SOSA.

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ABOUT THIS REPORT

This report has been primarily drafted as a technical report, but introductory text, a glossary, and labeled shell feature figures have been included to assist non-malacologists with aspects of freshwater mussels. Within this report, shell length is abbreviated "sl" and other shell dimensions are typically written out. From the onset of freshwater mussel studies by Texas Parks and Wildlife Department (TPWD) in 1992, time-since-death estimates were designated for shells, valves, and fragments that were encountered in surveys (e.g., very recently dead = soft tissues still attached to shells and valves). These were defined in TPWD's annual Management Data Series (MDS) mussel survey reports and can be found in Howells (2003) that is available on the Internet. These shell condition designations provided possible status indications ranging from whether living specimens may still occur at a particular site to locations where mussels occurred in the area once, but appear to have been lost long ago. Mussel collection site locations on maps herein sometimes use a single dot to designate two or more collection sites that are in close proximity. Therefore, simply counting dots on these maps may not necessarily represent the total number of collection records or sites. Finally, recent data from several reports that are in preparation or in press may or may not have been included based on availability of these data, and some unconfirmed amateur volunteer records may also have been omitted.

ACKNOWLEDGMENTS

Special appreciation goes to C.M. Mather, J.A.M. Bergmann, and W.H. McCullagh for providing data used in preparation of this report. Thanks also to T.D. Hayes and A.J. Haugen for invaluable editorial input.

INTRODUCTION TO FRESHWATER MUSSELS

Freshwater Bivalves

Many types of bivalve mollusks are called clams or mussels. Neither term is really specific to one group. A number of bivalve groups live in fresh water in Texas. Freshwater mussels, also called pearly freshwater mussels or unionids (Family Unionidae), have over 50 species in Texas and about 300 in North America. A number of tiny fingernailclams (Sphaeriidae) are also present in many waters. Exotic Asian clam (Corbiculidae) invaded Texas in the 1950s and 60s, and exotic zebra mussel (Dreissenidae) was found in Texas in 2009. Several native estuarine clams and mussels can also be found in the lower reaches of coastal rivers.

Native Freshwater Mussels

Freshwater mussels do not attach to solid objects (as adults) like true marine mussels and zebra mussels, but dig into substrates of mud, sand, and gravel. They usually have distinct sexes. Females brood eggs and developing larvae (called glochidia) in marsupial pouches on their gills. Glochidia are parasites on fishes. Upon release from the female, glochidia have only hours to find the appropriate species of host fish that has no immunity to infection and attach to the correct location on that fish or die. After a few weeks or months, the transformed juveniles drop from the host to begin life in the substrate. Generally little harm comes to the host.

Role in the Ecosystem

Freshwater mussels are Mother-Nature's biofilters that feed by removing algae, bacteria, and organics from the water. They remove environmental contaminants and concentrate them in their tissues. Unionids also serve as food for fishes, birds, mammals, and other organisms. They mix water body substrates much as earthworms do in garden soils.

Historic Harvest

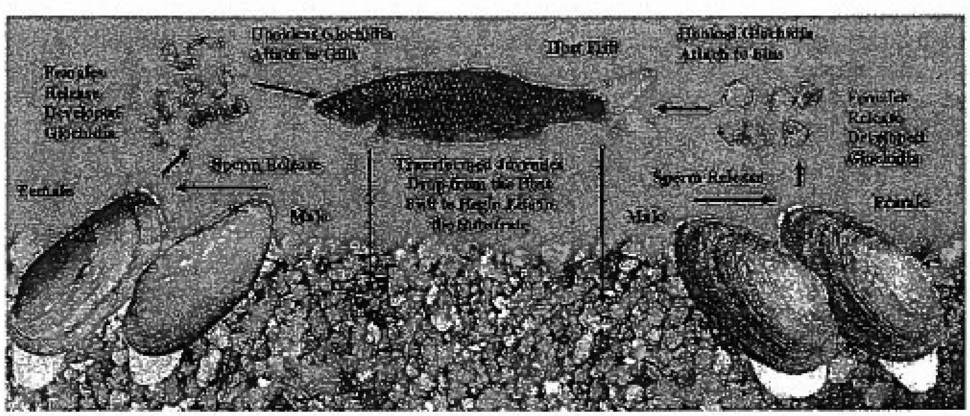
Native Americans harvested freshwater mussels for food, tools, ornament, and natural pearls. In the 1890s, shells of some species became important in button manufacturing (but to a limited extent in Texas). Some Texas mussels produce gem-quality pearls and they have been taken for this purpose since early Spanish times.

Recent Harvest

Limited harvest for pearls continues in Texas. In the late 1900s, some species were taken for their shells that were used to produce implant nuclei needed to create cultured pearls. They are occasionally captured for arts-and-crafts work, bait, and shell collectors. A license is required for any freshwater mussel harvest and some species are legally protected.

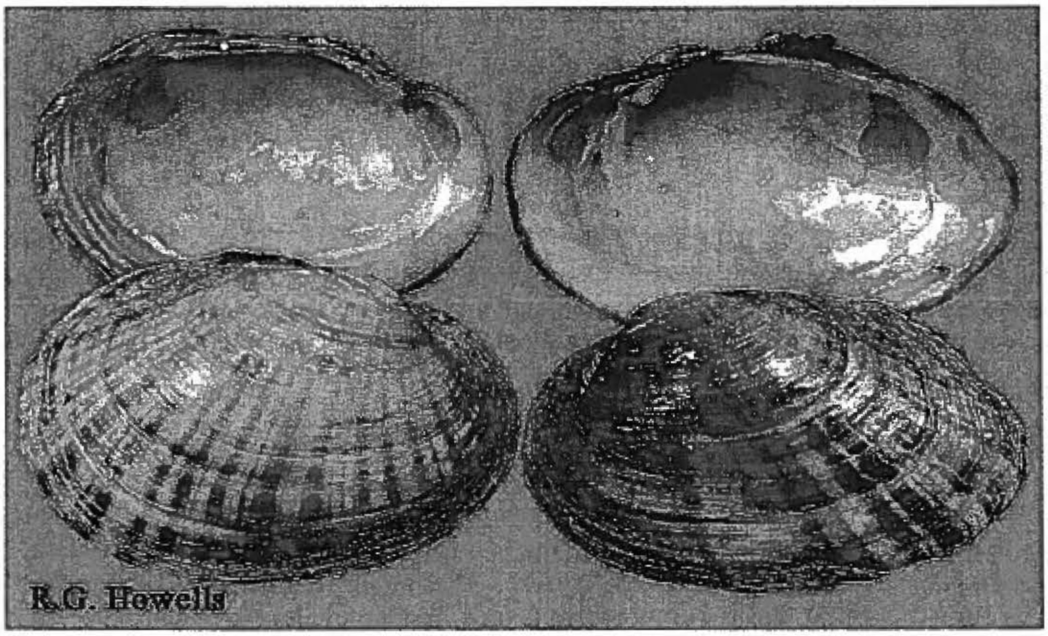
Conservation Status

Freshwater mussels are sensitive indicators of environmental quality. When there is any degradation in the ecosystem, these are usually the first organisms to decline or vanish. As a result, perhaps 80% of North American species are extinct, endangered, threatened, or will be soon. The State of Texas lists 15 species as legally threatened and another as endangered. Many of these are now under consideration for additional federal protection.



Freshwater mussel life cycle.

TEXAS FATMUCKET
Lampsilis bracteata (Gould 1855)



DESCRIPTION

Texas fatmucket has been described by Simpson (1914), Howells et al. (1996), and Howells (2010a). It reaches a maximum length of at least 100 mm sl. General shape is an elongate oval to elliptical or subrhomboidal. It is sexually dimorphic with males more elongate and round-pointed posteriorly; females more deep-bodied, inflated, and more broadly rounded or truncated posteriorly. Small juveniles may be rather thin shelled, but some large adults can be moderately thick. The posterior ridge is weak and ill-defined; the posterior slope is flattened or slightly concave. The beak is broad and raised above the hinge line, but is not highly elevated; the beak tip may be somewhat pointed. The disk is unsculptured, but may show slight growth-rest lines. Adductor muscle scars are relatively deeply impressed. Pseudocardinal teeth (two left, one right) are triangular, compressed, and sometimes rather delicate. Lateral teeth (two left, one right) are ca 26-40% sl, lamellar, and often rather thin. External coloration is tan to greenish-yellow with numerous irregular, wavy, broad and narrow dark brown rays, with broad rays widening noticeably as they approach the margin. Internal coloration is white, but sometimes shows a tint of yellow or salmon and is iridescent posteriorly. Soft tissues are tan to off white with gray to black edges on the mantle; gravid gills may be tan with dark gray to black on the outer third. Females in several populations possess mantle flaps that resemble minnows with a black and white eye spot and lateral line and filament-like fins. A population from Tom Green County in the Concho River drainage had a mantle flap that resembled a white surgical glove; however, this population appears to have been lost in recent years.

SPECIES BIOLOGY

Life History

Age and size at maturity
No studies of age, growth rate, or size at maturity have been published for Texas Fatmucket. Related Louisiana Fatmucket (*Lampsilis hydiana*) as small as 36.4 mm sl have been found brooding (Howells 2000); a similar size at maturity may be expected for Texas Fatmucket.

Brooding season
Females have been found with glochidia in marsupia from July through October; however, one gravid female that began to display in October continued for 10 months in a laboratory aquarium suggesting brooding may continue throughout the year (Howells 2000). Louisiana Fatmucket has been found brooding glochidia during most months in Texas waters (Howells 2000), further suggesting Texas fatmucket may do the same.

Fecundity
No fecundity estimates for Texas Fatmucket have been reported. Unfortunately, surviving numbers are so limited that it would be difficult to justify sacrificing existing females to generate such estimates. Related Louisiana Fatmucket has been reported with combined egg and glochidial count estimate range of 256,000-413,333 among five females 71-78 mm sl in Texas waters (Howells 1995); Texas Fatmucket may have similar levels of production.

Glochidia
Glochidia were described by Howells et al. (1996) as moderately large, subelliptical, spineless, 0.262-0.270 mm sh, 0.213-0.230 mm sl, 0.123-0.131 mm hinge length. Hoggarth (1994) also described Texas Fatmucket glochidia as 0.19 mm sl, 0.24 mm sh, and 0.11 mm along the hinge line; he also provided a SEM photograph of the glochidium.

Hosts
Glochidia transformed in 21 days at 24° C after attachment to gills of Bluegill (*Lepomis macrochirus*) and Green Sunfish (*L. cyanellus*) in laboratory studies; no attachment occurred on Blacktail Shiner (*Cyprinella venusta*) or Goldfish (*Carassius auratus*) (Howells 1997). Hosts (sunfishes) are common, widely-distributed species that occur in an array of habitat types and would not generally be expected to be a limiting factor in Texas Fatmucket reproduction.

Behavior
Gravid, displaying Texas Fatmucket females appeared less sensitive to disturbance under aquarium conditions than Louisiana Fatmucket females. Disturbed Texas Fatmucket females stopped displaying and withdrew their mantle flaps, but opened and continued displaying relatively soon after being agitated. Conversely, some Louisiana Fatmucket females would wait hours, or even days, before continuing to display after being disturbed (Howells 1994; R.G. Howells, unpublished data).

One female Texas Fatmucket from Gillespie County was found to have had its lure apparently bitten off by a predator. This individual nonetheless continued to present and attempt to wiggle the remaining stub. Of all the females examined by the author, this was the only individual found with such lure damage (R.G. Howells, unpublished data).

Habitat requirements

Among the few surviving Texas Fatmucket populations encountered since 1992 (when TPWD mussel studies began), each location had certain unique traits. Generally, Texas Fatmucket is restricted to moderate-size streams and smaller rivers in flowing waters. None have been found in ponds, lakes (no natural lakes occur within its range), or reservoirs. Populations typically occur in substrates of mud, sand, and gravel, or mixtures of these, often in association with other larger boulders and cobble in areas of moderate flow (Howells et al. 1996). Living specimens have been found in relatively shallow waters, rarely more the 1.5 m depths and usually less. Surviving populations appear to occur at sites where one or both banks are of relatively limited elevation, allowing flood waters to spread out over terrestrial lands and thereby reducing damage from scouring.

Runnels County: Areas frequented by Texas Fatmucket here included mud, sand, and gravel, with swept bedrock and cobble areas (R.G. Howells, unpublished data). Some individuals sought horizontal cracks in bedrock slabs and crawled into openings between layers, moving as far into the crack as their shell would allow (Howells et al. 1996). Presumably this behavior provides protection from scouring floods, desiccation during dewatering, and predation during low-water periods.

Tom Green County: This small stream, a tributary to a larger reservoir, was extremely rocky (bedrock and heavy cobble); unionids were restricted to limited areas of gravel and sand (R.G. Howells, unpublished data). Shells have been found above a small, low-rise dam in the lower reaches of this stream (presumably washed there from populations sites upstream), but no living Texas Fatmucket specimens have been recovered from the impoundment itself (only up- or downstream in flowing water).

Menard County: At this San Saba River site, unionids, including Texas Fatmucket, are present in sand and gravel areas in flowing waters among heavy cobble and macrophyte beds (R.G. Howells, unpublished data). Here, both mussels and rocks are heavily encrusted with calcium deposits (often confounding specimen identification). This is the only site where heavy macrophyte growths have been associated with Texas Fatmucket presence.

Gillespie County: Here one population in a small tributary of the Pedernales River in southern Gillespie County occurs in a short run of the stream between a small dam and the Pedernales River. The substrate is typically mud, sand, and gravel among larger boulders and bedrock ledges (R.G. Howells, unpublished data). Local residents have reported that during major droughts in the 1950s and 1970s, this stream continued to flow from spring water input even when the Pedernales River, itself, had become dry. A second population in western Gillespie County occurs in a small stream that feeds into the Llano River. Here living Texas Fatmucket specimens have been located in sand and gravel areas between heavy bedrock boulders. None appear to be present in areas of scoured bedrock or deep-shifting sands.

Kerr County: At this main channel Guadalupe River site, Texas Fatmucket specimens have been recovered in depositional areas below one dam following floods (though the actual habitation site has not been determined) and associated with steep banks among baldcypress root mats. Here some individuals were actually inserted directly into tree-root banks that were nearly vertical. This has not been observed at other sites (R.G. Howells, unpublished data).

Llano River: Burlakova (2010) reported finding Texas Fatmucket at a site on the Llano River, but did not reveal habitat details.

Taxonomy and Genetics

Species validity
Texas Fatmucket is a valid species with little or no question regarding its taxonomic status. However, the actual identities of specimens from several historic records have been debated.

This species was originally described as *Unio bracteatus* Gould 1855. Other terms applied have included *Margaron bracteatus* of Lea (1870) and *Lampsilis bracteatus* of Simpson (1900). Strecker (1931) also lists *U. rowellii* Singley, non Lea, of the Singley list.

Strecker (1931) noted possible confusion between this species and Louisiana Fatmucket (listed in his book as *L. luteolus* = *L. fasciata*). This confusion may be especially well pronounced among Louisiana Fatmucket populations in the Guadalupe-San Antonio and Nueces-Frio systems that are often less massive, more laterally compressed, and less vividly banded than others in eastern Texas and Louisiana waters, making them more similar to Texas Fatmucket. Louisiana Fatmuckets are typically more inflated, have heavier and thicker shells and fuller beaks that are less pointed terminally. They have dorsal muscle scars positioned along the dorsal roof of the beak cavity and dark rays, most of which barely widen between the beak and shell margin.

A record from the 1960s of H.D. Murray from Cibolo Creek, in the San Antonio River drainage, originally believed to be Rainbow (*Villosa iris*) was ultimately found to be a juvenile Texas Fatmucket (R.G. Howells, unpublished data).

Ecophenotypes
Two variations in morphology in Texas Fatmucket populations are worthy of notation. Like several other Central Texas unionid taxa, Texas Fatmucket specimens from some areas produce atypically elongate gravel-bar or riffle morphs. These were sometimes designated as the subspecies "*elongatus*" in older historic literature, but are no longer recognized as anything more than ecophenotypes. Additionally, females in one Tom Green County population (Concho River drainage) had unusual mantle flaps that appeared more like a white surgical glove than the minnow-mimic lures typical of the species. Shells were morphologically indistinguishable from other Texas Fatmucket populations, but no biochemical genetic studies were conducted to evaluate possible differences. This population is believed to have been completely eliminated and taxonomic significance, if any, will apparently remain unresolved.

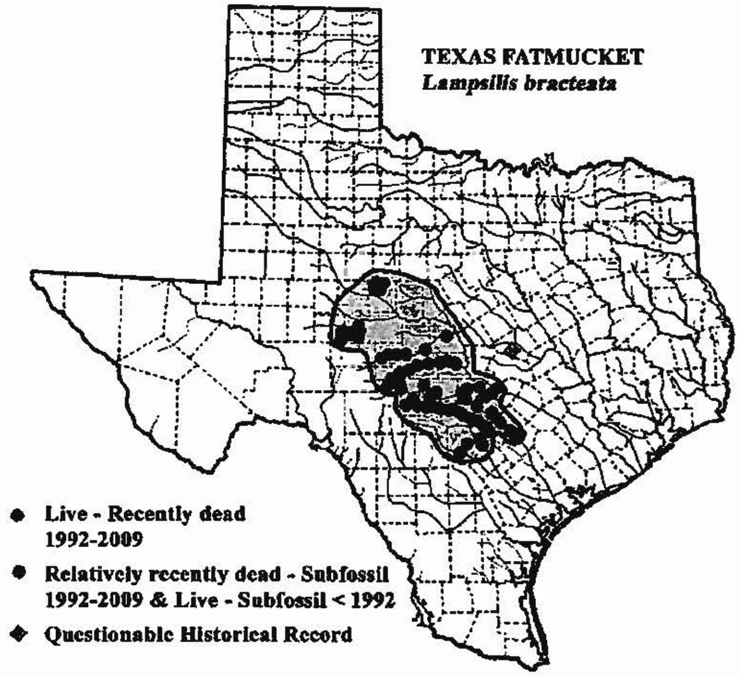


Figure 1. Presumptive historic range of Texas Fatmucket (*Lampsilis bracteata*) shown in blue in Central Texas.

