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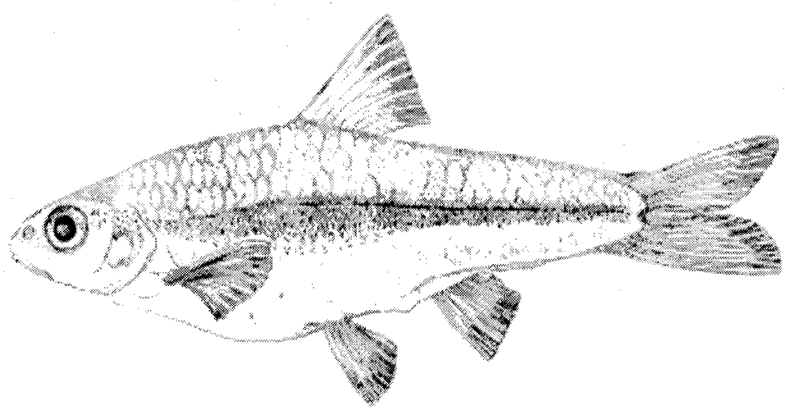

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GARY P. GARRETT AND NATHAN L. ALLAN

Declining Status of Freshwater Mussels in the Rio Grande, with Comments on Other Bivalves

Robert G. Howells

Abstract

Freshwater mussels (Family Unionidae) are one of the fastest declining faunal groups in North America due, in part, to their sensitivity to environmental degradation and modification. There has been a noteworthy paucity of data on unionid assemblages throughout the Rio Grande drainage despite its being a unique region of zoogeographic overlap between southern and northern faunas. Therefore, selected historic collections, state surveys by Texas Parks and Wildlife (TPW) 1992-1997, and federally-funded work by TPW and New Mexico Department of Game and Fish 1998-2001 were reviewed to provide a better understanding of mussel status in the system. At least 16 species of unionids occurred in the Rio Grande drainage of Texas, New Mexico, and Mexico. All have been dramatically reduced in both abundance and distribution in recent decades. Only six native species have been found alive within the past ten years along with two others that are apparent introductions. Among taxa endemic to the Rio Grande, Salina mucket (*Potamilus metnecktayi*) and Mexican fawnsfoot (*Truncilla cognata*) have not been found alive since 1972 (though recently dead valves of the former collected in the late 1990s suggest it may still survive) and living or recently dead Rio Grande monkeyface (*Quadrula couchiana*) were last documented in 1898. The remaining taxa, including some that may be abundant elsewhere, also appear to have disappeared from the system over the past 10 to 100 years. Factors contributing to this decline include natural and anthropogenic desertification, water and land management practices, habitat modification, pollution, siltation, and increased salinity (in some areas). Unfortunately, there is little indication status of unionids in the Rio Grande will improve in the future.

Introduction

The Rio Grande of the United States and Mexico is one of the longest rivers in North America and is an area of overlap for many northern and southern faunal groups (Neck, 1982; Neck and Metcalf, 1988). Despite the political, ecological, and economical importance of the area, relatively little effort had been directed at understanding freshwater mussels (Family Unionidae) of the Rio Grande (Neck and Metcalf, 1988). Freshwater mussels are one of the most rapidly declining faunal groups in North America (Neves, 1993; Williams et al., 1993) including within the Rio Grande (Howells and Garrett, 1995; Howells and Ansley, 1999). Their sensitivity to environmental disturbance and degradation in conjunction with development of the region now places them at the pinnacle of ecological concern.

Historical information comes from Dall (1896) and others who reported on early boundary surveys. Strecker (1931), Neck and Metcalf (1988), Taylor (1967, 1997), and Johnson (1998) discussed these and other historic museum collections from the drainage. Cockerell (1902) reported finding unionids in the Pecos River drainage of New Mexico; Metcalf (1982) discussed recent, subfossil, and fossil records in the drainage basin; Metcalf (1974) commented on the Pecos River fauna; Metcalf and Stern (1976) briefly mentioned Rio Grande fauna; Neck (1984) commented on declining mollusks in Texas; and Neck and Metcalf (1988) reviewed mussels of the lower Rio Grande. Metcalf and Smartt (1972) discussed introduced mollusks. Several studies examined benthic invertebrates in general (Metcalf, undated, 1966; Bane and Lind, 1978; Davis, 1980a, 1980b, 1980c). Nonetheless, data from all these sources on the unionids of the Rio Grande was limited.

Recently, Texas Parks and Wildlife's (TPW) Heart of the Hills Fisheries Science Center (HOH) initiated statewide surveys of this group, including sites within the Rio Grande drainage (Howells, 1994a, 1994b, 1995, 1996a, 1996b, 1996c, 1997a, 1997b, 1997c, 1998a 1998b; Howells and Garrett, 1995; Howells et al., 1996, 1997). In 1998, federally-funded work was jointly initiated by TPW and New Mexico Department of Game and Fish to further examine the mussel fauna of the system (Howells, 1999, 2000, 2001a; Howells and Ansley, 1999; Lang, 2000). Johnson (1999) provided an analysis of the unionid fauna of the system, based on his interpretation of museum specimens and the published literature. Howells (2001b) summarized previous records and recent TPW surveys. Collectively, from these sources, a picture of the unionid faunal composition, abundance, and distribution within the Rio Grande Basin has started to emerge. This paper presents a condensed summary of previously published reports and surveys.

MATERIALS AND METHODS

Standard mussel sampling protocols employed in HOH work were presented in Howells (1995, 1996a). Specimen counting methods follow Howells (1995, 1996a) and include single valves and matched pairs of valves as one individual, two unmatched valves (one valve from each of two different animals) as two individuals, etc. (note that a valve or half of a shell originated from a single animal). Shell condition terminology follows (Howells, 1995, 1996a) and is presented in Table 1. Taxonomy follows Howells et al. (1996) and Turgeon et al. (1998), except for the common name for *Disconaias conchos* presented here. Details relating to specific sampling and collection sites were presented in Howells (2001b) as were maps to all locations.