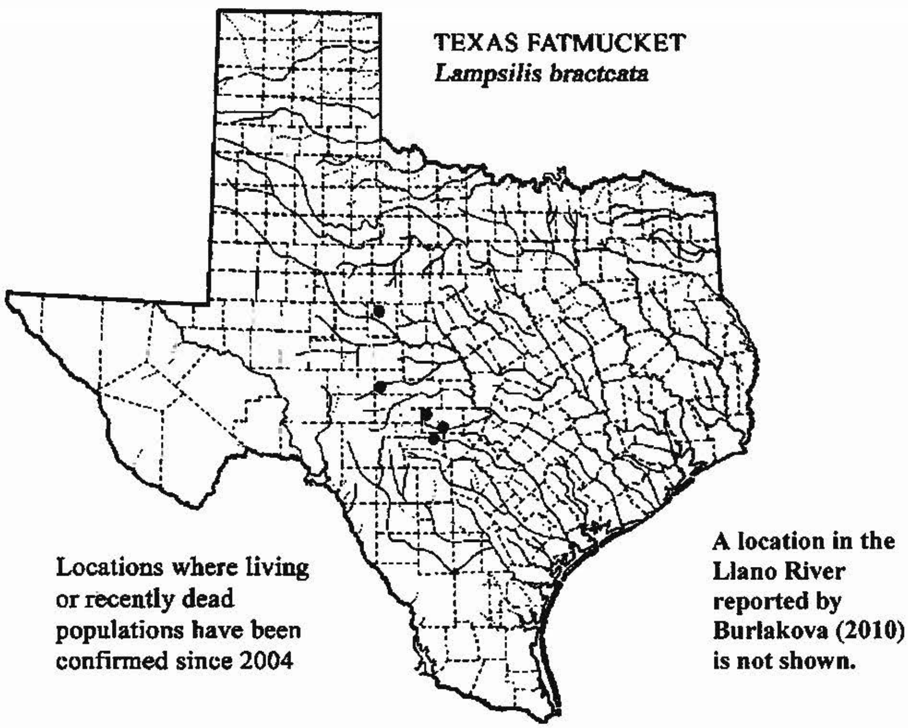


Figure 2. Populations of Texas Fatmucket (*Lampsilis bracteata*) confirmed since 2004.

Biochemical genetics

Howells (1993a) reported that several electrophoretic enzyme systems could be used to distinguish Texas Fatmucket and Louisiana Fatmucket. Texas Fatmucket has fast alleles at GPI, MDH, and IDH, but Louisiana Fatmucket had correspondingly slow alleles at these same loci (R.G. Howells, unpublished data). Harris et al. (2004) examined many *Lampsilis* species with biochemical genetic studies (DNA), including Texas Fatmucket and its association with other lampsiliids.

Range

Historical

Texas Fatmucket is endemic to the Texas Hill Country and eastcentral Edwards Plateau region of Central Texas (Howells et al. 1996). Drainage basins include the upper Colorado, Guadalupe, and San Antonio systems and their associated tributaries (Howells et al. 1996). It ranged from Travis County upstream to Runnels County in the Colorado drainage, from northern Gonzales County upstream to the headwaters in Kerr County in the Guadalupe system, and from Bexar County in the San Antonio drainage (Figure 1).

Strecker (1931) listed reports of Speckled Pocketbook (*L. streckeri*) from Onion Creek (Travis County, Colorado River drainage: originally reported as Brokenray *L. reeviana*) and Salado Creek (Bell County, Brazos River drainage) attributed to Askew. However, Speckled Pocketbook is endemic to the Little Red River system of Central Arkansas (Harris and Gordon, undated) and Brokenray does not occur in or near Texas. The Onion Creek material is believed to be misidentified Texas Fatmucket. The Salado Creek record was probably a misidentified Louisiana Fatmucket (*L. hydiana*) given that it does occur in western tributaries of the Brazos River, but Texas Fatmucket is not otherwise known in that basin.

Strecker (1931) also reported Texas Fatmucket from a lake in Victoria County in the lower Guadalupe River drainage. This report is almost certainly referable to a misidentified Louisiana Fatmucket. Texas Fatmucket does not occur in lakes or impoundments; however, Louisiana Fatmucket regularly inhabits lakes and reservoirs. Further, the Louisiana Fatmucket ecophenotypes in the lower Guadalupe River system are noticeably more delicate, not strongly inflated, not strongly rayed, and often somewhat compressed; these could easily be mistaken for Texas Fatmucket, particularly in past decades when the extent of morphological variation and exact ranges were less well understood.

Current

Since 1992 (with TPWD mussel surveys began) and the present (February 2010), living and recently dead Texas Fatmucket has only been found at seven locations within its historic range. One of these sites in Tom Green County appears to have been eliminated in 1999-2000 by dewatering and possibly over collecting (Howells et al. 2003; Howells 2006, 2009). Another site in Kerr County has been negatively impacted by dewatering and construction activities; its continued existence is uncertain (Howells 2006, 2009). The remaining sites and last record of living or recently dead specimens include: southern Gillespie County (2007), western Gillespie County (2004), Runnels County (2008), and Menard County (2005) (Howells et al. 2003; Howells 2005, 2006, 2009; Burlakova and Karatayev 2008). No details regarding the recently discovered Llano River site reported by Burlakova (2010) are available at this time. However, failure to find this population in numerous earlier surveys suggests the presence of an exceptionally large population is probably unlikely. Other surveys by TPWD beginning in 1992 failed to locate other populations in previously reported areas.

Population levels

No population estimates are available for any of the currently recognized Texas Fatmucket populations. Lack of population estimates reflects the apparently small numbers of this extremely rare species. Relatively few individuals have been encountered in any survey effort at any of the known population sites. Additionally, the physical nature of some sampling sites precludes efficient survey efforts. Small numbers of specimens located in deep, bedrock cracks or covered in calcium deposits among heavy cobble and dense macrophyte beds make accurate estimates of population size unrealistic. Nonetheless, no large populations have been confirmed in recent years.

CONSERVATION MEASURES

When TPWD created its first freshwater mussel harvest regulations in 1992 and 1993, minimum size limits were established and a series of no-harvest sanctuaries were designated. At that time, minimum harvest sizes focused on commercial shell species of unionids, but the designation of a minimum shell height of 63.5 mm sh (2.5 inches sh) was also designated for "all other species" (including Texas Fatmucket). This minimum harvest size applied both to living specimens and dead shells and valves and it remains in place today. Given that the largest Texas Fatmucket specimen documented by the author (100 mm sl) was only 59 mm sh (2.3 inches sh), Texas Fatmucket apparently never grows large enough to be legally taken (except under permit from TPWD)

No locations specifically supporting living Texas Fatmucket populations were known when TPWD no-harvest sanctuaries were first established. However, when a living population was confirmed in Runnels County, the site was added to the list of protective sanctuaries (Howells 1994b). In addition to TPWD regulations, Howells et al. (1997) provided a list of the designated TPWD no-harvest mussel sanctuaries. Ultimately in 2006, no-harvest sanctuaries were redefined and were formally passed by the TPW Commission in July 2007 (Texas Parks and Wildlife Department Proclamation 57.156-57.158; Howells 2009). Present or previously observed Texas Fatmucket populations at four locations are now in no-harvest sanctuaries including: sections of Live Oak Creek in Gillespie County, Guadalupe River in Kerr County, San Saba River in Menard County, and Elm Creek in Runnels County. An additional stream in western Gillespie County on private lands has not been included to date and Spring Creek in Tom Green County was omitted from the list of sanctuaries because that population is believed to have been lost. One additional location in the Llano River reported by Burlakova (2010) was discovered since the current sanctuary list was established.

It should be noted that TPWD no-harvest sanctuaries only legally preclude harvest of mussels from those designated waters and their tributaries. Mussel sanctuaries do not prohibit other area activities that could potentially have negative impacts on local unionids however.

In December 2009, TPWD moved to list Texas Fatmucket as a legally threatened species.

LISTING FACTORS

Habitat or Range (Destruction, Modification, Curtailment)

Throughout much of Texas, historic land utilization resulted in modification and elimination of some aquatic habitat critical to Texas Fatmucket and other unionids. Extensive overgrazing beginning in the mid-1800s resulted in significant loss of vegetative cover and soils, with subsequent increases in runoff causing scouring of many streams and rivers (Howells 1994c). Scouring impacts on Texas waters have been further exacerbated by changes in rainfall patterns to fewer light and moderate showers and longer periods of drought punctuated by heavy, damaging floods (http://www.epa.gov/climatechange/science/recentpsc.html; Howells and Power 2004). Additionally, decade-average rainfall has increased over the past century with more rain falling in the early 1990s than fell in 1900-1910 (Howells 1995b). Collectively, overgrazing, reduction in vegetative cover and soils, increasing numbers of scouring floods, and general increases in amount of precipitation have combined to dramatically reduce acceptable mussel habitat in many Texas waters. Anthropogenic developments (e.g., impervious surfaces, water flow manipulations) have magnified these impacts.

Central Texas in particular experienced a major drought in the late 1970s followed by several record floods between 1978 and 1981 (Howells et al. 1997; Howells and Power 2004). Some Central Texas mussel population sites that held assemblages of living unionids in the 1970s (including Texas Fatmucket) no longer supported living mussels when surveyed in the 1980s and 1990s (Howells et al. 1997). These events helped reduce the abundance and distribution of Texas Fatmucket and other unionids.

In addition to past and more-recent negative historic impacts (that continue), other broad-ranging and site-specific threats exist as well. By population site, these include:

Runnels County: The small stream where Texas Fatmucket has been documented is primarily located on private ranch lands. Generally, landowners actively graze these areas with no restrictions to hoofstock density or impact on stream banks and bottoms. Extensive flood damage has occurred here in the past and is likely to occur again. Increased ground-water pumping likely reduces spring flow into the system and may have contributed to problematic dewatering in the recent past. It is unclear if proposed electrical transmission line construction will impact this stream or not. Possible future bridge and low-water crossing work could also impact this area.

Tom Green County: Except for a short run of stream in a county park, this system too is located almost exclusively on private lands. Comments applying to the Runnels County site apply here as well. However, it appears this population has already been lost and unless the presence of living Texas Fatmucket can be demonstrated in the future, this stream seems to have already been eliminated from consideration.

Menard County: The Texas Fatmucket population in a short section of the San Saba River occurs upstream of an urban area and generally runs through private ranch lands. Flooding occurs here periodically, but moderate bank heights in many areas and wide areas for flows to dissipate have helped reduce scouring impacts thus far. Atypically heavy macrophyte growth (most unionids avoid dense macrophyte beds) suggests an undesirable level of nutrient input in this area or somewhere upriver. Possible nutrient sources have not been reported. Hoofstock is grazed throughout the area and increased residential development is occurring in the surrounding land and along the river banks. Possible impacts of bridge construction at a location upstream from the Texas Fatmucket site have likewise not been assessed.

Guadalupe River: The small Texas Fatmucket population in the Guadalupe River in Kerr County was thought to have been lost in 1998 when the city of Kerrville drained a section of the river to expedite construction of a park foot-bridge in the area (Howells 2009). However, in 2005, A.Y. Karatayev and L.E. Burlakova found several living individuals had survived (Howells 2006). Since this time, several building projects along the banks of the Guadalupe River and replacement of a bridge over the river have occurred between the upstream and downstream specimen collection locations. Despite several annual examinations of this stretch of river, no additional living Texas Fatmucket specimens have been documented in the area since 2005 (Howells 2009). Building and bridge construction in the area are continuing at this time (February 2010).

Gillespie County (eastern): Texas Fatmucket is only known to occur in a very short stretch of this stream within a small public park and golf course. Areas on private lands up- and downstream remain to be surveyed, but are scheduled for examination in spring 2010 (R.G. Howells, unpublished data). An impoundment constructed within the park and golf course is the subject of debate, with some parties desiring its removal. If the dam associated with this reservoir is removed, it would be difficult to avoid at least some degree of impact to the Texas Fatmucket population downstream. Similarly, if this impoundment were to be dredged or riparian areas modified, downstream impacts on unionids would need to be evaluated. The headwaters of this stream are primarily on private ranch lands, some of which are now being modified into residential areas. Some ranch lands have also been completely stripped of vegetation in efforts to control Ashe juniper (*Juniperus ashei*), called mountain cedar locally. Although invasive Ashe junipers are ecologically undesirable, bare lands also promote excess runoff and silt deposition. Other residential, commercial, highway, and general urban activities have occurred in the upstream drainage of this stream. In addition to the golf course associated with the city park where the Texas Fatmucket population occurs, a county fair ground and airport are present. Some private ranch land immediately downstream of the park area shows signs of riparian damage due to hoofstock-related erosion. Within the stream run where Texas Fatmucket has been found living, anglers have occasionally used local rocks to build temporary dams in an effort to create pools to facilitate angling. The area known to support Texas Fatmucket and the population size both appear to be quite small and possible sources of negative impact from adjacent sources suggest this population could be easily eliminated.

Gillespie County (western): The population in this stream was examined in 2004 (Howells 2005), but has not been surveyed again since then. It is located on private land where the landowner is particularly interested in land preservation and maintenance of natural vegetative cover. The major immediate threat to this site is probably presented by extreme or long-duration drought conditions and ground water pumping that reduces spring flow, both of which reduce stream flow.

Llano River: Burlakova (2010) reported finding this population, but did not discuss habitat details or threats. The Llano River was internationally known in the 1800s for its mussels and natural pearls; however, scouring floods over the past century have modified much of the river bed environment to deep-shifting sands and scoured bedrock, both unacceptable mussel habitats. Previous surveys throughout the length of the Llano River since 1992 have failed to confirm any established mussel populations remaining in the main channel of the river (Howells 2004, 2010b). Even if the Burlakova population has been previously overlooked or recently reinvaded from an adjacent tributary, negative impacts due to overgrazing, sand and gravel operations, and other factors suggest future ecological stability in this river may be questionable.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Texas Fatmucket has not been harvested in Texas as a commercial mussel species or pearl mussel (Howells 1993). Although minimum harvest sizes under TPWD regulations prohibit take of any unionid species less than 2.5 inches in shell height, anglers collecting mussels for use as bait are less discriminatory than commercial shell musselers and might take any species at any size (R.G. Howells, unpublished data). Two Texas Fatmucket shell fragments that were relatively recently dead that were found at the type locality in the Llano River, Mason County, in 1995 (Howells 1996) were suspected of being deposited there by an angler. However, TPWD regulations do not specifically restrict mussel harvest for use as bait and the extent of possible impact by anglers is undocumented.

To date, neither state nor federal resource managers have directed or monitored scientific activities and their impact on Texas Fatmucket populations. It is possible multiple researches may survey, sample, and even remove specimens from the same area in relatively narrow windows of time. It remains undetermined if this activity has been problematic at known population sites. Volunteer training and sampling programs associated with freshwater mussel research similarly have limited time and place focus for such activities and may also potentially conflict with formal scientific research and management activities.

Public release of sensitive population location information has also been problematic regarding the security of the remaining Texas Fatmucket populations. In the late 1990s, detailed location information provided by TPWD to The Nature Conservancy was passed to NatureServe that, in turn, placed location details on its Internet site. Shell collectors used this information to access sites where Texas Fatmucket and Texas Pimpleback (*Quadrula petrina*) occurred. At that time, some collectors even posted photos on the Internet to show the unionids they had been able to collect in Texas. In conjunction with prior flooding and subsequent drought-related dewatering, mussels in some areas were easily located. Collectively, these impacts appear to have eliminated one Texas Fatmucket and one Texas Pimpleback population and nearly destroyed a second Texas Fatmucket population (R.G. Howells, unpublished data). The Nature Conservancy, NatureServe, and other organizations have responded to this informational risk and modified their open releases of potentially harmful information. Unfortunately, even this report contains information that could be potentially misused and could be employed with negative impacts to surviving Texas Fatmucket populations.

Disease or Predation

No specific diseases have been reported in the published literature or observed during recent studies of Texas Fatmucket. Natural predators, like catfishes (Ictluridae) and Freshwater Drum (*Aplodinotus grunniens*) no doubt consume some Texas Fatmucket specimens, but no confirmation has been documented to date. One female Texas Fatmucket was found with a mantle flap bitten off, but this appears to be an unusual occurrence (R.G. Howells, unpublished data). Raccoons (*Procyon lotor*) and other similar predators have been observed preying on individual Texas Fatmucket when stranded by low-waters or deposited in shallows or on bars following flooding and low-water periods (R.G. Howells, unpublished data). However, no natural predators have been suspected of excessive or problematic impact on Texas Fatmucket populations (R.G. Howells, unpublished data).

Existing Regulatory Measures

At this time (February 2010), TPWD harvest regulations remain in place, including a minimum harvest size of 2.5 inches in shell height and establishment of no-harvest mussel sanctuaries covering four of the recognized Texas Fatmucket population sites (one population in western Gillespie County and the recently reported Llano River location have not been designated sanctuaries to date). Texas Fatmucket was listed a legally threatened species by TPWD in December 2009, also precluding most harvest. Sanctuary status prohibits all harvest (except as allowed under state permit); in non-sanctuaries, protected species may be disturbed during collection of non-protected mussels.

Unfortunately, mussel sanctuaries only address harvest and do not impact other human activities in those areas, some of which can be detrimental. Some such anthropogenic activities include livestock damage to riparian zones and stream beds, increased nutrient input, increased runoff (directed and non-directed), sand and gravel removal from bank areas (and stream beds during low-water periods), pesticide and other chemical contaminants in runoff waters (from residences, farms and ranches, industry, airports, golf courses, etc.), general bridge and building construction along stream bank areas, water removal (for irrigation, livestock, etc.), impact from chemical or physical removal of noxious vegetation, and numerous other factors. Limited public awareness of freshwater mussel status and associated regulatory measures remains problematic. Scientific awareness among resource managers also needs to be enhanced.

Other Natural or Manmade Factors Affecting Continued Survival

Another source of potentially extensive and adverse, yet difficult to quantify, impact involves the increasing human population within the range of Texas fatmucket and the resulting increase pumping of aquifer waters for direct and indirect human consumption. Flows in many Texas springs have been reduced or eliminated, with subsequent reduction or elimination of spring feeds to streams (Brune 1975, 2002). Historically, water allocation plans in Texas have not focused on preservation of rare mussel resources.

NEEDED INFORMATION

Taxonomy and Genetics

Although basic electrophoretic and DNA analyses have been performed on Texas Fatmucket and confirmed its taxonomic status, other biochemical genetic studies, such as DNA barcoding, could still contribute to helping to define this species. Probably many such activities can be conducted with mantle clips or other non-lethal sampling methods. Additionally, no studies have genetically compared existing Texas Fatmucket populations, all of which are isolated with no genetic exchange.

Distribution

Distribution of Texas Fatmucket is relatively well reported. However, it is possible additional small populations may exist on private lands in Texas at locations that have never been surveyed. Additionally, existing populations appear quite small and could be easily lost within a short time window. Several sites have not been examined in a number of years. The known population sites should be periodically monitored to confirm their status and document potential threats. However, some level of regulatory control should be exercised to prevent excessive or disruptive monitoring activities.

Reproductive Biology

Fecundity – Although no estimates of Texas Fatmucket fecundity are available, population levels appear far too low to justify sacrificing existing females to obtain these estimates. Unless previously-collected and preserved individuals in museum and university collections can be used, fecundity of Texas Fatmucket might be best approximated by comparing to fecundity estimates of more-common, related species like Louisiana Fatmucket and Fatmucket (*Lampsilis siliquoidea*).

Environmental Aspects of Biology

When species are extremely rare, difficult to observe or sample, and sensitive to disturbance, it can be extremely difficult to define critical aspects of species biology that relate to management of the species (e.g., in-stream flow limitations, minimum and maximum lethal temperature and oxygen levels, critical spawning and incubation temperatures, etc.). Documenting these various elements of Texas Fatmucket biology on those occasions when opportunity presents can be important, especially when multiple observations can be combined into meaningful summaries. Opportunities to record elements of species biology should not be neglected. It should also be noted that measurements of physicochemical parameters associated with Texas Fatmucket population sites need to be documented over long periods of time (years) to be meaningful. Quick snapshot studies in areas often subjected to extensive flood and drought extremes may not provide a good over-all view of the full range of relevant flow rates, water chemistry, and related parameters. Indeed, short snapshot studies can sometimes be more misleading than instructive.

Threats to Continued Survival

Continued human population growth and development in Central Texas are certain to have increasing impacts on native unionid populations. Habitat loss, modification, or disturbance in conjunction with decreasing water supplies can be anticipated.

PERSONAL CONCLUSIONS AND RECOMMENDATIONS

Texas Fatmucket is a species that is both representative of and endemic to Central Texas. Unfortunately, interest in its conservation status has been late materializing and it is dangerously close to slipping into extinction. At present, it may be restricted to five or fewer locations where very small numbers still endure. Surviving numbers are too limited to allow extensive studies of many aspects of its biology.

Although TPWD has listed Texas Fatmucket as a legally threatened species, it appears its federal status should be elevated to legally endangered. Efforts need to be directed at an improved and updated understanding distribution, biology (including reproductive biology), and pending threats to survival. However, these efforts need to be carefully considered and directed from a single focal source to prevent inappropriate or excessive impacts on surviving specimens.

RELEVANT LITERATURE

Brune, G. 1975. Major and historical springs of Texas. Texas Water Development Board, Report 189, Austin.

Brune, G. 2002. Springs of Texas. Volume 1. Springs of Texas. Texas A&M Press, College Station.

Burlakova, L.E. 2010. Unionid diversity and rarity in Texas. Texas Parks and Wildlife Department, Mussel Workshop, Austin.

Burlakova, L.E., and A.Y. Karatayev. 2008. State-wide assessment of unionid diversity in Texas. Performance Report. State Wildlife Grant report to Texas Parks and Wildlife Department, Austin.

Gould, A.A. 1855. New species of land and fresh-water shells from western (N.) America. Proceedings of the Boston Natural History Society 5:127-130.

Harris, J.L., and M.E. Gordon. Undated. Arkansas mussels. Arkansas Game and Fish Commission, Little Rock.

Harris, J.L, and six coauthors. 2004. Species limits and phylogeography of Lampsilinae (Bivalvia: Unionoida) in Arkansas with emphasis on species of *Lampsilis*. Arkansas Game and Fish Commission, Little Rock.

Hoggarth, M.A. 1994. A key to the glochidia of the Unionidae of Texas. Department of Life and Earth Science, Otterbein College, Westerville, Ohio. Prepared for the American Malacological Union Annual Meeting, Houston, Texas, 1994.

Howells, R.G. 1993a. Electrophoretic genetic analysis. Info-Mussel Newsletter 1(6):2.

Howells, R.G. 1993b. Preliminary survey of freshwater mussel harvest in Texas. Texas Parks and Wildlife Department, Management Data Series 100, Austin.

Howells, R.G. 1994a. Louisiana fatmucket mantle flaps. Info-Mussel Newsletter 2(1):3.

Howells, R.G. 1994b. Additional new mussel sanctuaries designated. Info-Mussel Newsletter 2(1):1-2.

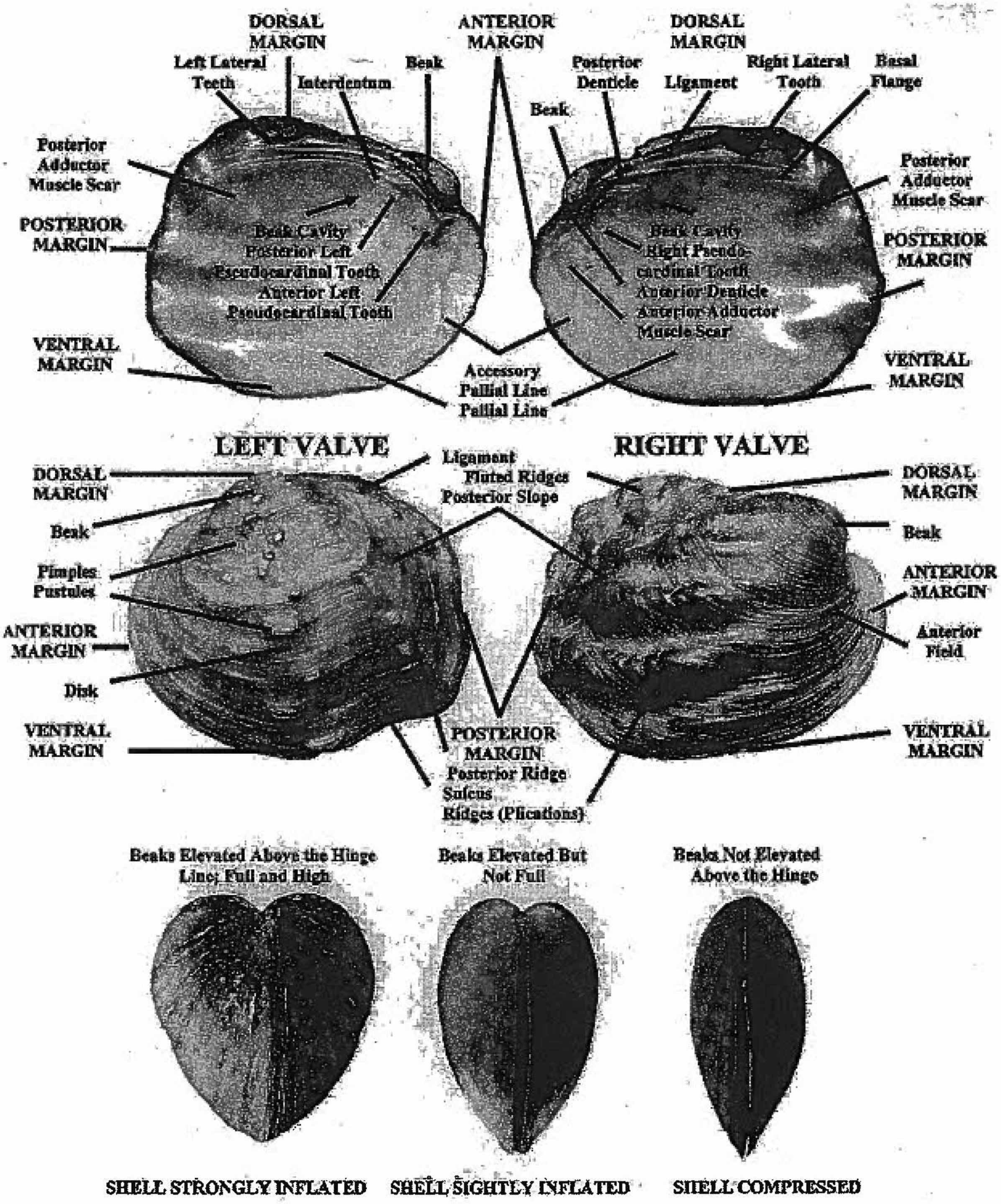
Howells, R.G. 1994c. Longhorn cattle and windmills linked to mussel declines. Info-Mussel Newsletter 2(5):5.

Howells, R.G. 1995a. Mussel fecundity. Info-Mussel Newsletter 2(12):4.
Howells, R.G. 1995b. Changes in precipitation patterns in Texas. Info-Mussel Newsletter 3(4):6.
Howells, R.G. 1996. Distributional surveys of freshwater bivalves in Texas: progress report for 1995. Texas Parks and Wildlife Department, Management Data Series 125, Austin.
Howells, R.G. 1997. New fish hosts for nine freshwater mussels (Bivalvia: Unionidae) in Texas. The Texas Journal of Science 49(3):255-258.
Howells, R.G. 2000. Reproductive seasonality of freshwater mussels (Unionidae) in Texas. Pages 35-48 *in* R.A. Tankersley and five coeditors. Freshwater mollusk symposia proceedings. Ohio Biological Survey Special Publication, Columbus.
Howells, R.G. 2003. Declining status of freshwater mussels of the Rio Grande. Pages 59-73 *in* G.P. Garrett and N.L. Allen, editors. Aquatic fauna of the northern Chihuahuan Desert. Texas Tech University Press, Lubbock. (Initially presented in 2001).
Howells, R.G. 2004. Texas freshwater mussels: species of concern. Texas Parks and Wildlife Department, Wildlife Diversity Conference, San Marcos, Texas. 18-20 August 2004.
Howells, R.G. 2005. Distributional surveys of freshwater bivalves in Texas: progress report for 2004. Texas Wildlife Department, Management Data Series 233, Austin.
Howells, R.G. 2006. Statewide freshwater mussel survey. State Wildlife Grant Final Report T-15-P, Texas Parks and Wildlife Department, Austin.
Howells, R.G. 2009. Biological opinion: conservation status of selected freshwater mussels in Texas. BioStudies, Kerrville, Texas.
Howells, R.G. 2010a. Guide to Texas freshwater mussels. BioStudies, Kerrville, Texas.
Howells, R.G. 2010b. Status of Texas unionids: where have all the mussels gone? Texas Parks and Wildlife Department Workshop, Austin.
Howells, R.G., J.L. Dobie, W.L. Lindemann, and J.A. Crone. 2003. Discovery of a new population of endemic *Lampsilis bracteata* in Central Texas, with comments on species status. Ellipsaria 5(2):5-6.
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. Niamo. 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.
Howells, R.G., R.W. Neck, and H.D. Murray. 1996. Freshwater mussels of Texas. Texas Parks and Wildlife Press, Austin.
Howells, R.G., and P. Power. 2004. Freshwater mussels of the San Marcos-Blanco River basin: history and status. 107th Annual Meeting of the Texas Academy of Science, Kerrville, Texas, 6 March 2005
Lea, I. 1870. A synopsis of the family Unionidae. 4th edition, very greatly enlarged and improved. Henry C. Lea, Philadelphia, Pennsylvania.
Simpson, C.T. 1900. Synopsis of the naiads, or pearly fresh-water mussels. Proceedings of the United States National Museum 22(1205):501-1044.
Simpson, C.T. 1914. A descriptive catalogue of the naiades, or pearly fresh-water mussels. Parts I-III. Bryant Walker, Detroit, Michigan.
Strecker, J.K. 1931. The distribution of naiads or pearly fresh-water mussels of Texas. Baylor University Museum Bulletin 2, Waco.

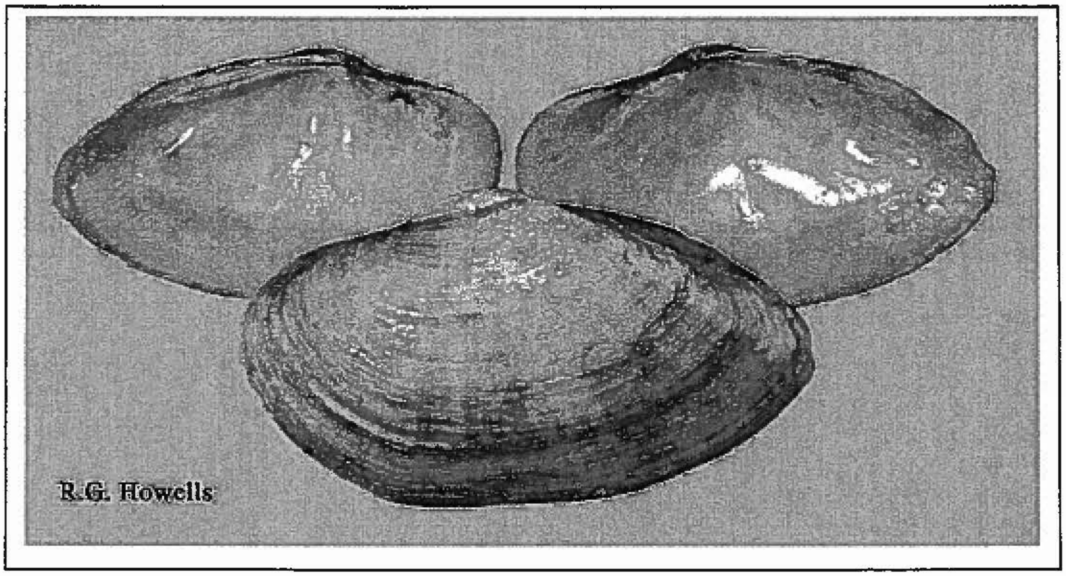
GLOSSARY OF SELECTED TERMS

Ala – a wing-like extension of the dorsal shell margin; usually posterior to the beak, sometimes anterior; "alate" means having a wing.
Beak – the umbo, the elevated (usually) part of the shell on the dorsal edge, anterior to the ligament in freshwater mussels, the oldest part of the shell.
Beak cavity – the inside of the beak within each valve, often forms a pocket or depression.
Beak sculpture – patterns of ridges, loops, and bumps that, like finger prints, can be unique to some species; often eroded and missing.
Chevron – V or arrowhead shaped, sometimes paired into Ws.
Compressed – flattened or pressed together.
Denticle – small (usually) tooth-like structures that may be present anterior and posterior to the right pseudocardinal tooth.
Concentric – circles, rings, or crescents with a common center or origin.
Dimorphic – having two distinct forms.
Ecophenotype – forms of a single species that are physically distinct in different environments.
Elliptical – ellipse shaped or an elongated oval.
Elongate – long or extended.
Endemic – found only in a particular area.
Exfoliated – eroded.
Extirpated – extinct in a particular area.
Fecundity – the number of eggs and/or larvae.
Fluted – grooves and ridges with a ruffle-like appearance.
Growth-rest lines – alternating dark and light concentric lines in a mussel shell indicating periods of slow and fast growth, respectively. In the far north, these may be annuli (formed each year), but in Texas growth may slow during summer droughts or continue over mild winters (therefore growth-rest bands cannot be counted as an indication of age).
Hinge – the area where the right and left valves (shell halves) articulate and are connected by an elastic ligament.
Hinge teeth – lateral and pseudocardinal teeth.
Inflated – swollen, expanded.
Interdentum – the area of the hinge between the lateral and pseudocardinal teeth; absent in some species.
Iridescent – a lustrous, pearly, or rainbow color appearance; only freshwater mussels and marine pearl oysters have iridescent nacre.
Lachrymose – drop-shaped pustules.
Lateral teeth – elongate structures along the hinge in many species located only posterior to the beak in freshwater mussels; absent in some species; these stabilize the hinge and are not true teeth at all.
Lunule – a cavity or depression, also called a sinus.
Nacre – the inner layer of the shell, mother-of-pearl.
Oval (ovate) – egg shaped.
Pallial line – a linear depression inside each valve interior to the shell margin, where the soft mantle tissues were attached.
Periostracum – the outer shell layer, shell epidermis.
Plications – folds, ridges, particularly multiple ridges.
Posterior ridge – a ridge on the posterior half of the shell running from the beak to the margin.
Posterior slope – shell area between the posterior ridge and the dorso-posterior margin.
Pseudocardinal teeth – tooth-like structures located below the beak area, usually two in the left valve and one in the right valve or none at all; may be compressed and leaf-like to heavy and molar-like.
Quadrate – square; often expressed as subquadrate (nearly quadrate).
Pustule – a bump or raised knob on the shell exterior.
Serrated – notched or grooved.
Shell margin – the exterior circumference edge of each valve (sometimes this term excludes the hinge line).
Solid – hard, thick, not soft and chalky.
Striated – with fine lines or grooves.
Truncate – shortened or squared off (sometimes obliquely).
Tubercle – projection from the shell, may be pointed, rounded, or knob-like.
Umbo – beak.
Valve – one half of a bivalve shell.
Wing – ala.

FRESHWATER MUSSEL SHELL FEATURES



TEXAS FAWNSFOOT (*TRUNCILLA MACRODON*): SUMMARY OF SELECTED BIOLOGICAL AND ECOLOGICAL DATA FOR TEXAS*



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April 2010
*** Not for Internet Distribution**

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Robert G. Howells is a fisheries scientist and aquatic ecologist. He has conducted research on freshwater mussels in Texas since 1992, in addition to his general fisheries studies and work with exotic species. Howells has served on the staff of the Cleveland Museum of Natural History; conducted environmental studies for 10 years for Ichthyological Associates, Inc., an environmental consulting firm; and spent 22 years with Texas Parks and Wildlife Department's Heart of the Hills Fisheries Science Center. He is the senior author of the book, Freshwater Mussels of Texas, and has written numerous scientific journal articles, symposia proceedings, technical reports, and informational guides. He is a member of the Freshwater Mollusk Conservation Society, American Malacological Society, and is currently working with others with the American Fisheries Society to update the distribution and conservation status of freshwater mussels of the United States, Canada, and Mexico. Howells retired from state employment in 2006, but has continued to study, write, and consult (BioStudies).

FUNDING SUPPORT

Funding support for this report was provided by Save Our Springs Alliance, P.O. Box 684881, Austin, Texas 78768; www.SOSAlliance.org. Individual funding was also provided by the Kirk Mitchell Environmental Law Fund and WildEarth Guardians. Copies of this report can be obtained from SOSA.

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CONTENTS

ABOUT THIS REPORT

This report has been primarily drafted as a technical report, but introductory text, a glossary, and labeled shell feature figures have been included to assist non-malacologists with aspects of freshwater mussels. Within this report, shell length is abbreviated "sl" and other shell dimensions are typically written out. From the onset of freshwater mussel studies by Texas Parks and Wildlife Department (TPWD) in 1992, time-since-death estimates were designated for shells, valves, and fragments that were encountered in surveys (e.g., very recently dead = soft tissues still attached to shells and valves). These were defined in TPWD's annual Management Data Series (MDS) mussel survey reports and can be found in Howells (2003) that is available on the Internet. These shell condition designations provided possible status indications ranging from whether living specimens may still occur at a particular site to locations where mussels occurred in the area once, but appear to have been lost long ago. Mussel collection site locations on maps herein sometimes use a single dot to designate two or more collection sites that are in close proximity. Therefore, simply counting dots on these maps may not necessarily represent the total number of collection records or sites. Finally, recent data from several reports that are in preparation or in press may or may not have been included based on availability of these data, and some unconfirmed amateur volunteer records may also have been omitted.