Physicochemical aspects of the Rio Grande within Texas were examined by reviewing selected water quality records of the U.S. Geological Survey for water years: 1968 (USGS, 1968), 1975 (USGS, 1975), 1986 (Buckner et al., 1986), 1996 (Gandara et al., 1996), 1999 (Gandara et al., 1999), and 2000 (Gandara et al., 2001). Data reported from these sources were averaged by site for all years combined, years for all sites combined, or both in an effort to identify temporal and upstream-to-downstream patterns. Precipitation data were obtained from the Texas Office of State Climatologist, College Station, Texas, and monthly and yearly totals were summed and decade (or partial decade) averages obtained.

Unless otherwise stated, recent survey work was largely confined to U.S. and boundary waters. Current status of bivalves in tributaries of the Rio Grande or other drainage basins in Mexico therefore remains unknown.

RESULTS AND DISCUSSION

SPECIES ACCOUNTS

At least 16 taxa of unionids occurred in the Rio Grande drainage of Texas, New Mexico, and Mexico (Howells et al., 1996). Three species are endemic to this drainage basin. Among the freshwater mussels, two are apparently recent introductions, as are Asian clams (*Corbicula* spp.; Family Corbiculidae), and another may have been lost, then reintroduced. Additionally, at least four fingernail clams (Family Sphaeriidae) have also been reported in the system.

Tampico pearlymussel (*Cyrtonaias tampicoensis*)

The native range of Tampico pearlymussel extends from the Brazos River, Texas, (Howells et al., 1996) south to at least the Río Papalopan system, Vera Cruz, Mexico (Johnson, 1999). Upstream records extend to the eastern boundary of Big Bend National Park (Howells, 1994b), with subfossil and fossil remains in the Pecos River upstream to Chaves and Eddy

Table 1. Shell condition terminology as presented by Howells (1995, 1996a). Note that it is not usually possible to determine exactly how long a freshwater mussel shell has been dead and many variables can impact specimen condition and rate of disintegration. Nonetheless, it is often useful to apply qualitative terms to help estimate time-since-death.

Term	Definition
Very recently dead	Soft tissue remains attached to the shell or valve; shell is in good conditiion, essentially as it would bein a living specimen; internal and external colors are not faded.
Recently dead	No soft tissue remains, but shell otherwise in good condition (looking like a living speciment that had been killed and cleaned); internally nacre is glossy and without evidence of algal or other staining, calcium deposition, or external erosive effects; internal and external colors are not significantly faded.
Relatively-recently dead	Shell is in good condition, but internally nacre is losing its glossy nature; algal or other staining, calcium deposition, or external erosive effects (or some combination of these) is evident on the nacre; internal and external colors are often somewhat faded.
Relatively-long dead	Similar to above, but more pronounced; shell epidermis often has sections beginning to flake.
Long dead	Shell shows signs of internal and external erosion, staining, calcium deposition, or some combination of these; most or all of the internal coloration and glossy nature of the nacre has faded (especially in species with colored nacre); shell epidermis often has major sections absent, or if present, clearly aged and flaking.
Very-long dead	Shell shows significant signs of internal and external erosion, staining, and calcium deposition more widely pronounced than above; coloratioin is often faded white or nearly so; often with relatively little epidermis remaining; for specimens in particularly erosive environments (scoured substrates, low pH waters, etc.), internal (e.g., shell teeth) and external features (e.g., pustules, ridges) are often weathered and smoothed, or otherwise exfoliated; shells are often chalky, brittle, and crumbling.
Subfossil	Shells have little or no epidermis remaining; nacre is faded white and entire shell is often bleached white; shell sometimes shows signs of erosion, staining, or calcium deposition of recent origin; shells are typically chalky and powdery to the touch, and often brittle and crumbling.

counties, New Mexico (Metcalf, 1982). It appears to be the most abundant unionid remaining in the Rio Grande. In the 1990s, populations were found in Amistad, Falcon, and Casa Blanca reservoirs, and in resacas, canals, oxbows, and reservoirs in Hidalgo and Cameron counties, Texas. However, the species is now apparently absent from areas upstream of Amistad Reservoir and Texas tributaries downstream to Starr County. Drought conditions, starting in mid-1995 and continuing into 1996 and beyond, also eliminated large numbers from Falcon and Amistad reservoirs as water levels fell.

Conchos disk (*Disconaias conchos*)

This species was first described by Taylor (1997) from 1969 collections near Saucillo, Rosetilla, and Julimes in the Río Conchos, Chihuahua, and a 1937 collection at Villa Juarez in the Río Sabinas, Coahuila, Mexico. It is apparently endemic to those systems and not known from the main stem of the Rio Grande or other tributaries. During desert fishes surveys by the HOH staff in 1994, 10 unmatched valves were found in the Río Conchos near Julimes, but were listed as unidentified (Howells and Garrett, 1995; Howells, 1996a). Among these, all were long dead except a single juvenile that was relatively-recently dead. Status of this species is uncertain, but the 1994 juvenile is the only suggestion the species may still survive.