ACKNOWLEDGMENTS

Special appreciation goes to N.A. Johnson, D.P. Johnson, C.M. Mather, J.A.M. Bergmann, W.H. McCullagh, B. Gottfried, and M.E. May for providing data used in preparation of this report. Thanks also to T.D. Hayes and A.J. Haugen for invaluable editorial input.

INTRODUCTION TO FRESHWATER MUSSELS

Freshwater Bivalves

Many types of bivalve mollusks are called clams or mussels. Neither term is really specific to one group. A number of bivalve groups live in fresh water in Texas. Freshwater mussels, also called pearly freshwater mussels or unionids (Family Unionidae), have over 50 species in Texas and about 300 in North America. A number of tiny fingernailclams (Sphaeriidae) are also present in many waters. Exotic Asian clam (Corbiculidae) invaded Texas in the 1950s and 60s, and exotic zebra mussel (Dreissenidae) was found in Texas in 2009. Several native estuarine clams and mussels can also be found in the lower reaches of coastal rivers.

Native Freshwater Mussels

Freshwater mussels do not attach to solid objects (as adults) like true marine mussels and zebra mussels, but dig into substrates of mud, sand, and gravel. They usually have distinct sexes. Females brood eggs and developing larvae (called glochidia) in marsupial pouches on their gills. Glochidia are parasites on fishes. Upon release from the female, glochidia have only hours to find the appropriate species of host fish that has no immunity to infection and attach to the correct location on that fish or die. After a few weeks or months, the transformed juveniles drop from the host to begin life in the substrate. Generally little harm comes to the host.

Role in the Ecosystem

Freshwater mussels are Mother-Nature's biofilters that feed by removing algae, bacteria, and organics from the water. They remove environmental contaminants and concentrate them in their tissues. Unionids also serve as food for fishes, birds, mammals, and other organisms. They mix water body substrates much as earthworms do in garden soils.

Historic Harvest

Native Americans harvested freshwater mussels for food, tools, ornament, and natural pearls. In the 1890s, shells of some species became important in button manufacturing (but to a limited extent in Texas). Some Texas mussels produce gem-quality pearls and they have been taken for this purpose since early Spanish times.

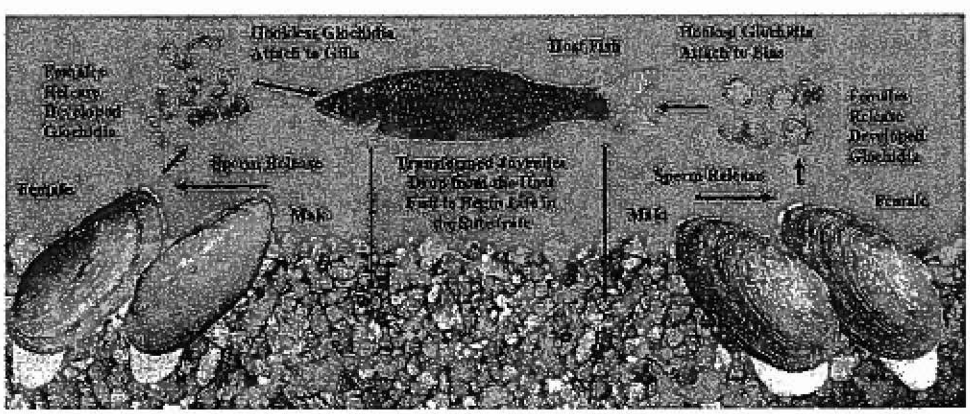
Recent Harvest

Limited harvest for pearls continues in Texas. In the late 1900s, some species were taken for their shells that were used to produce implant nuclei needed to create cultured pearls. They are occasionally captured for arts-and-crafts work, bait, and shell collectors. A license is required for any freshwater mussel harvest and some species are legally protected.

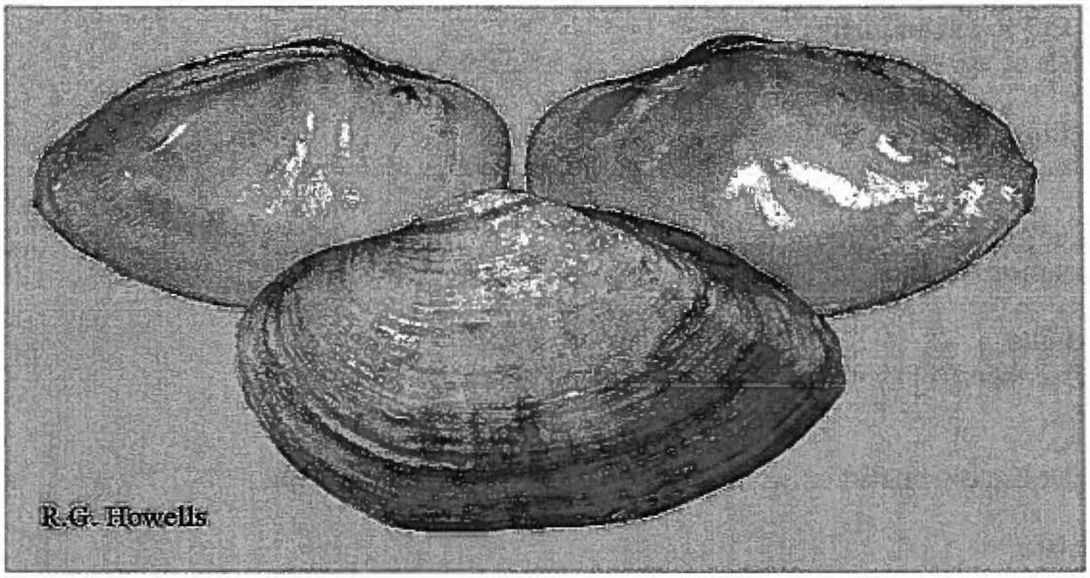
Conservation Status

Freshwater mussels are sensitive indicators of environmental quality. When there is any degradation in the ecosystem, these are usually the first organisms to decline or vanish. As a result, perhaps 80% of North American species are extinct, endangered, threatened, or will be soon. The State of Texas lists 15 species as legally threatened and another as endangered. Many of these are now under consideration for additional federal protection.

Freshwater mussel life cycle.



TEXAS FAWNSFOOT
Truncilla macrodon (Lea 1859)



DESCRIPTION

Descriptions of Texas Fawnsfoot have been presented by Simpson (1914), Howells et al. (1996), and Howells (2010). Shell length reaches at least 60 mm sl, but is usually much less. Shell shape is elongate oval, slightly to moderately compressed (much less inflated than other fawnsfoot species), solid, but rather thin to only moderately thick. Females are less pointed posteriorly. Beaks are flattened and only slightly raised above the hinge line; the beak cavity is shallow. The posterior ridge is somewhat angular dorsally, but broadly rounded near the margin. Adductor muscle scars are moderately impressed anteriorly, but only slightly impressed posteriorly. Pseudocardinal teeth (two left and one right) are not massive or strongly three-dimensional; the right valve usually has no particularly evident anterior or posterior denticles. Lateral teeth (two left and one right) are thin, of moderate length (29-30% sl), and straight to very slightly curved; the right tooth usually has no basal flange. The disk usually shows no external sculpturing, but occasionally has a suggestion of parallel, fluted ridges in the posterior field. External coloration is yellowish- or orangish-tan, brown, reddish-brown, or smoky-green, with a pattern of broken rays, of irregular blotches, inverted V's or W's, and zig-zag marking, sometimes with patterns placed between rays. Internal coloration is bluish-white or white and iridescent posteriorly. Fawnsfoot (*Truncilla donaciformis*) occurs in drainages east of the range of Texas Fawnsfoot and is usually shorter, less elongate, and more inflated. Mexican Fawnsfoot (*T. cognata*) is restricted to the Rio Grande (several drainage basins to the south of the range of Texas Fawnsfoot) and it is also typically shorter, less elongate, and more inflated.

SPECIES BIOLOGY

Life History

Age and size at maturity
No data on age or size at maturity were found during preparation of this report.

Brooding season
No data on brooding season were found during preparation of this report.

Fecundity
No estimates of fecundity were found during preparation of this report.

Glochidia
No descriptions of glochidia were found during preparation of this report.

Hosts
No host fish determinations were found during preparation of this report.

Behavior
Randklev et al. (2010) reported Texas Fawnsfoot specimens in the Brazos River actively burrowing in a long narrow depression of soft, sandy sediment.

Habitat requirements
Howells et al. (1996) indicated Texas Fawnsfoot habitat was unreported. Shells and recently dead specimens found during drought-related dewatering or deposited during high, flood waters have offered some suggestion of possible habitat preferences, but were not confirmation. Generally, it was observed that Texas Fawnsfoot preferred flowing waters of rivers and larger streams and, conversely, was intolerant of impoundment (no natural lakes occurred within its range). Failure to locate population sites during many surveys suggested that the species may prefer to inhabit areas in the lower reaches of tributaries of larger rivers (R.G. Howells, unpublished data). In 2008, Randklev et al. (2010) found a living population in the lower Brazos River and documented physicochemical parameters. These included a mean daily discharge of 78.0 m^3/s (historic U.S. Geological Survey records) for an adjacent area, but 0.16 m^3/s with an average flow rate of 0.018-0.003 m/s at the Texas Fawnsfoot site; dissolved oxygen of 4.87 mg/L; water temperature of 23.7° C; pH of 7.03; and conductivity of 868 µS/cm. Site photographs in Randklev et al. (2010) show partially exposed sandy bars; downed timber structure along the river bank; wooded, sandy banks of moderate height, with indication of some bank collapse and slumping. In 2009, N.A. Johnson (University of Florida, pers. comm.) found a living Texas Fawnsfoot population in the lower Colorado River and reported the species was found in a sandy substrate in turbid waters of moderate to high flows within 1-4 m of the bank. Durlak (2009) and Leggett (2009) reported A.Y. Karatayev and L.E. Burlakova had also located living Texas Fawnsfoot at this same Colorado River location; however, to date (March 2010), they have published no site description.

Taxonomy and Genetics

Species validity
Texas Fawnsfoot was described as *Unio macrodon* by Lea in 1859. Taxonomy summaries by Simpson (1914), Strecker (1931), and Howells et al. (1996) list subsequent placement in the genera *Margaron* and *Plagiola*, but ultimately the species was placed in the genus *Truncilla* of Rafinesque (1820) where it has remained. Texas Fawnsfoot is recognized as a distinct and valid species (Williams et al. 1993; Howells et al. 1996; Turgeon et al. 1998) and is still considered valid by the American Fisheries Society (Williams et al., In Preparation).

It should be noted that Johnson (1999) placed all three fawnsfoot species (*T. cognata*, *T. donaciformis*, and *T. macrodon*) in the single taxon *Truncilla donaciformis.* This appears to have been based on a limited number of museum specimens and lacked any genetic analysis to support this reclassification. Other authorities since have generally failed to accept Johnson's conclusion.

Ecophenotypes
No distinct ecophenotypes have been recognized for this species.

Biochemical genetics
No published, comparative biochemical studies were located during preparation of this manuscript. Tissue from all four *Truncilla* species were directed to a DNA lab in 2003 for study, but, to date, no subsequent publications appear to have been produced (R.G. Howells, unpublished data).

Range

Historical
Texas Fawnsfoot ranged throughout much of the basins of the Brazos and Colorado rivers (Strecker 1931; Howells et al. 1996; Howells 2009) (Fig. 1). Reports from the Trinity River and other eastern Texas areas appear to be misidentified Fawnsfoot (*T. donaciformis*). In the Colorado River is has been reported from Colorado County upstream to the North Fork Concho River in Sterling County (R.G. Howells database). In the Brazos River, records extend from Fort Bend County upstream to the lower reaches of the Clear Fork Brazos River in Stephens County (R.G. Howells database). Records appear curiously absent from the San Saba and Pedernales rivers and Pecan Bayou in the Colorado River drainage and the central and upper Navasota and several other central Brazos River tributaries (R.G. Howells database). It also appears to have been absent in the upper-most reaches of the Colorado and Brazos rivers in western Texas.

Current
Records of living to recently dead specimens found since 2004 (Fig. 2) have been very limited. Recently dead material was reported in the Clear Fork Brazos River, Young County, in 2009 (D.P. Johnson, Houston, Texas, pers. comm.) and Karatayev and Burlakova (2007) also documented a living specimen in the Brazos River, Austin and Waller counties, in 2007. A living Texas Fawnsfoot population was first found by Randklev et al. (2010) in the Brazos River in Washington County in 2008; M.E. May (Texas Parks and Wildlife Department, pers. comm.)

indicated living specimens had also been found just upstream of this site in 2003. In 2009, N.A. Johnson (University of Florida, pers. comm.) found living material in the Colorado River, Colorado County, and Durlak (2009) also reported that A.Y. Karatayev and L.E. Burlakova also confirmed a population of Texas Fawnsfoot at this same location in 2009.

Generally, it appears Texas Fawnsfoot has maintained at least moderate populations in the Brazos River for a distance both up- and down-stream from the confluence of the Navasota River and in the Colorado River, Colorado County. Limited numbers also appear to be present in the lower Clear Fork Brazos River and main run of the Brazos immediately downstream of their confluence and in the lower Brazos River, Austin and Waller counties. Additional areas with historical records examined by TPWD and others since 1992 failed to produce populations.

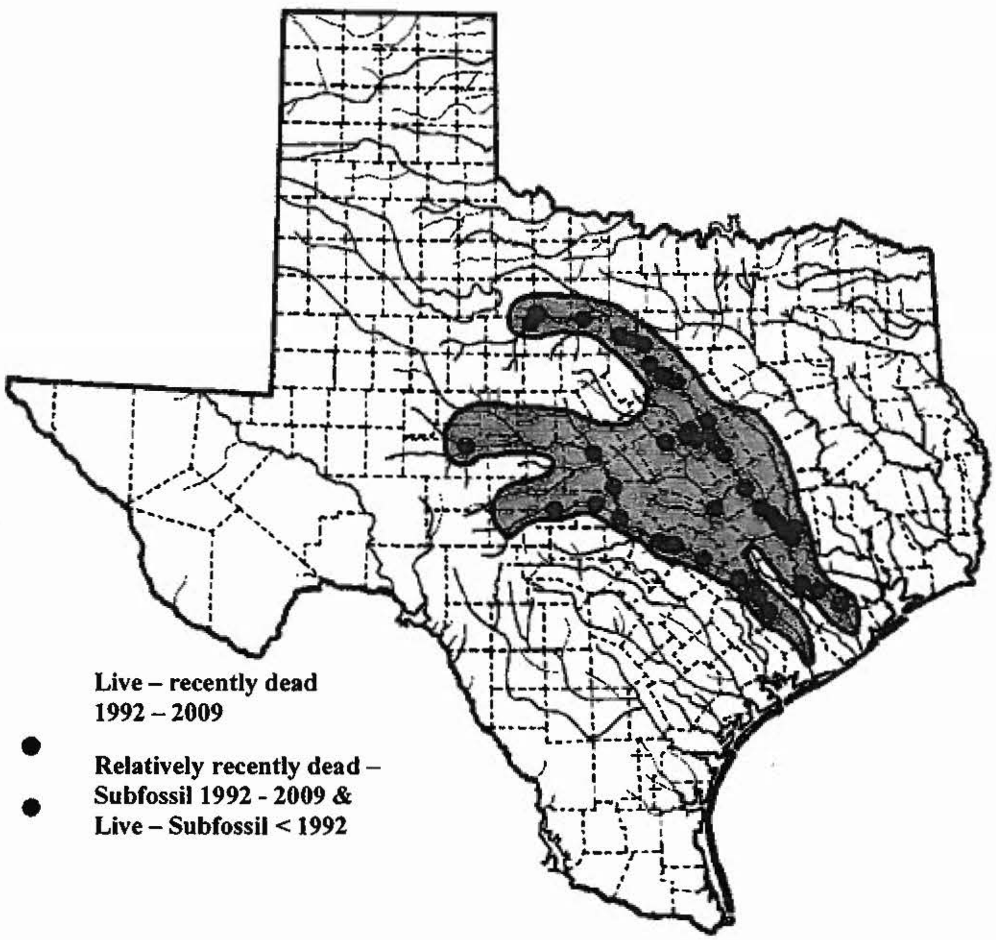


Figure 1. Presumptive historic range of Texas Fawnsfoot (*Truncilla macrodon*) shown in blue in Central Texas.

Figure 2. Populations of Texas Fawnsfoot (*Truncilla macrodon*) reported alive to recently dead since 2004.

Population levels

Historically, Texas Fawnsfoot remained rare to uncommon throughout its range and early collections generally included limited numbers. From the 1960s through the 1990s, malacologists working in Central Texas (e.g., H.D. Murray, R.W. Neck, C.M. Mather, J.A.M. Bergmann, R.G. Howells) continued to find few specimens and population locations (Howells 2002, 2006, 2009). In 2006, 2007, and 2008, Howells (2006), Karatayev and Burlakova (2007), and Randklev et al. (2010) found additional specimens in the Central Brazos River and its associated tributaries. In 2008, Durlak (2009) and Leggett (2009) reported A.Y. Karatayev and L.E. Burlakova found a population in the Colorado River, Colorado County, and in 2009, N.A. Johnson (University of Florida, pers. comm.) also found living specimens at this site. It is interesting that despite numerous survey efforts in previous decades by knowledgeable individuals significant new discoveries occurred in recent years. Some of these new locations had not been previously examined. However, 2007 was an extremely wet year. One upriver site in the Guadalupe drainage recorded 129 cm of rainfall in 2007. Then, subsequent years were very dry. The same upriver site had only 30 cm in 2008 and 31 cm from January through August in 2009 (R.G. Howells, unpublished data). It is possible very high-water conditions displaced Texas Fawnsfoot specimens from scattered established sites and concentrated numbers of them in depositional areas in 2007. These, then, were more easily located in late 2007, 2008 and early

2009 when river levels were very low. Some earlier Texas Fawnsfoot collection records were clearly associated with high-water deposition (Howells 2000). It needs to be determined if new collection records and reported densities are artificially inflated by depositional concentration or whether these "populations" will continue to endure over a long period of time. Apparent status at recent individual locations includes:

Lower Clear Fork Brazos River:
Two recently dead specimens were reported in the Clear Fork Brazos River, Young County, in 2009 (D.P. Johnson, Houston, Texas, pers. comm.). Several very recently dead specimens were found upstream at two sites near Crystal Falls, Stephens County, in 1994 (Howells 1996) as well. Neither area appears to have been surveyed again since these reports and no estimations of population size are available.