Yellow sandshell (*Lampsilis teres*)

Yellow sandshell ranges throughout much of the central U.S. and is often common elsewhere in Texas (Howells et al., 1996). In the Rio Grande drainage, it has been documented in the Pecos River, Val Verde County, Texas (Johnson, 1999); the Rio Grande near Del Rio, Val Verde County, downstream to Cameron County, Texas (Strecker, 1931); and the Río Sabinas, Coahuila (Johnson, 1999); and Río Salado near Anahuac, Nuevo Leon (Metcalf, 1982), Mexico. Neck and Metcalf (1988) described it as common in resacas in the Lower Rio Grande Valley and second in abundance only to Tampico pearlymussel. However, HOH surveys found only: 1) one subfossil valve in the Rio Grande downstream of Falcon Dam, Starr County, 1994 (Howells, 1996a); 2) a very-long dead valve in an oxbow pond, La Coma Tract – Lower Rio Grande National Wildlife Refuge, Hidalgo County, 1999 (Howells, 2000); and 3) a recently dead specimen in Elm Creek, Eagle Pass, Maverick County, 1992 (Howells, 1994a). A Late Archaic archeological site at Eagle Pass examined in 1995 (dated to 2,200-1,200 years before present) revealed yellow sandshell to have been the most abundant unionid material recovered (Howells, 1998c). Unfortunately, when the Elm Creek site was reexamined in 1996, the stream bottom was covered over 1 m deep in soft silt that had eliminated all unionids (Howells, 1997a). Despite a history of wide distribution in the system, the 1992 Elm Creek specimen was the only suggestion living animals might remain, but none have been located since.

Washboard (*Megalonaias nervosa*)

The range of this large waterbody species includes the central United States and lower river reaches in Texas from the Red River to the Rio Grande (Howells et al., 1996). In the Rio Grande, fossil shells have been found as far upstream as the Pecos River, Eddy County, New Mexico (Metcalf, 1982). Records in Texas range from a fragment at Elm Creek, Maverick County (Metcalf, 1982) and Las Moras Creek, Kinney County (Strecker, 1931) to fresh shells in the Rio Grande at Chapeno downstream of Falcon Dam in the mid-1970s (Neck and Metcalf, 1988). Records from Mexico include the Río Sabinas (Johnson, 1999) and fossil material from the Río Salado near Anahuac, Nuevo Leon, and subfossil specimens near Villa Juarez, Coahuila (Metcalf, 1992). Neck and Metcalf (1988) indicated washboard was rare in the Rio Grande and possibly extinct. Collections by HOH produced only a single very-long dead shell near Chapeno. However, D. Kumpe (South Padre Inland, Texas; pers. comm.) reported being given a fresh specimen taken from the lower Rio Grande and seeing washboard shell fragments in dredge spoils at the mouth of the Edinburg Canal, Hidalgo County, Texas, in the mid-1990s. Additionally, P.D. Hartfield (U.S. Fish and Wildlife Service, Jackson, Mississippi; pers. comm.) interviewed a commercial musseler in the 1990s who was in possession of washboards he claimed had been recently collected in the lower Rio Grande Valley of Texas. The collection also contained Tampico pearlymussels (that could only have come from Texas or Mexico). HOH collections in Starr, Hidalgo, and Cameron counties failed to find fresh or living washboards, but some deepwater areas of the main channel remain to be examined, as does the main stem run between Amistad Dam and the Falcon Reservoir.

Texas hornshell (*Popenaias popeii*)

Though sometimes reported as endemic to the Rio Grande (Howells et al., 1997), Texas hornshell historically ranged south along the Mexican coastal systems at least to the Río Cazones, Vera Cruz (Johnson, 1999). It has been found upstream in the Rio Grande to sites just downstream of Big Bend, Brewster County, Texas (Howells, 1999); upstream in the Pecos River to Chaves and Eddy counties, New Mexico (Cockerell, 1902; Metcalf, 1982); in the Devils River upstream of Dolan Springs, Val Verde County, Texas (Howells, 2000); as well as several Mexican tributaries of the lower Rio Grande (Johnson, 1999). A shell found in the Llano River in 1971 at Castell, Llano County (Ohio State University Museum collection), and another recently dead shell taken in the South Concho River in 1992 at Cristoval, Tom Green County (N. Strenth, Angelo State University, San Angelo, Texas; pers. comm.), both in the Colorado River drainage of Texas, are enigmatic. However, numerous collections throughout this system have failed to find evidence of other specimens. The only records in the past decade of living or recently dead specimens include one recently dead shell in 1992 from the mouth of San Francisco Creek, Brewster and Terrell counties, Texas (Howells, 1994a); three recently dead shells in 1998 found in the Rio Grande between Big Bend and San Francisco Creek, Brewster County, Texas (Howells, 1999); and an extant population in the Black River (Pecos River tributary), Eddy County, New Mexico (Lang, 2000). The Black River population in New Mexico and a possible relict population in the Rio Grande downstream of Big Bend may be the only surviving Texas hornshell in the United States.

Salina Mucket (*Potamilus metnecktayi*)

Salina mucket has been included under both *Disconaias* and *Potamilus* (Howells et al., 1996). Johnson (1998) redescribed endemic animals from the Rio Grande as *Potamilus metnecktayi* and seems to have combined a number of other related species to the south of the Rio Grande under *Disconaias disca*. In the Rio Grande, the species has been documented from just upstream of Boquillas Canyon, Brewster County, Texas (Howells, 1999), and from fossil material from the Pecos River, Eddy County, New Mexico (Metcalf, 1982), downriver to below Falcon Dam, Starr County, Texas (Neck and Metcalf, 1988), and the Río Salado of Tamaulipas, Coahuila, and Nuevo Leon, Mexico (Johnson, 1999). Living specimens were found in 1968 in the lower Pecos River, Val Verde County, Texas (Johnson, 1999) and fresh shells were found in the Rio Grande west of Del Rio, Val Verde County, in 1972 (Metcalf, 1982). No living specimens have been documented since. Two recently dead specimens were found at Dryden Crossing, Terrell County, Texas, in 1992 (Howells, 1994a); 11 recently dead and two relatively recently dead shells or valves were collected in 1998 between Dean Canyon, Brewster County, and 4.4 km downstream of San Francisco Creek, Terrell County (Howells, 1999); and a single relatively recently dead valve was found just upstream of Boquillas Canyon in 1999 (Howells, 2000), all in the Rio Grande. In nearly 30 years, these are the only records that suggest the Salina mucket is still extant.

Bleufer (*Potamilus purpuratus*)

The native range of bleufer extends from the Guadalupe-San Antonio drainage of Texas north and east (Howells et al., 1996). Previous reports of this species in the Rio Grande represent misidentified Tampico pearlymussels (Howells, 1997c). However, shells and living specimens were found in Amistad Reservoir, Val Verde County, Texas, in 1994 and 1995 where it appears to have been introduced (Howells, 1997c). It was documented there again in 1998 (Howells, 1999).

Giant floater (*Pyganodon grandis*)

Though widely distributed and often common in Texas and elsewhere in the United States (Howells et al., 1996), there have been few reports of giant floater from the Rio Grande. Records include the El Toro Cement Agency Lake, El Paso County, Texas, 1969 (specimens at the U.S. National Museum and Philadelphia Academy of Science); Granjeno Lake (Strecker, 1931) and canals at Mercedes (Ellis et al., 1930), both Hidalgo County, Texas; and fossil material from Billingslea Draw near Toyah in the Pecos River drainage, Reeves County, Texas (Metcalf, 1982). None were taken in any HOH surveys conducted since 1992; however, in 2000, Lang (2000) found living specimens in the Pecos River upstream of Avalon Reservoir and in the main stem at Flume Park Carlsbad, Eddy County, New Mexico. Metcalf and Smartt (1972) considered giant floater to have been introduced at the El Paso site, as did Lang of the New Mexico specimens. The El Paso site has not been reexamined in many years and the status of that population is undetermined. Other than the population in New Mexico (possibly non-native stock), there is no other recent confirmation of the species in the Rio Grande drainage.

Southern mapleleaf (*Quadrula apiculata*)

Although southern mapleleaf is common throughout most of Texas and other Gulf states (Howells et al., 1996), it is absent from the fossil record (Metcalf, 1982), historical, and Mexican collections from the Rio Grande. Neck and Metcalf (1988) suggested it may be an introduction. It is known to occur in Lake Casa Blanca, Maverick County; Falcon Reservoir, Zapata County; and in the Rio Grande, canals, resacas, oxbows, and impoundments in Starr, Hidalgo, and Cameron counties, Texas (Neck and Metcalf, 1988; Howells, 1996a, 1997a, 1999, 2000).

Rio Grande monkeyface (*Quadrula couchiana*)

This endemic species has been reported as fossil remains as far upstream in the Pecos River as Eddy County, New Mexico, and the Pecos River near the mouth of Hackberry Draw, Ward County, Texas (Metcalf, 1982), with other material from the Devils River (Johnson, 1999) and downstream in the Rio Grande tributary of Las Moras Creek, Fort Clark (Brackettville), Kinney County, Texas (Strecker, 1931). Other subfossil and fossil specimens have been found at sites in the Río Salado, Coahuila and Nuevo Leon, Mexico (Metcalf, 1982). A record from the Nueces River drainage, Zavalla County, Texas, is thought to be spurious (Johnson, 1999). This species may have been last seen alive or recently dead in the 1898 collections in Las Moras Creek (see Taylor, 1967). Neck (1984) reported D.W. Taylor had told A.L. Metcalf that he had found living specimens in the Río Conchos, Chihuahua, Mexico; however, no subsequent published record has been presented and none were found there during HOH surveys of this system in the 1990s. Otherwise, only fossil material has been found in the past century and the species may well be extinct.

False spike (*Quincuncina mitchelli*)

This species is known only from two disjunct populations, one in Central Texas and the second in the Rio Grande drainage (Howells et al., 1996). Living specimens have not been found in Central Texas since the late 1970s (Howells et al., 1997). Nearly all records from the Rio Grande are those of Metcalf (1982) who documented subfossil and fossil specimens from the Pecos River, Eddy County, New Mexico; the Pecos River drainage of Reeves and Ward counties, Texas; and in Mexico in the Río San Juan of Nuevo Leon, and Río Salado, Nuevo Leon and Coahuila, Mexico. Johnson (1999) noted an additional collection from the Río Salado, Tamaulipas, in the University of Michigan Museum of Zoology, but did not comment on the condition of the specimen. Surveys by HOH have failed to find even fossil fragments of false spike in the Rio Grande and the species is likely extinct in the basin. Two recently dead valves found in the lower Guadalupe River drainage in 2000 (Howells, 2001) are the only suggestion the Central Texas population has not been lost as well.

Lilliput (*Toxolasma parvus*)

Taxonomic confusion among species in this genus has been problematic, particularly with historic collections. Lilliput occurs throughout most of Texas and much of the United States (Howells et al., 1996), but in the Rio Grande, it is restricted to the lower reaches where it has been rather rare. Reports include Delta Reservoir, Hidalgo County (H.D. Murray; collection now at the Philadelphia Academy of Science) and resacas of the lower Rio Grande (Neck and Metcalf, 1988). However, during HOH surveys collections included only a single relatively recently dead valve in 1994 from Lake Casa Blanca, Maverick County (Howells, 1996a), and four living specimens in 1995 from Falcon Reservoir, Zapata County (Howells, 1996b). No other occurrences have been documented since.