Brazos River – Vicinity of the Confluence of the Navasota River:
A number of living specimens, shells, and valves have been reported from the Brazos River from Milam and Robertson counties downstream to Washington and Grimes counties (R.G. Howells database). In 1999, some 34 very recently dead specimens were found on a rock and gravel bar in the Brazos River, Brazos County, following a high-water period (Howells 2000) suggesting a population could occur at this site or just upstream. Further downstream, M.E. May (TPWD, pers. comm.) reported two living specimens in 2003. A small, reproducing population was found downstream of the confluence of the Navasota River in 2008 (Randklev et al., 2010), with confirmation of 10 living individuals producing a density estimate of $0.06/m^2$ and catch-per-unit-effort (CPUE) of 6/hour.

Lower Brazos River:
Karatayev and Burlakova (2007) reported finding a single living Texas Fawnsfoot in the Brazos River, Austin and Waller counties, in 2007. An earlier survey at this site in 1996 by TPWD produced only a single long dead valve (Howells 1997). It remains to be determined if a population is present at this site or just upstream, or if specimens found here were washed down river from sites further upstream during flood conditions.

Colorado River – Colorado County:
Two living specimens were found here by N.A. Johnson (University of Florida, pers. comm.) in 2009. Durlak (2009) and Leggett (2009) reported that A.Y. Karatayev and L.E. Burlakova also found a population at this location in 2009 and estimated the population size to be approximately 3,000 specimens (though no details regarding sampling methods, data obtained, or calculations employed were presented).

CONSERVATION MEASURES

When Texas Parks and Wildlife Department (TPWD) created its first freshwater mussel harvest regulations in 1992 and 1993, minimum size limits were established and a series of no-harvest sanctuaries were designated. At that time, minimum harvest sizes focused on commercial shell species of unionids, but included a minimum of 63.5 mm (2.5 inches) in shell height for all non-commercial species, including Texas Fawnsfoot. The largest Texas Fawnsfoot specimen measured by the author to date was 60 mm shell length (R.G. Howells, unpublished data) and substantially less than legally harvestable size. Now, listing by TPWD in December 2009 as a legally threatened species prohibits all harvest (except under special permit).

No locations specifically supporting living Texas Fawnsfoot populations were known when TPWD no-harvest sanctuaries were first established. Howells et al. (1997) provided a list of the designated TPWD no-harvest mussel sanctuaries. Ultimately in 2006, no-harvest sanctuaries were redefined and were formally passed by the TPW Commission in July 2007 (Texas Parks and Wildlife Department Proclamation 57.156-57.158; Howells 2009). Although the only two sites that do appear to support populations of Texas Fawnsfoot were identified only after these regulations were passed, one no-harvest sanctuary in the Brazos River downstream of Possum Kingdom Reservoir was specifically designated with this species in mind (based on specimens found in this area in the 1990s). Several other sanctuary sites could potentially contain Texas Fawnsfoot as well.

It should be noted that TPWD no-harvest sanctuaries only legally preclude harvest of mussels from those designated waters and their tributaries. Mussel sanctuaries do not prohibit other area activities that could potentially have negative impacts on local unionids however.

In December 2009, TPWD moved to list Texas Fawnsfoot as a legally threatened species.

LISTING FACTORS

Habitat or Range (Destruction, Modification, Curtailment)

Throughout much of Texas, historic land utilization resulted in modification and elimination of some aquatic habitat critical to Texas Fawnsfoot and other unionids. Extensive overgrazing beginning in the mid-1800s resulted in significant loss of vegetative cover and soils, with subsequent increases in runoff causing scouring of many streams and rivers (Howells 1994). Scouring impacts on Texas waters have been further exacerbated by changes in rainfall patterns to fewer light and moderate showers and longer periods of drought punctuated by heavy, damaging floods (http://www.epa.gov/climatechange/science/recentpsc.html; Howells and Power 2004). Additionally, decade-average rainfall has increased over the past century with more rain falling in the early 1990s than fell in 1900-1910 (Howells 1995). Collectively, overgrazing, reduction in vegetative cover and soils, increasing numbers of scouring floods, and general increases in amount of precipitation have combined to dramatically reduce acceptable mussel habitat in many Texas waters. Anthropogenic developments (e.g., impervious surfaces, water flow manipulations) have magnified these impacts.

Central Texas in particular experienced a major drought in the late 1970s followed by several record floods between 1978 and 1981 (Howells et al. 1997; Howells and Power 2004). Some Central Texas mussel population sites that held assemblages of living unionids in the 1970s (including Texas Fawnsfoot) no longer supported living mussels when surveyed in the 1980s and 1990s (Howells et al. 1997). These events helped reduce the abundance and distribution Texas Fawnsfoot and other unionids.

In addition to past and more-recent negative impacts (that continue), other broad-ranging and site-specific threats exist as well. By recent population site, these include:

Lower Clear Fork Brazos River:
Many of the areas drained by this branch of the Brazos River run through ranch and farm lands. The City of Abilene is present in the upper reaches of this branch and a new reservoir (Cedar Ridge Reservoir) is planned. However, this impoundment would be located well upriver of the locations where Texas Fawnfoot has been documented over the past 20 years. Given that other Texas Fawnsfoot specimens have also been found downstream of Possum Kingdom Reservoir and Lake Granbury (R.G. Howells database), if minimal flows are maintained during and after reservoir construction and building efforts are environmentally conscientious, impact on possible surviving Texas Fawnsfoot specimens in the lower reaches of the Clear Fork Little Brazos River should be limited. Some runs of the Clear Fork Brazos River have high levels of organic material in their substrates suggesting possible sources of nutrient input that need to be identified and evaluated (R.G. Howells, unpublished data).

Brazos River – Vicinity of the Confluence of the Navasota River:
Much of the central Brazos River has moderate to high sand banks that are unstable and frequently collapse into the river and associated bars of deep-shifting sands. Both are undesirable freshwater mussel habitat. Localized areas of more desirable habitat, therefore, can be particularly important to mussel survival in the area and need to be preserved. The City of Waco is located upstream in the central Brazos River drainage and other tributaries drain from towns of Temple, Georgetown, and Killeen; the Fort Hood military reservation; and ranch and farm lands. All carry an array of possible impact concerns.

Lower Brazos River:
This stretch of the Brazos River has particularly high, unstable, sandy banks and associated sandy bars. It is crossed by a major rail line and interstate highway. However, it has yet to be demonstrated whether a significant Texas Pimpleback population is present here or not.

Colorado River – Colorado County:
This location has not been examined by the author, so specific details are wanting. Generally, this stretch of the lower Colorado River includes surrounding agricultural lands, a few smaller urban areas, and some industrial sites as well as a number of highway and railroad crossings. No specific impact threats to Texas Fawnsfoot have been evaluated at this time.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Because of its small size and shell that has no particular commercial interest, there has been no noted overutilization problems impacting Texas Fawnsfoot populations in Texas waters (Howells 1993; R.G. Howells, unpublished data). Occasional collection for use as live bait may occur, but has not been documented to date, and no record of excessive impact from scientific or educational harvest has been reported. Shell collectors have reported taking this species in recent years, but there are no estimates of the extent of this harvest (R.G. Howells, unpublished data).

To date, neither state nor federal resource managers have directed or monitored scientific activities and their impact on Texas Fawnsfoot populations. It is possible multiple researches may survey, sample, and even remove specimens from the same area in relatively narrow windows of time. It remains undetermined if this activity has been problematic at known population sites. Volunteer training and sampling programs associated with freshwater mussel research similarly have limited time and place focus and may also potentially conflict with formal scientific research and management activities.

Public release of sensitive population location information has also been problematic regarding the security of some rare unionids in Texas. Some organizations have responded to this informational risk and modified their open releases of potentially harmful information. Unfortunately, even this report contains information that could be potentially misused and could be employed with negative impacts to surviving Texas Fawnsfoot populations.

Disease or Predation

No specific diseases have been reported in the published literature or observed during recent studies of Texas Fawnsfoot (R.G. Howells, unpublished data). Natural predators, like catfishes (Ictaluridae) and freshwater drum (*Aplodinotus grunniens*), no doubt consume some Texas Fawnfoot, but no confirmation has been documented to date. Neither disease nor predation appears to be problematic issues for this species.

Existing Regulatory Measures

Until December 2009, neither state nor federal regulations offered Texas Fawnsfoot threatened or endangered species protections despite its apparent rarity and declining status. Several no-harvest mussel sanctuaries might include this species (one probably does), but otherwise, none of the existing populations are confirmed to be present in designated mussel sanctuaries. The minimum harvest size of 2.5 inches in shell height precluded legal harvest from the earliest TPWD mussel regulations. In December 2009, TPWD has listed Texas Fawnsfoot as a legally threatened species, blocking all legal harvest (except under special permits).

Other Natural or Manmade Factors

Another source of potentially extensive and adverse, yet difficult to quantify, impact involves the increasing human population within the range of Texas Fawnsfoot and the resulting increased pumping of aquifer waters for direct and indirect human uses. Flows in many Texas springs have been reduced or eliminated, with subsequent reduction or elimination of spring feeds to streams (Brune 1975, 2002). Historically, water allocation plans in Texas have not focused on preservation of rare mussel resources.

NEEDED INFORMATION

Taxonomy and Genetics

To date (March 2010), no published reports have addressed biochemical genetics of Texas Fawnsfoot; none have compared it to other *Truncilla* species or compared populations from the Brazos and Colorado basins. Additionally, other genetic approaches, like DNA barcoding, could still contribute to helping to define this species. Probably many such activities can be conducted with mantle clips or other non-lethal sampling methods.

A particularly biochemical genetic need is the analysis of specimens from the upper Trinity River drainage, particularly in waters southeast of the Dallas area, that superficially resemble Texas Fawnsfoot (compressed, elongate, pointed posteriorly). Morphological (conchological) features have been insufficient for positive resolution of species status of some specimens from this area. Determining if these are Fawnsfoot or Texas Fawnsfoot is critical to the evaluating the conservation status of both species in Texas waters.

Distribution

Although the distribution of Texas Fawnsfoot has been refined over time and is now believed restricted to the Colorado and Brazos drainage basins, questions still remain about the status of some specimens from the upper Trinity River. Additional field surveys in the upper Trinity River are needed and should be linked to appropriate genetic studies of material from these waters.

Until 2008, no actual population sites had been reported for Texas Fawnsfoot. Most records represented moribund specimens, shells, and valves found on bars or river banks after high-waters had receded. Clearly this species has been difficult to locate during field surveys. Additional survey efforts throughout the Brazos and lower Colorado drainages are needed. Such surveys also need to focus on areas between access points, not simply at highway crossings and below dams. Survey efforts also need to be conducted over time, not as simple snapshot views, and need to take advantage of favorable sampling conditions (e.g., low-water periods).

Reproductive Biology

Spawning and brooding seasons are unknown, glochidia undescribed, and hosts undetermined for Texas Fawnsfoot. Good species management efforts cannot be employed when such critical aspects of species biology are not known. Unless the Colorado County population is sufficiently large, Texas Fawnsfoot may already be too rare to justify sacrificing females to obtain fecundity estimates.

Environmental Aspects of Biology

Physical habitat and critical physicochemical parameters associated with Texas Fawnsfoot have been very poorly reported in the scientific literature and need to be better defined. These issues need to be examined repeatedly over an extended period of time rather than simply as snapshot views that can be more misleading than instructive. Further, habitat and physicochemical measurements need to be applied specifically to Texas Fawnsfoot and not collectively to broad unionid assemblages of mixed species.

When species are very rare, difficult to observe or sample, and sensitive to disturbance, it can be extremely challenging to define critical aspects of species biology that relate to management of the species (e.g., in-stream flow limitations, minimum and maximum lethal temperatures and oxygen levels, critical spawning and incubation temperatures, etc.). Documenting these various elements for Texas Fawnsfoot biology on those occasions when opportunity presents can be important, especially when multiple observations can be combined into meaningful summaries. Opportunities to record elements of species biology should not be neglected. It should also be noted that measurements of physicochemical parameters associated with Texas Fawnsfoot population sites need to be documented over long periods of time (years) to be meaningful. Quick snapshot studies in areas often subjected to extensive flood and drought extremes may not provide a good over-all view of the full range of relevant flow rates, water chemistry, and related parameters. Indeed, short snapshot studies can sometimes be more misleading than instructive.

Threats to Continued Survival

Continued human population growth and development in Central Texas are certain to have increasing impacts on native unionid populations. Habitat loss, modification, or disturbance in conjunction with decreasing water supplies can be anticipated. Threats to those in the lower Colorado River remain largely undocumented. Populations in the central Brazos River drainage are potentially many, but here too, are generally unstudied and unreported. Except for possible survivors in the lower Clear Fork Brazos River and an apparent population in the lower Colorado River, the other known surviving Texas Fawnsfoot specimens appear to occur in limited numbers at scattered locations in the main Brazos River run primarily from below Possum Kingdom Reservoir downstream to below the mouth of the Navasota River. Occurring at scattered locations over an extended area helps limit the impact of possible localized losses. However, when survivors at most existing locations are confined to a single river run, catastrophic events (drought, toxic spills, etc.) could have dramatic potential impacts to species conservation status.

PERSONAL CONCLUSIONS AND RECOMMENDATIONS

Texas Fawnsfoot is a unique unionid within the fawnsfoot complex that is endemic to Central Texas. Although two newly discovered populations were located in 2008 and 2009, all but one area where survivors are known or expected are within the same drainage basin. Although one population may be more numerous than historical records suggest, Texas Fawnsfoot should still be legally listed as an endangered species under both state and federal regulations.

Many elements of species biology, including reproductive biology, remain unknown and should be the subject of scientific investigation whenever possible, but with the caveat the species may already be too rare at all but possibly one location to permit some types of intense study.

RELEVANT LITERATURE

Brune, G. 1975. Major and historical springs of Texas. Texas Water Development Board, Report 189, Austin.

Brune, G. 2002. Springs of Texas. Volume 1. Springs of Texas. Texas A&M Press, College Station.

Burlakova, L.E. 2010. Unionid diversity and rarity in Texas. Texas Parks and Wildlife Department, Mussel Workshop, Austin.

Durlak, M.A. 2009. Great Lakes scientists discover rare species of mollusk. Buffalo State: The Bulletin 54(35): July 16, 2009.

Howells, R.G. 1993. Preliminary survey of freshwater mussel harvest in Texas. Texas Parks and Wildlife Department, Management Data Series 100, Austin.

Howells, R.G. 1994. Longhorn cattle and windmills linked to mussel declines. Info-Mussel Newsletter 2(5):5.

Howells, R.G. 1995. Changes in precipitation patterns in Texas. Info-Mussel Newsletter 3(4):6.

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

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

Howells, R.G. 2000. Distributional surveys of freshwater bivalves in Texas: progress report for 1999. Texas Wildlife Department, Management Data Series 170, Austin.

Howells, R.G. 2002. Distributional surveys of freshwater bivalves in Texas: progress report for 2003. Texas Wildlife Department, Management Data Series 200, Austin.

Howells, R.G. 2003. Declining status of freshwater mussels of the Rio Grande. Pages 59-73 *in* G.P. Garrett and N.L. Allen, editors. Aquatic fauna of the northern Chihuahuan Desert. Texas Tech University Press, Lubbock. (Initially presented in 2001).

Howells, R.G. 2004. Texas freshwater mussels: species of concern. Texas Parks and Wildlife Department, Wildlife Diversity Conference, San Marcos, Texas. 18-20 August 2004.

Howells, R.G. 2005. Distributional surveys of freshwater bivalves in Texas: progress report for 2004. Texas Wildlife Department, Management Data Series 233, Austin.

Howells, R.G. 2006. Statewide freshwater mussel survey. State Wildlife Grant Final Report T-15-P, Texas Parks and Wildlife Department, Austin.

Howells, R.G. 2009. Biological opinion: conservation status of selected freshwater mussels in Texas. BioStudies, Kerrville, Texas.

Howells, R.G. 2010. Guide to Texas freshwater mussels. BioStudies, Kerrville, 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. Niamo. 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.

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

Howells, R.G., and P. Power. 2004. Freshwater mussels of the San Marcos-Blanco River basin: history and status. 107th Annual Meeting of the Texas Academy of Science, Kerrville, Texas, 6 March 2005

Johnson, R.I. 1999. Unionidae of the Rio Grande (Rio Bravo del Norte) system of Texas and Mexico. Occasional Papers on Mollusks 6(77):1-66.

Karatayev, A.Y., and L.E. Burlakova. 2007. Distributional surveys and habitat utilization of freshwater mussels. Final report. Buffalo State College, Buffalo, New York. Prepared for the Texas Water Development Board, Austin.

Lea, I. 1859. Descriptions of seven new uniones from South Carolina, Florida, Alabama, and Texas. Proceedings of the Academy of Natural Sciences of Philadelphia 11:145-155.

Leggett, M. 2009. Austin area mussel is a big discovery. The Austin-American Statesman, Tuesday, August 6, 2009.

Rafinesque, C.S. 1820. Morphographie des coquilles bivalves fluviatiles de la riviere Ohio. Contentant douze generes et soixante-huit especes. Annales generales des sciences Physiques a Bruxelles 5(15):287-322, pls. 80-82.

Randklev, C.R., B. Lundeen, R.G. Howells, and J.H. Kennedy. 2010. Habitat preference and first account of a living population of Texas fawnsfoot, *Truncilla macrodon* (I. Lea, 1859), in the Brazos River, Texas. The Southwester Naturalist 55(2):302-303.

Simpson, C.T. 1914. A descriptive catalogue of the naiades, or pearly fresh-water mussels. Parts I-III. Bryant Walker, Detroit, Michigan.