Texas lilliput (*Toxolasma texasiensis*)

Although Turgeon et al. (1998) and Williams et al. (1993) recognized lilliput as well as Texas lilliput and western lilliput (*T. mearnsi*), genetic analysis (Howells, 1997b) failed to distinguish the latter taxon as a distinct species (Howells, 1997b). Howells et al. (1996) included western lilliput under Texas lilliput. Often locally abundant in much of Texas (Howells et al., 1996), Texas lilliput has only rarely been reported in the Rio Grande. Historic collections, all in Texas, include the mouth of the Devils River, Val Verde County, and Las Moras Creek, Fort Clark (Brackettville), Kinney County (Strecker, 1931; Taylor, 1967). Texas lilliput was third in abundance in archeological excavations along Elm Creek, Maverick County (Howells, 1998c), where its sexually dimorphic shells were readily apparent. However, it was not found in HOH survey sites throughout the basin examined during the past decade.

Mexican fawnsfoot (*Truncilla cognata*)

This Rio Grande endemic is known only from a small number of specimens. Originally described from the Río Salado, Nuevo Leon, Mexico in 1860, it has also been taken from the same river in the state of Tamaulipas (U.S. National Museum; Johnson, 1999). Metcalf (1982) reported a specimen of probably fossil origin from the Río Salado, Nuevo Leon. Metcalf (1982) also noted finding fresh shells in 1968 in the lower Pecos River and in 1972 in the Rio Grande west of Del Rio, both in Val Verde County, Texas. C.M. Mather (University of Science and Arts of Oklahoma, Chickasha; pers. comm.) collected a weathered valve in the Rio Grande 72 km west of Laredo in 1975. A relatively-long dead and deformed valve found in Falcon Reservoir in 1996 and initially attributed to this species (Howells, 1997b) may be a misidentification. None have been documented otherwise since the 1972 Metcalf collection.

Pondhorns (sp.?)
(*Uniomerus tetralasmus – U. declivis*)

A pondhorn, given as *Unio manibius*, was taken in an early boundary survey at Río Agualeguas, Puntiagudo, near General Trevino, Nuevo Leon, Mexico, in the 1850s (see photograph in Johnson, 1999). Morrison (1976) synonymized *Unio minibus* and *Uniomerus declivis*, and he and Frierson (1903) both considered *U. tetralasmus* and *U. declivis* to be valid species. However, Johnson (1999) combined them. Neck (1987) considered both the Río Agualeguas specimen and others from Baffin Bay drainage, the next system to the north, to be *U. tetralasmus*. Many Texas *Uniomerus* populations are intermediate between the two species (HOH unpublished data), as are both Río Agualeguas and Baffin Bay examples, and their true taxonomic affinities remain unclear. Neck and Metcalf (1988) indicated specimens collected in the 1920s in Cottingham Resaca, Brownsville, Texas, were present in the Corpus Christi Museum collection; however, this collection could not be located for examination. Regardless, Neck (1987) concluded that no members of this genus were currently known from the lower Rio Grande Valley. Recent work supports the conclusion that all pondhorns of any species appear to have been eliminated from the system.

Paper pondshell (*Utterbackia imbecillis*)

Paper pondshell is often common in most Texas drainages and elsewhere in the United States. In the Rio Grande, it has been documented from Matamoros in the mid-1800s, Tamaulipas, and Río Salado near Anahuac, Nuevo Leon, Mexico (Johnson, 1999). Historic sites in Texas include: Brownsville, Cameron County (Johnson, 1999); San Lorenzo Creek, Webb County (Johnson, 1999); Las Moras Creek, Kinney County (Strecker 1931); Rio Grande upstream of the Río Conchos in 1979, Presidio County (Metcalf, undated); and Beaver Lake on the upper Devils River, Val Verde County (Strecker, 1931). More recent Texas records include: an oxbow pond and Sapo Lake, Hidalgo County (Howells, 2000); Falcon Reservoir, Zapata County (Howells, 1998a, 1999); Lake Casa Blanca, Maverick County (Howells, 1994a, 1996a, 1997a); the lower Devils River, Val Verde County (Howells, 1996a); and Lake Balmorhea, Reeves County (Howells, 1998a, 1999). Two lots of paper pondshell taken by R.D. Camp early in the past century upstream of El Paso in the San Jose River near San Rafael, Valencia County, New Mexico are present in the Corpus Christi Museum collection (J. Deisler-Seno, Corpus Christi Museum; pers. comm.). Small populations probably persist in ponds, impoundments, and backwaters from the lower Rio Grande Valley upstream to the lower Devils River and in spring runs at Balmorhea of the Pecos River drainage. Status of the species in Mexico and New Mexico is uncertain.

SPECIES REPORTS OF DOUBTFUL VALIDITY

Threeridge (*Amblema plicata*) was reported by Dall (1896), as *Unio undulatus*, from Kinney County based on a single "badly broken, and much worn right valve." In as much as even fossil specimens are otherwise lacking from the system, it seems likely the valve was either a misidentified washboard or the collection locality was incorrect. Round pearlshell (*Glebula rotundata*) was listed by Simpson (1914) and Strecker (1931), based on an earlier report by Conrad (1855), from the Rio Grande. The species is otherwise not known from areas south of Green Lake at the mouth of the Guadalupe River and reports of round pearlshell from the Rio Grande are likely misidentified Tampico pearlymussel (Howells et al., 1996). Although it is probably not part of the Rio Grande assemblage, P.D. Hartfield (U.S. Fish and Wildlife Service, Jackson, Mississippi; pers. comm.) reported seeing this species among others a commercial musseler claimed to have taken from the Rio Grande (as discussed above). Nonetheless, recent survey efforts failed to find it.

FRESHWATER BIVALVES IN OTHER FAMILIES

Asian clam (*Corbicula fluminea*), first found near El Paso in the mid-1960s (Metcalf, 1966), occurs throughout the drainage basin (Howells et al., 1996). A second possible species in the genus has also been reported from the Rio Grande (Hillis and Patton, 1981; Hillis and Mayden, 1985). Among the fingernail clams, several have been documented including: long fingernailclam *Musculium transversum*, ubiquitous peaclam *Pisidium casertanum*, striated fingernailclam *Sphaerium striatinum*, mottled fingernailclam *Eupera cubensis* (Metcalf, undated; Davis, 1980a, b, c). Asian clam is an undesirable exotic, but its status in the Rio Grande has rarely been quantified. Fingernail clams are even less well studied than unionids.

POSSIBLE REASONS FOR DECLINE

CLIMATE AND WEATHER

The Rio Grande drainage basin has been naturally changing from a cooler, more-moist climate to a warmer and dryer situation. Wilkins (1992) described a general climatic trend toward warming and drying since the end of the Wisconsin glaciation about 18,000 years ago. Smith and Miller (1986) discussed a regional shift from woodlands to grasslands and deserts from about 11,500 years ago. Loss of species like washboard from upriver areas in New Mexico and its range reduction to the lower-most Rio Grande reflects this ongoing climatic change. Similarly, Rio Grande monkeyface and false spike may have been in a mode of natural decline prior to European impact.

Recent precipitation pattern changes may also play a role in mussel decline. Long-term precipitation records for selected sites in Texas yield 10-year averages demonstrating a pattern of increasing rainfall at Brownsville (61.7 cm in the 1950s to 83.0 cm in the 1990s) and Laredo (112.0 cm in the 1940s to 133.6 cm in the 1990s). However, this pattern was less evident at Del Rio and was not found at El Paso. In addition to increasing net rainfall in some areas, weather records also indicate a shift to fewer light and moderate showers and more severe storm events (MICRA, 1995). Thus, recent decades have experienced more major storms producing scouring floods that directly destroy unionids and alter habitat, with long periods of insufficient precipitation in between resulting in dewatering losses. Freshwater mussels need stable conditions to survive and prosper. Current precipitation trends are clearly unfavorable.

WATER FLOW PATTERNS

Human impact appears to be the major reason for the massive reduction in mussel faunal diversity and abundance in the Rio Grande. Overgrazing, land clearing, construction of impervious surfaces, and other anthropogenic modifications have also contributed to increased runoff during storms and additional scouring and riverbed modifications. Increased groundwater pumping, in turn, reduces spring flows and subsequently river water levels during dry periods. All of these factors can contribute to negative impacts on unionids.

Flow rates reflect an interrelationship of both precipitation and water retention or releases from impoundments, as well as other factors. The U.S. National Park Service (NPS, 2001) reported 69-86% of the water in the Rio Grande downstream from Presidio originated from the Río Conchos, Mexico, and that although a treaty between the U.S. and Mexico defined allotments related to annual flows, the treaty did not specify release schedules for Mexican rivers. Mean annual flows by site are least at El Paso and Brownsville, but greatest between Langtry and Rio Grande City (Table 3). Mean annual flows during the years examined display a pattern of decrease over time from the Rio Grande downstream of Amistad dam to Brownsville (Table 3). Flows at Laredo in 1975 averaged 149 m^3/s, but dropped in 2000 to 43.2 m^3/s. At Brownsville, flows were 100 m^3/s in 1975, but fell to 1 m^3/s in 1999 and 5 m^3/s in 2000. In 2001, flow downstream of

Brownsville stopped and freshwater failed to reach the Gulf of Mexico at times. Historic droughts have also reduced or eliminated flows in the Rio Grande as in 1952, 1955, 1957, and 1958 when the riverbed was dry at Johnson Ranch, Big Bend National Park (NPS, 2001). Past dewatering likely reduced or eliminated some unionid populations and the current pattern of flow rate decline poses an increasing threat again. However, large-volume releases below mainstem dams, which may actually occur during drought conditions, can cause scouring-related damage to mussels and aquatic habitat at downstream sites as well.

NUTRIENT LOADS

Mean annual levels of total phosphorus between El Paso and Brownsville and in the Pecos River at Langtry were below 0.5 mg/L (Table 2). Similarly, sulfate ranged from 161-290 mg/L in the main channel of the Rio Grande, was low in the Devils River (9 mg/L), but averaged over 2,000 mg/L in the upper and central Pecos River of Texas (Table 2). Among all years combined, nitrate levels averaged below 1.4 mg/L in the main channel and the Pecos River at Langtry, except at Brownsville where it slightly exceeded 1.6 mg/L (Table 2). Interestingly, nitrate concentrations show a significant pattern of decline over time. In 1968, levels were very high in the Rio Grande at Langtry (3.2 mg/L), Laredo (3.7 mg/L), and Brownsville (6.0 mg/L), but decreased to < 1.0 mg/L at these same sites in 2000, with a decline to 0.2 mg/L at Brownsville (Table 3). Although there is little published information associating nutrient levels and freshwater mussels, it seems unlikely that concentrations currently found in the Rio Grande would be problematic (but with some concern about sulfate in the upper and central Pecos River).

Table 2. Mean values for selected physicochemical parameters at locations on the Rio Grande, Pecos River, and Devils River, Texas, obtained from measurements presented in U.S. Geological Survey reports for water years 1968 (USGS, 1968), 1975 (USGS, 1975), 1986 (Buchner et al., 1986), 1996 (Gandara et al., 1996), 1999 (Gandara et al., 1999), and 2000 (Gandara et al., 2001). Values for Amistad, Falcon, and Anzalduas dams were actually taken in the Rio Grande downstream of those structures.