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

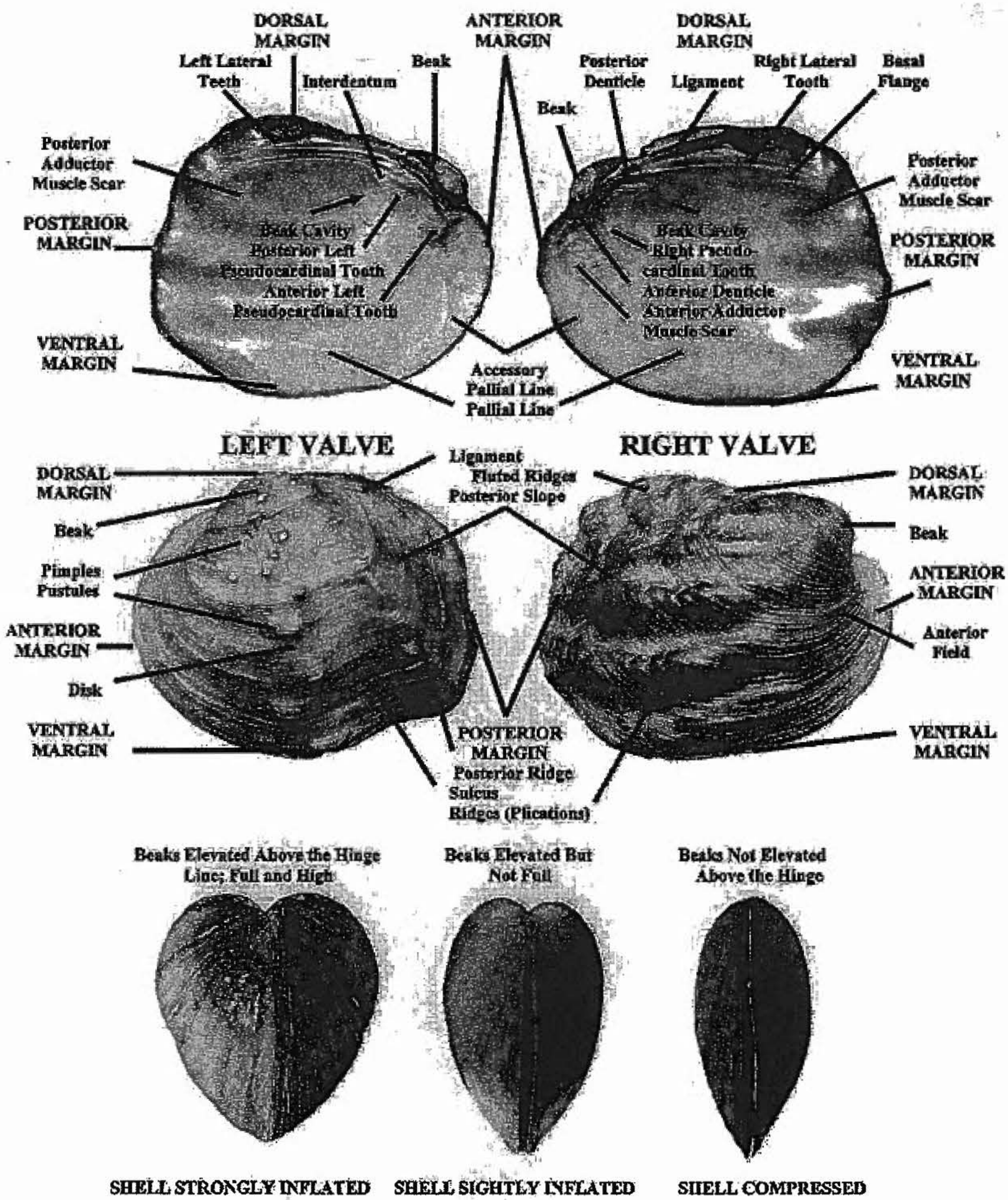
Turgeon, D.D., and nine coauthors. 1998. Common and scientific names of aquatic invertebrates of the United States and Canada: Mollusks. American Fisheries Society Special Publication 16, Bethesda, Maryland.

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

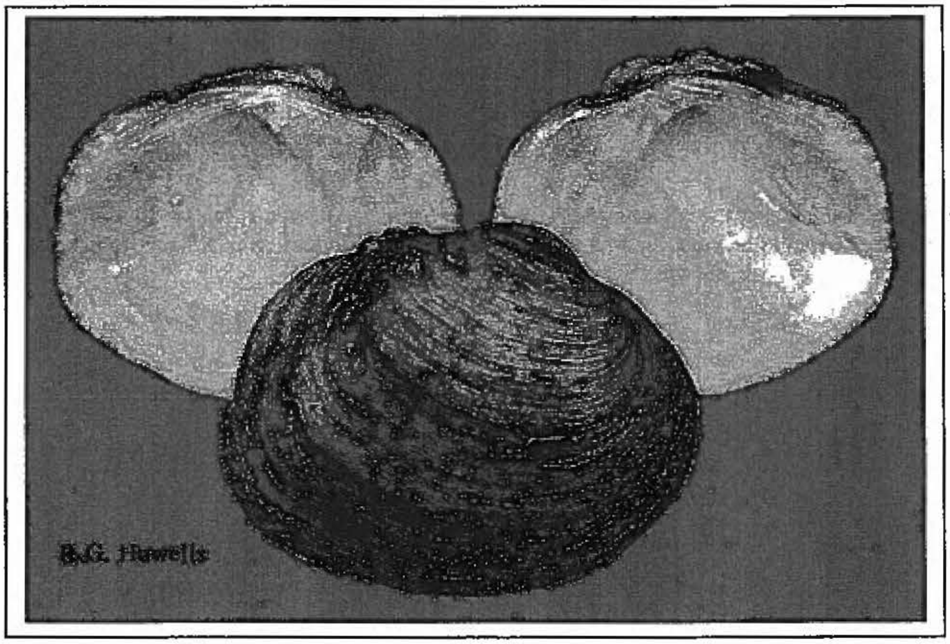
GLOSSARY OF SELECTED TERMS

Ala – a wing-like extension of the dorsal shell margin; usually posterior to the beak, sometimes anterior; "alate" means having a wing.
Beak – the umbo, the elevated (usually) part of the shell on the dorsal edge, anterior to the ligament in freshwater mussels, the oldest part of the shell.
Beak cavity – the inside of the beak within each valve, often forms a pocket or depression.
Beak sculpture – patterns of ridges, loops, and bumps that, like finger prints, can be unique to some species; often eroded and missing.
Chevron – V or arrowhead shaped, sometimes paired into Ws.
Compressed – flattened or pressed together.
Denticle – small (usually) tooth-like structures that may be present anterior and posterior to the right pseudocardinal tooth.
Concentric – circles, rings, or crescents with a common center or origin.
Dimorphic – having two distinct forms.
Ecophenotype – forms of a single species that are physically distinct in different environments.
Elliptical – ellipse shaped or an elongated oval.
Elongate – long or extended.
Endemic – found only in a particular area.
Exfoliated – eroded.
Extirpated – extinct in a particular area.
Fecundity – the number of eggs and/or larvae.
Fluted – grooves and ridges with a ruffle-like appearance.
Growth-rest lines – alternating dark and light concentric lines in a mussel shell indicating periods of slow and fast growth, respectively. In the far north, these may be annuli (formed each year), but in Texas growth may slow during summer droughts or continue over mild winters (therefore growth-rest bands cannot be counted as an indication of age).
Hinge – the area where the right and left valves (shell halves) articulate and are connected by an elastic ligament.
Hinge teeth – lateral and pseudocardinal teeth.
Inflated – swollen, expanded.
Interdentum – the area of the hinge between the lateral and pseudocardinal teeth; absent in some species.
Iridescent – a lustrous, pearly, or rainbow color appearance; only freshwater mussels and marine pearl oysters have iridescent nacre.
Lachrymose – drop-shaped pustules.
Lateral teeth – elongate structures along the hinge in many species located only posterior to the beak in freshwater mussels; absent in some species; these stabilize the hinge and are not true teeth at all.
Lunule – a cavity or depression, also called a sinus.
Nacre – the inner layer of the shell, mother-of-pearl.
Oval (ovate) – egg shaped.
Pallial line – a linear depression inside each valve interior to the shell margin, where the soft mantle tissues were attached.
Periostracum – the outer shell layer, shell epidermis.
Plications – folds, ridges, particularly multiple ridges.
Posterior ridge – a ridge on the posterior half of the shell running from the beak to the margin.
Posterior slope – shell area between the posterior ridge and the dorso-posterior margin.
Pseudocardinal teeth – tooth-like structures located below the beak area, usually two in the left valve and one in the right valve or none at all; may be compressed and leaf-like to heavy and molar-like.
Quadrate – square; often expressed as subquadrate (nearly quadrate).
Pustule – a bump or raised knob on the shell exterior.
Serrated – notched or grooved.
Shell margin – the exterior circumference edge of each valve (sometimes this term excludes the hinge line).
Solid – hard, thick, not soft and chalky.
Striated – with fine lines or grooves.
Truncate – shortened or squared off (sometimes obliquely).
Tubercle – projection from the shell, may be pointed, rounded, or knob-like.
Umbo – beak.
Valve – one half of a bivalve shell.
Wing – ala.

FRESHWATER MUSSEL SHELL FEATURES



TEXAS PIMPLEBACK (*QUADRULA PETRINA*): SUMMARY OF SELECTED BIOLOGICAL AND ECOLOGICAL DATA FOR TEXAS*



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April 2010
*** Not for Internet Distribution**

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Robert G. Howells is a fisheries scientist and aquatic ecologist. He has conducted research on freshwater mussels in Texas since 1992, in addition to his general fisheries studies and work with exotic species. Howells has served on the staff of the Cleveland Museum of Natural History; conducted environmental studies for 10 years for Ichthyological Associates, Inc., an environmental consulting firm; and spent 22 years with Texas Parks and Wildlife Department's Heart of the Hills Fisheries Science Center. He is the senior author of the book, Freshwater Mussels of Texas, and has written numerous scientific journal articles, symposia proceedings, technical reports, and informational guides. He is a member of the Freshwater Mollusk Conservation Society, American Malacological Society, and is currently working with others with the American Fisheries Society to update the distribution and conservation status of freshwater mussels of the United States, Canada, and Mexico. Howells retired from state employment in 2006, but has continued to study, write, and consult (BioStudies).

FUNDING SUPPORT

Funding support for this report was provided by Save Our Springs Alliance, P.O. Box 684881, Austin, Texas 78768; www.SOSAlliance.org. Individual funding was also provided by the Kirk Mitchell Environmental Law Fund and WildEarth Guardians. Copies of this report can be obtained from SOSA.

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ABOUT THIS REPORT

This report has been primarily drafted as a technical report, but introductory text, a glossary, and labeled shell feature figures have been included to assist non-malacologists with aspects of freshwater mussels. Within this report, shell length is abbreviated "sl" and other shell dimensions are typically written out. From the onset of freshwater mussel studies by Texas Parks and Wildlife Department (TPWD) in 1992, time-since-death estimates were designated for shells, valves, and fragments that were encountered in surveys (e.g., very recently dead = soft tissues still attached to shells and valves). These were defined in TPWD's annual Management Data Series (MDS) mussel survey reports and can be found in Howells (2003) that is available on the Internet. These shell condition designations provided possible status indications ranging from whether living specimens may still occur at a particular site to locations where mussels occurred in the area once, but appear to have been lost long ago. Mussel collection site locations on maps herein sometimes use a single dot to designate two or more collection sites that are in close proximity. Therefore, simply counting dots on these maps may not necessarily represent the total number of collection records or sites. Finally, recent data from several reports that are in preparation or in press may or may not have been included based on availability of these data, and some unconfirmed amateur volunteer records may also have been omitted.

ACKNOWLEDGMENTS

Special appreciation goes to N.A. Johnson, C.M. Mather, J.A.M. Bergmann, and W.H. McCullagh for providing data used in preparation of this report. Thanks also to T.D. Hayes and A.J. Haugen for invaluable editorial input.

INTRODUCTION TO FRESHWATER MUSSELS

Freshwater Bivalves

Many types of bivalve mollusks are called clams or mussels. Neither term is really specific to one group. A number of bivalve groups live in fresh water in Texas. Freshwater mussels, also called pearly freshwater mussels or unionids (Family Unionidae), have over 50 species in Texas and about 300 in North America. A number of tiny fingernailclams (Sphaeriidae) are also present in many waters. Exotic Asian clam (Corbiculidae) invaded Texas in the 1950s and 60s, and exotic zebra mussel (Dreissenidae) was found in Texas in 2009. Several native estuarine clams and mussels can also be found in the lower reaches of coastal rivers.

Native Freshwater Mussels

Freshwater mussels do not attach to solid objects (as adults) like true marine mussels and zebra mussels, but dig into substrates of mud, sand, and gravel. They usually have distinct sexes. Females brood eggs and developing larvae (called glochidia) in marsupial pouches on their gills. Glochidia are parasites on fishes. Upon release from the female, glochidia have only hours to find the appropriate species of host fish that has no immunity to infection and attach to the correct location on that fish or die. After a few weeks or months, the transformed juveniles drop from the host to begin life in the substrate. Generally little harm comes to the host.

Role in the Ecosystem

Freshwater mussels are Mother-Nature's biofilters that feed by removing algae, bacteria, and organics from the water. They remove environmental contaminants and concentrate them in their tissues. Unionids also serve as food for fishes, birds, mammals, and other organisms. They mix water body substrates much as earthworms do in garden soils.

Historic Harvest

Native Americans harvested freshwater mussels for food, tools, ornament, and natural pearls. In the 1890s, shells of some species became important in button manufacturing (but to a limited extent in Texas). Some Texas mussels produce gem-quality pearls and they have been taken for this purpose since early Spanish times.

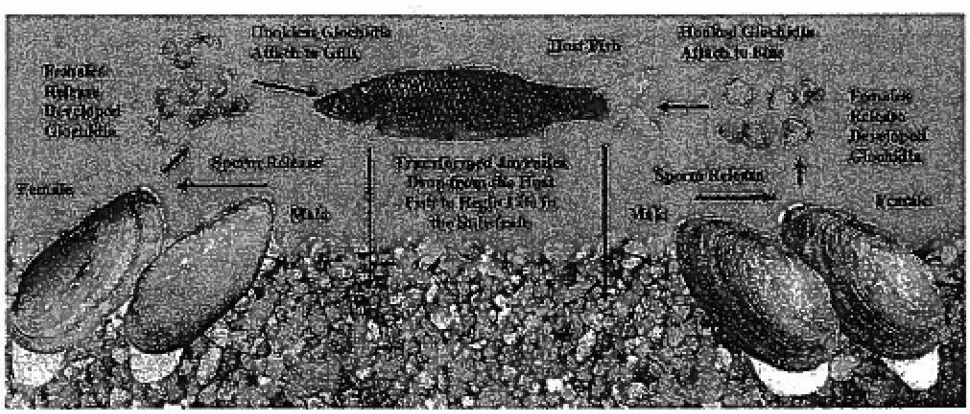
Recent Harvest

Limited harvest for pearls continues in Texas. In the late 1900s, some species were taken for their shells that were used to produce implant nuclei needed to create cultured pearls. They are occasionally captured for arts-and-crafts work, bait, and shell collectors. A license is required for any freshwater mussel harvest and some species are legally protected.

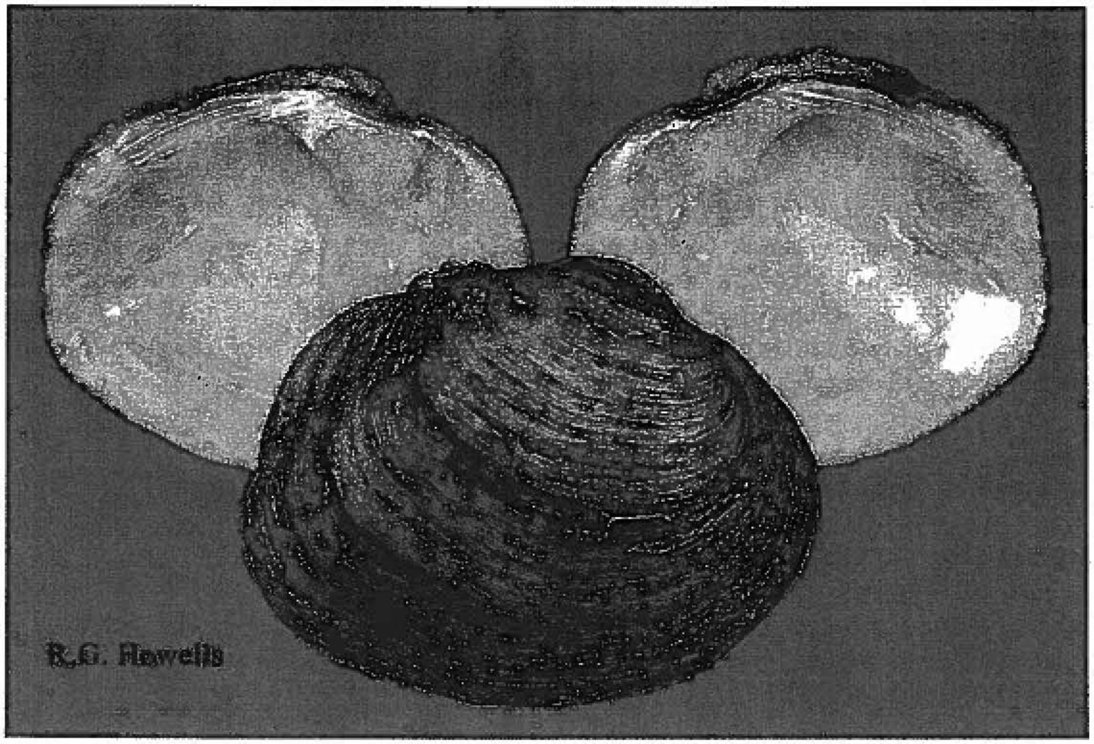
Conservation Status

Freshwater mussels are sensitive indicators of environmental quality. When there is any degradation in the ecosystem, these are usually the first organisms to decline or vanish. As a result, perhaps 80% of North American species are extinct, endangered, threatened, or will be soon. The State of Texas lists 15 species as legally threatened and another as endangered. Many of these are now under consideration for additional federal protection.

Freshwater mussel life cycle.



TEXAS PIMPLEBACK
Quadrula petrina (Gould 1855)



DESCRIPTION

Texas pimpleback has been described by Simpson (1914), Howells et al. (1996), and Howells (2002, 2010). Size is often larger than other pimpleback species in Texas and shell length is often 60-90 mm sl, but can exceed 103 mm sl. Shell outline is subquadrate, subrhomboidal, to nearly oval; slightly to moderately inflated; solid; and moderately thick. Beaks are full, high, and elevated moderately above the hinge; beak cavities are deep. The posterior ridge is broadly rounded, usually not strongly pronounced, but sometimes with a second or third ridge on the posterior slope. Aside from growth-lines, the shell disk is only very rarely sculptured, but occasionally shows a vague suggestion of pustules on the mid-disk. Many specimens show a series of curving ridges on the posterior slope (not evident in the specimen shown above). Pseudocardinal teeth (two left and one right) are massive and usually heavily grooved, with the anterior left tooth often triangular and leaning forward; small to moderate anterior and posterior denticles are often present in the right valve. Lateral teeth (two left and one right) are heavy and slightly curved, with a basal flange usually running the length of the right tooth. The interdentum is short, but wide. Externally, coloration ranges from yellowish-tan to dark brown, with some individuals mottled or obscurely rayed in dark green. Internally the nacre is white and iridescent posteriorly.