	Rio Grande – Main channel							
Parameter	El Paso	Langtry	Amistad Dam	Laredo	Falcon Dam	Rio Grande City	Anzalduas Dam	Brownsville
Flow rate (m^3/s)	22.2	52.1	45.6	83.1	63.5	68.2	34.6	33.0
Total phosphorus (mg/L)	0.41	0.9	<0.01	0.13	0.06	-	-	0.15
Sulfate (mg/L)	289	290	214	161	200	209	233	233
Nitrate (mg/L)	0.89	1.35	0.22	1.14	0.40	-	-	1.62
Chloride (mg/L)	148	117	141	116	116	136	167	181
Conductivity (µS/cm)	1368	1214	1103	959	971	1065	1020	1322
Suspended sediments (mg/L)	535	2685	5	137	20	-	-	64
Dissolved solids (mg/L)	863	772	663	598	589	645	730	761
Turbidity (NTU)	140	775	1	53	8	-	-	27

	Pecos River			Devils River
	Orla	Girvin	Langtry	Comstock
Flow rate (m^3/s)	2.1	1.0	9.5	6.4
Total phosphorus (mg/L)	-	-	0.04	-
Sulfate (mg/L)	2012	3477	467	9
Nitrate (mg/L)	-	-	0.92	0.94
Chloride (mg/L)	3477	5818	777	15
Conductivity (µS/cm)	12651	21585	34551	381
Suspended sediments (mg/L)	-	-	12	22
Dissolved solids (mg/L)	9742	12953	2038	214
Turbidity (NTU)	-	-	10	5

Table 3. Annual mean values for flow rate, nitrate concentration, and suspended sediments at locations on the Rio Grande, Pecos River, and Devils River, Texas, obtained from measurements presented in U.S. Geological Survey reports for water years 1968 (USGS, 1968), 1975 (USGS, 1975), 1986 (Buchner et al., 1986), 1996 (Gandara et al., 1996), 1999 (Gandara et al., 1999), and 2000 (Gandara et al., 2001). Values for Amistad, Falcon, and Anzalduas dams were actually taken in the Rio Grande downstream of those structures.

	Year					
	1968	1975	1986	1996	1999	2000
	Flow Rate (m^3/s)					
Rio Grande – El Paso	-	-	27.2	16.9	19.9	24.8
Rio Grande – Langtry	-	54.8	52.0	35.2	65.3	53.4
Rio Grande – Amistad Dam	-	-	80.4	46.2	30.4	25.5
Rio Grande – Laredo	-	148.9	110.9	46.8	65.8	43.2
Rio Grande – Falcon Dam	-	-	98.4	61.4	32.7	61.5
Rio Grande – Rio Grande City	-	-	97.4	64.0	56.6	54.9
Rio Grande – Los Ebanos	-	-	98.3	30.4	41.7	38.1
Rio Grande – Anzalduas Dam	-	-	39.0	33.4	34.8	31.1
Rio Grande – Brownsville	81.1	99.5	8.2	3.1	1.0	5.1
Pecos River – Orla	2.4	2.6	0.8	2.5	-	-
Pecos River – Langtry	0.5	2.0	7.2	16.0	0.6	0.7
Devils River – Comstock	-	-	6.0	6.9	3.6	4.0
	Nitrate (mg/L)					
Rio Grande – Langtry	3.2	1.5	1.1	0.7	0.8	0.8
Rio Grande – Laredo	3.7	0.6	0.4	-	0.7	0.5
Rio Grande – Brownsville	6.0	0.3	0.9	0.1	0.4	0.2
Pecos River – Langtry	-	1.8	0.6	0.3	0.4	0.9
Devils River – Comstock	-	-	1.2	0.7	-	-
	Suspended sediments (mg/L)					
Rio Grande – Langtry	-	-	654	2364	4113	3609
Rio Grande – Falcon Dam	-	-	122	29	19	20
Rio Grande – Brownsville	-	-	120	63	47	64

CHLORIDE AND CONDUCTIVITY

Chloride concentrations and associated conductivity values may have a direct impact on mussel presence or absence at some locations in the basin. Averages among years produce chloride values from El Paso to Brownsville of 116-181 mg/L and conductivity values of 959-1,368 µS/cm that are typically greatest at up- and downstream sites (Table 2). In the Devils River, chloride averaged only 15 mg/L and conductivity 381 µS/cm (Table 2). However, chloride concentrations in the upper (Orla), central (Girvin), and lower (Langtry) Pecos River were dramatically elevated to 3,477, 5,818, and 777 mg/L, respectively (Table 2). Similarly conductivity at these same sites was 12,651, 21,585, and 34,551 µS/cm, respectively (Table 2).

Thus the Pecos River is the major source of elevated chloride and conductivity values in the system. Natural salt seeps and deposits are present in the area, but groundwater pumping that has reduced freshwater input, long periods of reduced precipitation, and brines from oil and gas drilling operations likely contribute to current saline conditions. Chloride and conductivity levels in the mainstem Rio Grande are probably not limiting (though upper lethal limits for most unionids remain undefined). However, levels in the upper and central reaches of the Pecos River in Texas are probably sufficiently high as to preclude long-term mussel survival. At most sites in the Pecos River, Texas, even disturbance-tolerant Asian clam is not present. In addition to the dam at Red Bluff Reservoir, salt waters probably genetically isolate the Texas hornshell population in the Black River, New Mexico, from any survivors in the Rio Grande downstream of Big Bend.