SPECIES BIOLOGY

Life History

Age and size at maturity
The smallest brooding female documented was 45 mm sl (Howells 2000a), but no estimates of age at maturity were found during preparation of this report.

Brooding season
Howells (2000a) reported finding females with marsupial eggs in July and August and marsupial glochidia June through August (with both eggs and glochidia in July). However, Howells (2000a) also noted that glochidia found in marsupia in August were observed in 1997, a year with a cold, wet spring that appeared to delay reproductive seasonality in other unionids. In summary, it appears that Texas Pimpleback may brood from late May through August, with varying timing reflecting seasonal temperature patterns.

Fecundity
No estimates of species fecundity were found during preparation of this report.

Glochidia
Glochidia are hookless, elliptical in shape, 0.205-0.246 mm sl, 0.311 mm in shell height, and 0.136 mm along the hinge line (Howells et al. 1996). Hoggarth (1994) also described Texas Pimpleback glochidia as 0.24 mm sh, 0.29 mm shell height, and 0.13 mm along the hinge line and provided a photograph of the glochidium.

Hosts
No hosts have been confirmed for Texas Pimpleback. Howells (1997) reported glochidia attached to and encysted on Flathead Catfish (*Pylodictis olivaris*), Yellow Bullhead (*Ameiurus natalis*), and Bluegill (*Lepomis macrochirus*), but none transformed to the juvenile stage. Nonetheless, catfishes (Ictaluridae) are used by other quadrulids and probably serve as hosts for Texas Pimpleback.

Behavior
No reports of Texas Pimpleback behavior were found during publication of this report.

Habitat requirements
Habitat associations have been reported by Howells et al. (1996) and Howells (2002). Texas Pimpleback typically occurs in rivers and moderate-size streams in flowing waters, usually on mud, sand, gravel, and cobble, occasionally in gravel-filled cracks in bedrock slab bottoms. No natural lakes occur within its range and no populations have been documented in reservoirs. It has not been recorded at depths over 2 m and appears to prefer more shallow areas. Texas pimpleback appears to avoid soft silt, shifting sands, and scoured areas.

Horne and McIntosh (1979) reported on Texas Pimpleback in the lower Blanco River upstream and downstream of a water treatment facility. They noted Texas Pimpleback was one of only two species found at flow rates greater then 1 m/sec with substrates of cobble and mixed gravel and boulders. They monitored several chemical parameters and conducted tolerance tests, but did not apparently include Texas Pimpleback in these tests. Nonetheless, their measurements of chemical components and associated mussel distribution can provide insight into water chemistry associated with Texas Pimpleback. No living Texas Pimpleback specimens have been subsequently reported at this site.

Specific examples of locations where Texas Pimpleback has been found alive since 1992 include:

Concho County - Concho River upstream of the Paint Rock area: Much of this area of the Concho River has extensive, scoured, bedrock-slab bottoms with gravel-filled cracks. Some areas of the upper reaches also contained areas of mud-sand and gravel and small pools. Just north of Paint Rock (city), a long run of bedrock ends at the upper reaches of pooled waters resulting from a small, city park dam just downstream. Flood waters sometimes wash mussels from upstream areas and deposit them at the foot of this bedrock run along with mud, gravel, and Asian clams (*Corbicula* spp.). In this depositional area, Asian clam density was often so great as to become a major element of the substrate in which Texas Pimpleback specimens lived and apparently reproduced. No Texas Pimpleback or other unionids have been found between the upper reaches of this pooled area and the dam downstream. Below this park dam, solid bedrock runs for several km and supports limited numbers of mussels. Generally the depth in areas where Texas Pimpleback occurs is less than 1 m. This run of river is downstream of the City of San Angelo and its water-management practices can dramatically impact flow rates in this area. Between San Angelo and Paint Rock, some landowners may withdraw waters from the river as well; however, spring flows and tributary streams also input water downstream of San Angelo. Adjacent banks are largely ranch land. Some landowners have fenced their banks to protect them from hoofstock damage, but others have not (and few unionids occur in areas where livestock has beaten down banks and damaged the river bed). Banks are moderate to substantially elevated heights in this region (R.G. Howells, unpublished data).

Runnels County – Elm Creek: Areas frequented by Texas Pimpleback here included mud, sand, and gravel, with swept bedrock and cobble areas (R.G. Howells, unpublished data). Water depths are typically quite shallow and less than 1 m (R.G. Howells, unpublished data).

Menard County – San Saba River: At this site in the San Saba River, unionids, including Texas Pimpleback, are present in sand and gravel areas in flowing waters among heavy cobble and macrophyte beds (R.G. Howells, unpublished data). Here, both mussels and rocks are often heavily encrusted with calcium deposits (confounding specimen identification). This is the only site where heavy macrophyte growths have been associated with Texas Pimpleback presence. Recently dead shells found at downriver sites in recent decades were located following flood conditions that may have swept them from upstream locations.

Hays County – Upper San Marcos River: The San Marcos River headwaters are spring fed and run throughout the year. Generally, freshwater mussels do not occur in spring head areas due to lack of food in the water column and non-fluctuating water temperatures. However, a short distance below the headwaters of the San Marcos River, the Blanco River (similar in length) enters and influences water and habitat conditions. Living Texas Pimpleback specimens found here in 2004 (Howells and Power 2004; Howells 2005) were located near the confluence of these rivers. Substrates in this stretch of river are often swept sand and gravel, with mud and silt deposits in low-flow areas. Scattered aquatic and emergent native and exotic macrophyte growths occur over much of the area. Banks heights vary. Much of the surrounding lands are urban and city park environments.

Victoria County – Guadalupe River southwest of Victoria: This location was found in September 2009 by N.A. Johnson (University of Florida, pers. comm.) and was reported just below a small bridge, but without other site descriptors.

San Saba and Mills counties – Colorado River:
This location was only documented in August 1999 when the entire Colorado River ceased flowing, ran dry, and all local unionids at this site were apparently lost (Howells 2000b); no description of the environment at this site was provided when the discovery of very recently dead Texas Pimpleback specimens was reported to TPWD.

Taxonomy and Genetics

Species validity
Texas Pimpleback is a valid species with no questions about its taxonomic status (Turgeon et al. 1998). It was first described as *Unio petrinus* by Conrad in 1855. It was placed for a time in *Margaron*, but ultimately moved to *Quadrula* (Simpson 1900).

Ecophenotypes
Like some other unionid species in Central Texas, Texas Pimpleback occasionally produces exceptionally elongate riffle or gravel-bar morphs. However, these are not recognized as taxonomically distinct.

Biochemical genetics
Howells (2002) reported comparative electrophoretic comparisons of Texas Pimpleback and other pimpleback species from Texas and other Gulf States. Serb et al. (2003) presented DNA analysis of many quadrulid species and genetically linked Texas Pimpleback more closely to Wartyback (*Quadrula nodulata*) than to Golden Orb (*Q. aurea*), Pimpleback (*Q. pustulosa*), or Western Pimpleback (*Q. mortoni*).

Range

Historical
Texas Pimpleback is endemic to the Colorado and Guadalupe-San Antonio drainage basins of Central Texas (Stecker 1931; Howells et al. 1996; Howells 2002, 2010). It ranged from downriver locations upstream to Bexar County and the City of San Antonio and up the Medina River to the Medina Reservoir area in the San Antonio River basin; up the Guadalupe River to Kerr County; and up the Colorado River as far as Runnels County, with subfossil valves found on the North Concho River in Sterling County.

Current
Although sites throughout its historic range were surveyed by TPWD since 1992, from 2005 to the present, Texas Pimpleback has only been found alive or recently dead at two locations:

Concho County – Concho River upstream of the Paint Rock area: This location was examined in 1993, 1994, 1997, and 2005 (Howells 2006) and supported the greatest numbers located in TPWD surveys. Burlakova and Karatayev (2008) surveyed this area again in 2008 and confirmed significant numbers of individuals were present; they speculated that it may be the only "considerable" population remaining in Texas. However, in 2009 and 2010, landowners at this site contacted the author to report water flow was being retained upstream in San Angelo and the river was largely dry with mussels being lost to extensive dewatering (R.G. Howells, unpublished data). Currently (March 2010) the present status of the Texas Pimpleback population in the Paint Rock area is unknown, but low-water reports from late 2009 suggest reasons for concern.

Guadalupe River – South-southwest of Victoria: Two living specimens were found at this location in September 2009 by N.A. Johnson (University of Florida, pers. comm.). The Johnson collection was made to obtain tissue samples for genetic analysis and the status of Texas Pimpleback at this site remains otherwise unreported.

Two additional sites where Texas Pimpleback may still persist:

Menard County – San Saba River upstream of Menard: Living Texas Pimpleback specimens were found here in 1997, but none were found during a subsequent survey in 2005 (Howells 2006) and no subsequent records were found in preparation of this report. However, this location is difficult to access (private land issues) and is difficult to survey (due to macrophyte growths and heavy calcium deposition on both the substrate and mussels there that confounds identification). Although no living Texas Pimpleback specimens have been confirmed here in over 10 years, this area requires further survey efforts before assuming the population lost.

Hays County – San Marcos River near the confluence of the Blanco River: Two living specimens were found here in 2004 (Howells and Power 2004; Howells 2005). This area has been extensively studied by TPWD, USFWS, Texas State University (Southwest Texas State University) and others for many years (R.G. Howells, unpublished data) and this species was known to occur in the lower Blanco River just a few km upstream in 1977 (Horne and McIntosh 1979). However, surveys by TPWD in the 1990s failed to find any evidence of continued survival here (Howells and Power 2004; Howells 2006, 2009). If Texas Pimpleback still persists here, numbers are almost certainly very small, but their apparent extreme rarity makes it hard to confirm status and unwise to dismiss the possibility of survival here.

Population levels

Concho County – Concho River upstream of Paint Rock: When first surveyed by TPWD in 1993, 100% of the Texas Pimpleback specimens located were alive (Howells 2006). The percentage alive fell in subsequent surveys: 90.3% (1994), 94.1% (1997), and 22.9% (2005) (Howells 2006). Juveniles were found here in the 1993 and 1994 surveys (R.G. Howells, unpublished data). Burlakova and Karatayev (2008) used transect samples to estimate population size from the town of Paint Rock upriver for 3.5 km (2.2 miles) and calculated 4,030±498 individuals in the area. They also noted that the population appeared dominated by large adults (not reproducing) and commented on low-water conditions limiting distribution.

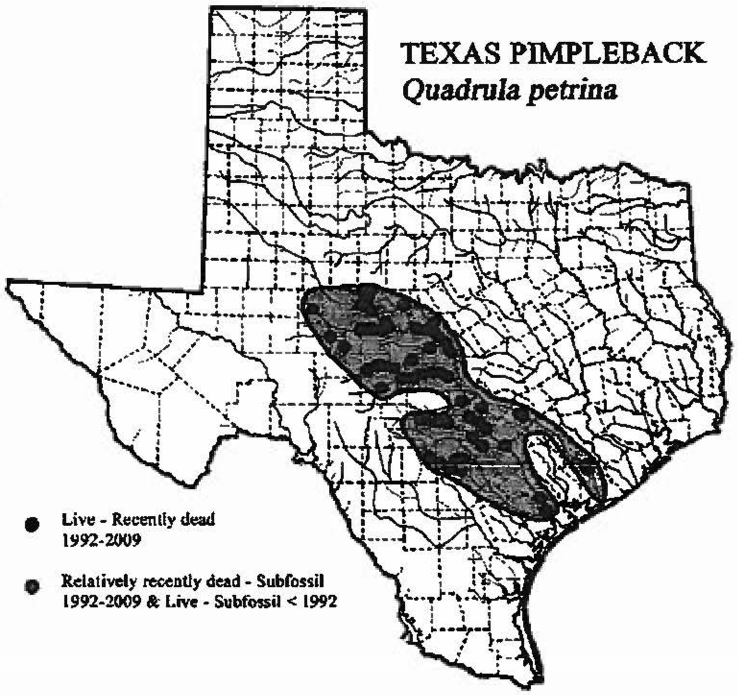


Figure 1. Presumptive historic range of Texas Pimpleback (*Quadrula petrina*) shown in blue in Central Texas.

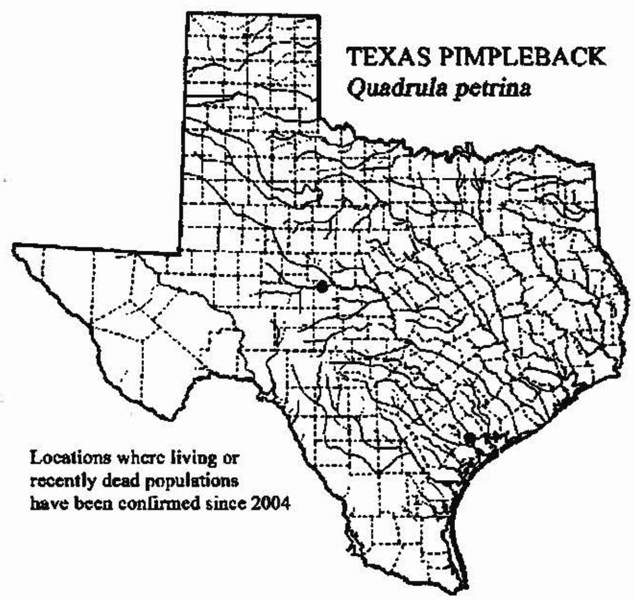


Figure 2. Populations of Texas Pimpleback (*Quadrula petrina*) confirmed since 2004.

Guadalupe River – South-southwest of Victoria: In September 2009, two living specimens were found here (N.A. Johnson, University of Florida, pers. comm.), but no population size estimates have been developed.

Two additional sites of consideration:
Menard County – San Saba River upstream of Menard: In 1997, five living specimens and several dead shells and valves were located at this site, but no living Texas Pimpleback, their shells or valves were found in 2005 (Howells 2006). Again, this area is both difficult to access and sample. If this species even persists here, population levels will be difficult to assess.

Hays County – San Marcos River near the confluence of the Blanco River: Two living animals found in 2004 are the only record of living Texas Pimpleback specimens in this area since the late 1970s (Howells and Power 2004). If survivors do persist here, the population size is likely very small.

CONSERVATION MEASURES

When Texas Parks and Wildlife Department (TPWD) created its first freshwater mussel harvest regulations in 1992 and 1993, minimum size limits were established and a series of no-harvest sanctuaries were designated. At that time, minimum harvest sizes focused on commercial shell species of unionids, including 69.9 mm (2.75 inches) in shell height for all pimpleback species. Some Texas Pimpleback specimens about 80 mm shell height or greater may be within a legally harvestable size (see measurements presented in Howells 2002). Because Texas Pimpleback shells are solid, thick, and white-nacred, they have been taken incidentally by shell musselers in Texas (R.G. Howells, unpublished data; Howells 1993); however, listing by TPWD as a legally threatened species now prohibits such harvest.

When TPWD no-harvest sanctuaries were first established in the early 1990s, the Concho River site near Paint Rock was listed. Thereafter, when a living population was confirmed in Runnels County, the site was added to the list of protective sanctuaries (Howells 1994a). In addition to TPWD regulations, Howells et al. (1997) provided a list of the designated TPWD no-harvest mussel sanctuaries. Ultimately in 2006, no-harvest sanctuaries were redefined and were formally passed by the TPW Commission in July 2007 (Texas Parks and Wildlife Department Proclamation 57.156-57.158; Howells 2009). Among the sites where Texas Pimpleback populations have been observed in recent years or are currently known to exist, four locations are now in no-harvest sanctuaries including: the Concho River near Paint Rock in Concho County, San Saba River in Menard County, Elm Creek in Runnels County, and the San Marcos River along its entire run. The specimens in the Guadalupe River in Victoria County were discovered in 2009 after the current regulations were passed.

It should be noted that TPWD no-harvest sanctuaries only legally preclude harvest of mussels from those designated waters and their tributaries. Mussel sanctuaries do not prohibit other area activities that could potentially have negative impacts on local unionids however. The upper San Marcos River also supports an array of state- and federally-listed threatened and endangered species, with associated restrictions on potentially harmful activities in the area (that benefit unionids as well).

LISTING FACTORS

Habitat or Range (Destruction, Modification, Curtailment)

Throughout much of Texas, historic land utilization resulted in modification and elimination of some aquatic habitat critical to Texas Pimpleback and other unionids. Extensive overgrazing beginning in the mid-1800s resulted in significant loss of vegetative cover and soils, with subsequent increases in runoff causing scouring of many streams and rivers (Howells 1994b). Scouring impacts on Texas waters have been further exacerbated by changes in rainfall patterns to fewer light and moderate showers and longer periods of drought punctuated by heavy, damaging floods (http://www.epa.gov/climatechange/science/recentpsc.html; Howells and Power 2004). Additionally, decade-average rainfall has increased over the past century with more rain falling in the early 1990s than fell in 1900-1910 (Howells 1995). Collectively, overgrazing, reduction in vegetative cover and soils, increasing numbers of scouring floods, and general increases in amount of precipitation have combined to dramatically reduce acceptable mussel habitat in many Texas waters. Anthropogenic developments (e.g., impervious surfaces, water flow manipulations) have magnified these impacts.

Central Texas in particular experienced a major drought in the late 1970s followed by several record floods between 1978 and 1981 (Howells et al. 1997; Howells and Power 2004). Some Central Texas mussel population sites that held assemblages of living unionids in the 1970s (including Golden Orb) no longer supported living mussels when surveyed in the 1980s and 1990s (Howells et al. 1997). These events helped reduce the abundance and distribution Texas Pimpleback and other unionids.

In addition to past and more-recent negative impacts (that continue), other broad-ranging and site-specific threats exist as well. By population site, these include:

Concho County – Concho River upstream of Paint Rock: Lands surrounding the Texas Pimpleback population in the Concho River upstream of Paint Rock are largely ranch and farm lands. Landowner land care and conservation approaches are extremely variable. One ranch upstream of Paint Rock fenced the banks of the Concho River and allowed livestock only access at a single point. This effort maintained stable riparian areas and, not coincidentally, also supported a significant population of Texas Pimpleback and other unionids. A distance upstream, hoofstock on another ranch allowed unrestricted access to the river banks with subsequent damaged, collapsing banks that shed mud and silt into the adjacent river waters creating unacceptable mussel habitat. Particularly in the Concho River drainage upstream of the Paint Rock area, extensive cotton farming occurs. Chemicals and nutrients associated with this and other farming and ranching activities can potentially contribute contaminants to the system.