TOTAL DISSOLVED SOLIDS AND SEDIMENT LOAD

Total dissolved solids average from El Paso to Brownsville range from 589-863 mg/L, are lower in the Devils River (214 mg/L), but dramatically elevated in the Pecos River (2,038-12,953 mg/L)(Table 2). Mean suspended sediment levels (mg/L) by location from upstream to downstream in the Rio Grande were 535 (El Paso), 2,685 (Langtry), 5 (Rio Grande downstream of Amistad Dam), 137 (Laredo), 20 (downstream of Falcon Dam), and 64 (Brownsville), and were 12 (Pecos River, Langtry) and 22 (Devils River, Comstock)(Table 2). The increase in suspended sediment agrees with field observations of heavy recent, silt deposition at and upstream (in the Rio Grande) of the Pecos River mouth. Indeed, comparing annual means indicates suspended sediment loads typical of the system in general in the Rio Grande at Langtry in 1986 (654 mg/L), but with levels elevating in the late 1990s to 2,364 (1996), 4,113 (1999), and 3,609 mg/L (2000)(Table 3). U.S. Geological Survey (Gandara et al., 2001) data from a sampling station in the Rio Grande just downstream of the Río Conchos indicated an average suspended sediment load in 2000 of 169 mg/L, lower than location averages elsewhere in the mainstem of the Rio Grande. The Río Conchos, then, appears not to be the main source of the suspended sediments that have increased between Presidio and Langtry. Turbidity measurements follow the same pattern found with suspended sediments (Table 2). Although the primary source of increased sediment is unclear from recent freshwater mussel survey work, certainly overgrazing, development, and other typical anthropogenic factors contribute. It is noteworthy the only areas in the Rio Grande of Texas where Texas hornshell and Salina mucket may still be surviving are in or just upstream of the major site of silt deposition. Deep soft silts are unacceptable mussel habitat (Howells et al., 1996). Finally, despite heavy silt loads and deposition at Langtry, Amistad Reservoir appears to block much of this material from progressing downstream, as does Falcon Reservoir to a lesser extent downriver. Although this may benefit mussels still surviving in the river below these dams, it suggests a questionable future for reservoir populations.

RESERVOIR CONSTRUCTION AND POLLUTION

Reservoir construction and resultant impounded waters may eliminate some mussels and their natural habitat while creating additional habitat for other species (Howells et al., 1996). Indeed, neither Texas hornshell nor any of the endemic unionids in the Rio Grande are known from reservoirs and may well require flowing water situations. Conversely, Tampico pearlymussel adapts well to reservoirs, despite having evolved in riverine environments (Howells, 1996c; Howells et al., 1996). Even when unionids are able to survive in impounded waters, water management practices can still be destructive. Rapidly fluctuating water levels and long periods of dewatering are common sources of mortalities. These problems were particularly evident in Amistad and Falcon reservoirs when water levels began to decline substantially in mid-1995. Reservoirs may also block movement of host fishes required for parasitic unionid larvae. Host fishes utilized by Tampico pearlymussel, yellow sandshell, washboard, bleufer, giant floater, lilliput, Texas lilliput, pondhorn (sp.?), and paper pondshell (Howells, 1997d; Howells et al., 1996), as well as Texas hornshell (Gordon, 2000) are probably not seriously limited by dams in the basin. However, hosts required by Conchos disk, Salina mucket, southern mapleleaf, Rio Grande monkeyface, and Mexican fawnsfoot are unknown; thus host availability issues cannot be addressed.

Pollution and habitat modification associated with human development have probably impacted unionid fauna of the Rio Grande as they have throughout the country, but documentation locally is largely lacking. However, some areas reportedly have a high potential for chemical impacts (Kelly and Reed, 1998). Tremendous human population growth and human development has occurred in the drainage basin over the past 30 years (Kelly and Reed, 1998). The North American Free Trade Agreement (NAFTA) of recent years has no doubt enhanced the speed and extent of this development. It is not apparent, however, that any NAFTA-related development has ever specifically considered impacts on unionids.

COMMERCIAL HARVEST

Freshwater mussels have supported important commercial shell fisheries elsewhere in Texas and the U.S. (Howells, 1993). Historically, the U.S. military harvested local shells for buttons early in the past century in Cameron County, Texas (Neck, 1990), and a button factory operated briefly at Mercedes, Hidalgo County, Texas (Garrett, 1929). Pearl harvesters that seek Tampico pearlymussel in the Colorado and Brazos drainages, Texas (Howells, 1993, 1996c) appear not to focus similar harvest efforts on the Rio Grande. A survey of both resident and non-resident mussel license holders in Texas (Howells, 1993) found no respondents indicating they took mussels from the Rio Grande. There is no indication that commercial harvest for shells or pearls is, or has ever been, economically important or contributed to the decline of the fauna locally.

SUMMARY

All unionid species in the Rio Grande drainage basin have been dramatically reduced in abundance and distribution both historically and in recent years. Among the 16 freshwater mussel taxa reported in the system, two are likely extinct (Rio Grande monkeyface and false spike). Seven other taxa have not been documented in recent years and are either extinct or reduced to very low numbers (Conchos disk, Mexican fawnsfoot, yellow sandshell, washboard, lilliput, Texas lilliput, and pondhorn (sp.?). Texas hornshell is still extant in a short stretch of the Black River in southern New Mexico and a small relict population may also be present in the Rio Grande downstream of Big Bend. Similarly, Salina mucket may still survive in low numbers just downriver of Big Bend. Tampico pearlymussel, paper pondshell, and introduced southern mapleleaf are currently maintaining populations in Texas waters, and a bleufer population introduced in Amistad Reservoir is presumed to be present as well. Among other bivalves, Asian clams are widely distributed and even abundant in some areas. Fingernail clams are still present, but current species, abundance, and distribution are poorly defined. Unfortunately, ecological sensitivity of unionids, projected future development within the drainage, and general disinterest among regulatory authorities suggest an extremely dim future for this unique faunal group.

ADDENDUM

Since this manuscript was drafted, unionid collections in 2002 in the Rio Grande in Webb County have included one living and several recently dead shells or valves each of washboard and Texas hornshell, as well as several recently dead shells and valves of Mexican fawnsfoot. Additional survey efforts are planned to better define the status of these species in the Webb County area.

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Address of author:

ROBERT G. HOWELLS

Texas Parks and Wildlife Department
Heart of the Hills Fisheries Science Center
HC 7, Box 62
Ingram, Texas 78025
e-mail: robert.howells@tpwd.state.tx.us