Unfortunately, dewatering has become one of the greatest challenges threatening mussels in the Paint Rock area of the Concho River. In 1997, river flow was dramatically reduced resulting in the loss of many Texas Pimpleback (Howells 1998), with deaths due both directly to dewatering and to over-heated shallows where some animals were trapped. Again, in 1999-2000, the Concho River ceased to flow in the Paint Rock area leaving only a few shallow pools of stagnant water in many places (Howells 2000, 2006). Burlakova and Karatayev (2008) also reported similar low-water impacts on the Texas Pimpleback population. More recently in late 2009 and 2010, landowners just upstream of Paint Rock contacted the author to report reduced flows in the Concho River attributed to water retention upstream in San Angelo and with some pumping by property owners between San Angelo and Paint Rock, but with some springs and tributaries still contributing water in areas downstream of San Angelo (R.G. Howells, unpublished data).

Guadalupe River – South-southwest of Victoria: This location was not examined by the author and details of the river and surroundings have apparently not been published. Urban, residential, agricultural, and industrial activities in the area suggest a number of potential impact topics that deserve more-detailed attention.

Two additional sites of consideration:

Menard County – San Saba River upstream of Menard: The Texas Pimpleback population in a short section of the San Saba River occurs upstream of an urban area and generally runs through private ranch lands. Flooding occurs here periodically, but only moderate bank heights at many sites and wide areas for flows to dissipate have helped reduce scouring impacts during rises thus far. Atypically heavy macrophyte growth (most unionids avoid dense macrophyte beds) suggests an undesirable level of nutrient input in this area or somewhere upriver. Possible nutrient sources have not been reported. Hoofstock is grazed throughout the area and increased residential development is occurring in the surrounding land and along the river banks. Possible impacts of bridge construction at a location upstream from the Texas Pimpleback site have likewise not been assessed.

Hays County – San Marcos River near the confluence of the Blanco River: This area of the San Marcos River, within the City of San Marcos, contains other state- and federally-listed threatened and endangered species. Regulations covering these organisms will also impact any Texas Pimpleback specimens that may persist there. However, this site is within a city with potential associated urban, residential, highway, railroad, and industrial impact considerations.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Texas Pimpleback is one of the few particularly rare unionids in Texas waters that has occasionally been taken by commercial shell musselers (for pearl implant nuclei) and it has been observed in commercial collections of Southern Mapleleaf (*Quadrula apiculata*) as an incidental take (R.G. Howells, unpublished data; also see Howells 1993). Although there has been no indication of over harvest by shell musselers or pearl hunters, the TPWD classification of legally threatened now precludes this take, as well as any incidental harvest by anglers seeking mussels as bait.

To date, neither state nor federal resource managers have directed or monitored scientific activities and their impact on Texas Pimpleback populations. It is possible multiple researchers may survey, sample, and even remove specimens from the same area in relatively narrow windows of time. It remains undetermined if this activity has been problematic at known population sites. Volunteer training and sampling programs associated with freshwater mussel research similarly have limited time and place focus and may also potentially conflict with formal scientific research and management activities.

Public release of sensitive population location information has also been problematic regarding the security of the remaining Texas Pimpleback populations. In the late 1990s, detailed location information provided by TPWD to The Nature Conservancy was passed to NatureServe that, in turn, placed location details on its Internet site. Shell collectors used this information to access sites where Texas Pimpleback and Texas Fatmucket (*Lampsilis bracteata*) occurred. At that time, some collectors even posted photos on the Internet to show the unionids they had been able to collect in Texas. In conjunction with prior flooding and subsequent drought-related dewatering, mussels in some areas were easily located at that time. Collectively, these impacts appear to have eliminated the Texas Pimpleback population in Runnels County and none have been found here since (Howells 2006, 2009; Burlakova and Karatayev 2008; R.G. Howells, unpublished data). The Nature Conservancy, NatureServe, and other organizations have responded to this informational risk and modified their open releases of potentially harmful information. Unfortunately, even this report contains information that could be potentially misused and could be employed with negative impacts to surviving Texas Pimpleback populations.

Disease or Predation

No specific diseases have been reported in the published literature or observed during recent studies of Texas Pimpleback. Natural predators, like catfishes (Ictaluridae) and Freshwater Drum (*Aplodinotus grunniens*) no doubt consume some Texas Pimpleback specimens, but no confirmation has been documented to date.

Existing Regulatory Measures

At this time (March 2010), TPWD regulations preclude harvest of Texas Pimpleback and its shells and valves as a legally threatened species. Additionally, four current and past population sites are in no-harvest mussel sanctuaries. Sanctuary status prohibits all harvest (except as allowed under state permit); in non-sanctuaries, protected species may be disturbed during collection of non-protected mussels. TPWD has wisely retained several sanctuary sites even though this species has not been confirmed alive there in a number of years. However, the recently-discovered population in Victoria County remains to be designated as a sanctuary. Additionally, the Concho River sanctuary in the Paint Rock area needs to be extended upstream to cover specimens found surviving upriver of Kickapoo Creek.

Unfortunately, mussel sanctuaries only address harvest and do not impact other human activities in those areas, some of which can be detrimental. Some such anthropogenic activities include livestock damage to riparian zones and stream beds, increased nutrient input, increased runoff (directed and non-directed), sand and gravel removal from bank areas (and stream beds during low-water periods), pesticide and other chemical contaminants in runoff waters (from residences, farms and ranches, industry, airports, golf courses, etc.), general bridge and building construction along stream bank areas, water removal (for irrigation, livestock, etc.), impact from chemical or physical removal of noxious vegetation, and numerous other factors. Limited public awareness of freshwater mussel status and associated regulatory measures remains problematic. Scientific awareness among resource managers also needs to be enhanced.

Other Natural or Manmade Factors

Water physicochemical associations with Texas Pimpleback and other unionids in Texas waters have rarely been documented in detail. In the Concho River in the Paint Rock no-harvest mussels sanctuary, Webb and Dawkins (1998) reported comparative trace element concentrations in the river substrate and within the tissues of Asian clam (*Corbicula* spp.) for 16 elements. They did not report concentrations of arsenic and, given that this toxic element has been associated with cotton production (that occurs in the drainage basin), its status and any association with Texas Pimpleback remain to be studied and reported.

Some sites within the Concho River mussel sanctuary have been reported to contain high densities of Asian clams (Howells et al. 1996; Webb and Dawkins 1998). No particular negative impact on Texas Pimpleback has been confirmed, but high densities of this exotic bivalve suggest possible function as a competitor and should be examined more closely.

Another source of potentially extensive and adverse, yet difficult to quantify, impact involves the increasing human population within the range of Texas Pimpleback and the resulting increased pumping of aquifer waters for direct and indirect human consumption. Flows in many Texas springs have been reduced or eliminated, with subsequent reduction or elimination of spring feeds to streams (Brune 1975, 2002). Historically, water allocation plans in Texas have not focused on preservation of rare mussel resources. Spring flows in the Concho River between San Angelo and Paint Rock have helped prevent this stretch of river from becoming dry at times. Mussel losses in the Concho River in this area could be greater if these spring flows cease.

NEEDED INFORMATION

Taxonomy and Genetics

Although basic electrophoretic and DNA analyses have been performed on Texas Pimpleback and confirmed it taxonomic status, other biochemical genetic studies, such as DNA barcoding, could still contribute to helping to define this species. Probably many such activities can be conducted with mantle clips or other non-lethal sampling methods. Additionally, no studies have genetically compared existing Texas Pimpleback populations, all of which are isolated with no significant genetic exchange.

Distribution

Distribution of Texas Pimpleback is relatively well reported. However, it is possible additional small populations may exist on private lands in Texas at locations that have never been surveyed. Additionally, existing population sizes are unknown. One in the Concho River experienced dewatering in 2009 and the second in the lower Guadalupe River has only been recently discovered and has not been fully surveyed. Either could be easily lost within a short time window. Several sites that previously had populations have not been examined in a number of years. The known population sites should be periodically monitored to confirm their status and document potential threats. In particular, dewatering threats reported in the Concho River in the Paint Rock area need to be assessed. If Texas Pimpleback specimens still persist in the Concho River and claims of water retention upstream are correct, collection and removal of surviving Texas Pimpleback to another secure location may be necessary to prevent the total elimination of this population. Further, some level of regulatory control should be exercised to prevent excessive or disruptive monitoring activities.

Reproductive Biology

Although Texas Pimpleback glochidia have been described, reproductive season is poorly known and necessary host fish remain completely unknown. Both need to be determined. Unfortunately, this species has apparently become far too rare and too close to extinction to justify sacrificing specimens to develop fecundity estimates (unless previously collected preserved material can be used).

Environmental Aspects of Biology

No reports of physicochemical parameters specific to Texas Pimpleback were found during preparation of this report. Accumulating historical records of physicochemical parameters from waters associated with Texas Pimpleback population records may be useful in defining habitat requirements. Past and recent water levels and flow rate values may be of particular value.

When species are rare, difficult to observe or sample, and sensitive to disturbance, it can be extremely challenging to define critical aspects of species biology that relate to management of the species (e.g., in-stream flow limitations, minimum and maximum lethal temperatures and oxygen levels, critical spawning and incubation temperatures, etc.). Documenting these various elements of Texas Pimpleback biology on those occasions when opportunity presents can be important, especially when multiple observations can be combined into meaningful summaries. Opportunities to record elements of species biology should not be neglected. It should also be noted that measurements of physicochemical parameters associated with Pimpleback population sites need to be documented over long periods of time (years) to be meaningful. Quick snapshot studies in areas often subjected to extensive flood and drought extremes may not provide a good over-all view of the full range of relevant flow rates, water chemistry, and related parameters. Indeed, short snapshot studies can sometimes be more misleading than instructive.

Threats to Continued Survival

Continued human population growth and development in Central Texas are certain to have increasing impacts on native unionid populations. Habitat loss, modification, or disturbance in conjunction with decreasing water supplies can be anticipated. The largest population documented in recent decades (in the Concho River) appears seriously threatened by dewatering. This issue needs to be confirmed, clearly defined, and possible solutions should be posed.

PERSONAL CONCLUSIONS AND RECOMMENDATIONS

Texas Pimpleback is a unique unionid within the pimpleback complex that is endemic to Central Texas. One newly discovered site is encouraging, but other locations have either lost their populations or have been significantly reduced in abundance in recent years. Dewatering threats are continuing at present.

Many elements of species biology, including reproductive biology, remain unknown and should be the subject of scientific investigation before this unionid becomes too rare to allow intense study.

Texas Pimpleback is clearly an endangered species in need of immediate protection and study. It should be listed as such by both federal and state regulatory agencies.

RELEVANT LITERATURE

Brune, G. 1975. Major and historical springs of Texas. Texas Water Development Board, Report 189, Austin.

Brune, G. 2002. Springs of Texas. Volume 1. Springs of Texas. Texas A&M Press, College Station.

Burlakova, L.E., and A.Y. Karatayev. 2008. State-wide assessment of unionid diversity in Texas. Performance Report. State Wildlife Grant report to Texas Parks and Wildlife Department, Austin.

Hoggarth, M.A. 1994. A key to the glochidia of the Unionidae of Texas. Department of Life and Earth Science, Otterbein College, Westerville, Ohio. Prepared for the American Malacological Union Annual Meeting, Houston, Texas, 1994.

Horne, F.R., and S. McIntosh. 1979. Factors influencing distribution of mussels in the Blanco River of central Texas. The Nautilus 94:119-133.

Howells, R.G. 1993. Preliminary survey of freshwater mussel harvest in Texas. Texas Parks and Wildlife Department, Management Data Series 100, Austin.

Howells, R.G. 1994a. Additional new mussel sanctuaries designated. Info-Mussel Newsletter 2(1):1-2.

Howells, R.G. 1994b. Longhorn cattle and windmills linked to mussel declines. Info-Mussel Newsletter 2(5):5.

Howells, R.G. 1995. Changes in precipitation patterns in Texas. Info-Mussel Newsletter 3(4):6.

Howells, R.G. 1997. Texas pimpleback host work inconclusive. Info-Mussel Newsletter 5(7-8):7.

Howells, R.G. 1998. Distributional surveys of freshwater bivalves in Texas: progress report for 1997. Texas Parks and Wildlife Department, Management Data Series 147, Austin.

Howells, R.G. 2000a. Reproductive seasonality of freshwater mussels (Unionidae) in Texas. Pages 35-48 *in* R.A. Tankersley and five coeditors. Freshwater mollusk symposia proceedings. Ohio Biological Survey Special Publication, Columbus.

Howells, R.G. 2000b. Distributional surveys of freshwater bivalves in Texas: progress report for 1999. Texas Parks and Wildlife Department, Management Data Series 125, Austin.

Howells, R.G. 2002. Freshwater mussels (Unionidae) of the pimpleback complex (*Quadrula* spp.) in Texas. Texas Parks and Wildlife Department, Management Data Series 197, Austin.

Howells, R.G. 2003. Declining status of freshwater mussels of the Rio Grande. Pages 59-73 *in* G.P. Garrett and N.L. Allen, editors. Aquatic fauna of the northern Chihuahuan Desert. Texas Tech University Press, Lubbock. (Initially presented in 2001).

Howells, R.G. 2004. Texas freshwater mussels: species of concern. Texas Parks and Wildlife Department, Wildlife Diversity Conference, San Marcos, Texas. 18-20 August 2004.

Howells, R.G. 2005. Distributional surveys of freshwater bivalves in Texas: progress report for 2004. Texas Wildlife Department, Management Data Series 233, Austin.
Howells, R.G. 2006. Statewide freshwater mussel survey. State Wildlife Grant Final Report T-15-P, Texas Parks and Wildlife Department, Austin.
Howells, R.G. 2009. Biological opinion: conservation status of selected freshwater mussels in Texas. BioStudies, Kerrville, Texas.
Howells, R.G. 2010. Guide to Texas freshwater mussels. BioStudies, Kerrville, 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. Niamo. 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.
Howells, R.G., R.W. Neck, and H.D. Murray. 1996. Freshwater mussels of Texas. Texas Parks and Wildlife Press, Austin.
Howells, R.G., and P. Power. 2004. Freshwater mussels of the San Marcos-Blanco River basin: history and status. 107th Annual Meeting of the Texas Academy of Science, Kerrville, Texas, 6 March 2005
Lea, I. 1859. Descriptions of seven new species of uniones from South Carolina, Florida, Alabama, and Texas. Proceedings of the Academy of Natural Sciences of Philadelphia 11:154-155.
Serb, J.M., J.W. Buhay, and C. Lydeard. 2003. Molecular systematics of the North American bivalve genus *Quadrula* (Unionidae: Ambleminae) based on mitochondrial ND1 sequences. Molecular Phylogenetics and Evolution 28(2003):1-11.
Simpson, C.T. 1900. Synopsis of the naiads, or pearly fresh-water mussels. Proceedings of the United States National Museum 22(1205):501-1044.
Simpson, C.T. 1914. A descriptive catalogue of the naiades, or pearly fresh-water mussels. Parts I-III. Bryant Walker, Detroit, Michigan.
Strecker, J.K. 1931. The distribution of naiads or pearly fresh-water mussels of Texas. Baylor University Museum Bulletin 2, Waco.
Turgeon, D.D., and 13 co-editors. 1998. Common and scientific names of aquatic invertebrates of the United States and Canada: mollusks. American Fisheries Society Special Publication 26, Bethesda, Maryland.
Webb, D.E., and R.C. Dawkins. 1998. A comparison of trace element concentrations in *Corbicula* sp. (Bivalvia: Corbiculidae) and sediment from the Concho River by energy dispersive x-ray fluorescence. The Texas Journal of Science 50(2):149-154.

GLOSSARY OF SELECTED TERMS

Ala – a wing-like extension of the dorsal shell margin; usually posterior to the beak, sometimes anterior; "alate" means having a wing.
Beak – the umbo, the elevated (usually) part of the shell on the dorsal edge, anterior to the ligament in freshwater mussels, the oldest part of the shell.
Beak cavity – the inside of the beak within each valve, often forms a pocket or depression.
Beak sculpture – patterns of ridges, loops, and bumps that, like finger prints, can be unique to some species; often eroded and missing.
Chevron – V or arrowhead shaped, sometimes paired into Ws.
Compressed – flattened or pressed together.
Denticle – small (usually) tooth-like structures that may be present anterior and posterior to the right pseudocardinal tooth.
Concentric – circles, rings, or crescents with a common center or origin.
Dimorphic – having two distinct forms.
Ecophenotype – forms of a single species that are physically distinct in different environments.
Elliptical – ellipse shaped or an elongated oval.
Elongate – long or extended.
Endemic – found only in a particular area.
Exfoliated – eroded.
Extirpated – extinct in a particular area.
Fecundity – the number of eggs and/or larvae.
Fluted – grooves and ridges with a ruffle-like appearance.
Growth-rest lines – alternating dark and light concentric lines in a mussel shell indicating periods of slow and fast growth, respectively. In the far north, these may be annuli (formed each year), but in Texas growth may slow during summer droughts or continue over mild winters (therefore growth-rest bands cannot be counted as an indication of age).
Hinge – the area where the right and left valves (shell halves) articulate and are connected by an elastic ligament.
Hinge teeth – lateral and pseudocardinal teeth.
Inflated – swollen, expanded.
Interdentum – the area of the hinge between the lateral and pseudocardinal teeth; absent in some species.
Iridescent – a lustrous, pearly, or rainbow color appearance; only freshwater mussels and marine pearl oysters have iridescent nacre.
Lachrymose – drop-shaped pustules.
Lateral teeth – elongate structures along the hinge in many species located only posterior to the beak in freshwater mussels; absent in some species; these stabilize the hinge and are not true teeth at all.
Lunule – a cavity or depression, also called a sinus.
Nacre – the inner layer of the shell, mother-of-pearl.
Oval (ovate) – egg shaped.
Pallial line – a linear depression inside each valve interior to the shell margin, where the soft mantle tissues were attached.
Periostracum – the outer shell layer, shell epidermis.
Plications – folds, ridges, particularly multiple ridges.
Posterior ridge – a ridge on the posterior half of the shell running from the beak to the margin.
Posterior slope – shell area between the posterior ridge and the dorso-posterior margin.
Pseudocardinal teeth – tooth-like structures located below the beak area, usually two in the left valve and one in the right valve or none at all; may be compressed and leaf-like to heavy and molar-like.
Quadrate – square; often expressed as subquadrate (nearly quadrate).
Pustule – a bump or raised knob on the shell exterior.
Serrated – notched or grooved.
Shell margin – the exterior circumference edge of each valve (sometimes this term excludes the hinge line).
Solid – hard, thick, not soft and chalky.
Striated – with fine lines or grooves.
Truncate – shortened or squared off (sometimes obliquely).
Tubercle – projection from the shell, may be pointed, rounded, or knob-like.
Umbo – beak.
Valve – one half of a bivalve shell.
Wing – ala.

FRESHWATER MUSSEL SHELL FEATURES