Section 6 Report Review

Attachment to letter dated 24 May 2002

Project: Survey of Abundance, Distribution, and General Biology of Texas Hornshell (*Popenaias popei*) and Other Unionids in the Rio Grande, Texas

Final or interim report? Final

Job #: WER 49(90)

Reviewer's Station: Austin ES

Lead station was contacted and concurs with the following comments:
___ Yes ___ No _X_ Not applicable (reviewer is from lead station)

Report: _X_ is acceptable as is

____ is acceptable as is for an interim report, but the following comments are made for future reference

____ needs revision (listed below)

Comments: (Note to commenter: If you make comments directly on a copy of the report, write legibly and dark so comments will reproduce well when photocopied.)

Dr. Robert Howells has done an excellent job in the work on mussels in the Rio Grande and the report is comprehensive and well-written. Some of the original project objectives related to general biology of Texas hornshell were abandoned early in the project due to the lack of living individuals collected during extensive survey efforts. However, the report includes much information that goes well beyond the original project objectives, such as the detailed species accounts of all Rio Grande mussels, the comprehensive analysis of historical information on Rio Grande mussels, and the thorough assessment of possible reasons for decline and current threats.

FINAL REPORT

As Required by

THE ENDANGERED SPECIES PROGRAM

TEXAS

Grant No. E-1-13

Endangered and Threatened Species Conservation

Project WER49(90): Survey Of Abundance, Distribution, And General Biology Of Texas Hornshell (*Popenaias Popei*) And Other Unionids In The Rio Grande, Texas

Prepared by: Robert Howells

TEXAS PARKS & WILDLIFE

John Herron
Program Director, Wildlife Diversity

Robert Cook
Executive Director

March 31st, 2002

FINAL REPORT

STATE: Texas **GRANT NO:** E – 1 – 13

PROGRAM TITLE: Endangered and Threatened Species Conservation

PERIOD COVERED: September 1, 2000 – December 31, 2001

PROJECT NUMBER: WER49(90)

PROJECT TITLE: **Survey Of Abundance, Distribution, And General Biology Of Texas Hornshell (*Popenaias Popei*) And Other Unionids In The Rio Grande, Texas**

SEGMENT COST:
TOTAL - $11,896.89
FEDERAL SHARE - $8,922.68

PROJECT OBJECTIVES:

To survey waters of the Rio Grande, Texas, to determine abundance and distribution of Texas hornshell (*Popenaias popei*) and other local unionids and gather data on the general biology of these species.

PREPARED BY: Robert Howells 11/31/01

APPROVED BY: [signature] 03/22/02
Neil E. Carter Date
Federal Aid Coordinator

JOB DESCRIPTION

State: Texas **Project Number/Grant Number:** 90 / (WER49)

Grant Title: Endangered and Threatened Species Conservation

Project Title: Status of the Texas hornshell and native freshwater mussels (Unionoidea)
(Both States) in the Rio Grande and Pecos River of New Mexico and Texas

Project Title: Survey of abundance, distribution, and general biology of Texas hornshell
(Texas) (*Popenaias popeii*) and other unionids in the Rio Grande, Texas

Reporting/Contract Period: 1 September 1997 to: 31 August 2001

Program Objectives (Both States).

Document the distribution and abundance of Unionoidea of the Pecos River and Rio Grande of New Mexico and Texas, with special emphasis on the Texas hornshell mussel (*Popenaias popeii*; federal Species of Concern), state listed species, and rare native mussels. Quantify microhabitats and document the life history of *Popenaias* and other native mussels, including gametogenesis, brooding periodicity, and glochidial fish host(s). Conduct genetic analyses (allozymic and mitochondrial DNA) to assess the taxonomic position of *Popenaias*.

Program Objectives (Texas).

To survey the waters of the Rio Grande, Texas, to determine abundance and distribution of Texas hornshell (*Popenaias popei*) and other local unionids and gather data on general biology of these species.

Need and Justification.

Freshwater mussels are the most rapidly declining faunal group in North America, including within the Rio Grande. Despite their ecological importance and economic value, the current status and basic biology of many unionids is poorly known. Rio Grande mussel fauna in particular has received little scientific attention. As the Rio Grande border areas experience development and additional human impacts, knowledge of the status of these organisms has become increasingly important. Drought and flood conditions over the past decade have also reduced unionid populations in the Rio Grande. Unfortunately resource managers have little baseline information on local freshwater mussels relating to distribution, abundance, biology, or even identification of taxa on which to base management decisions. This study attempted to fill many of these voids in needed critical information.

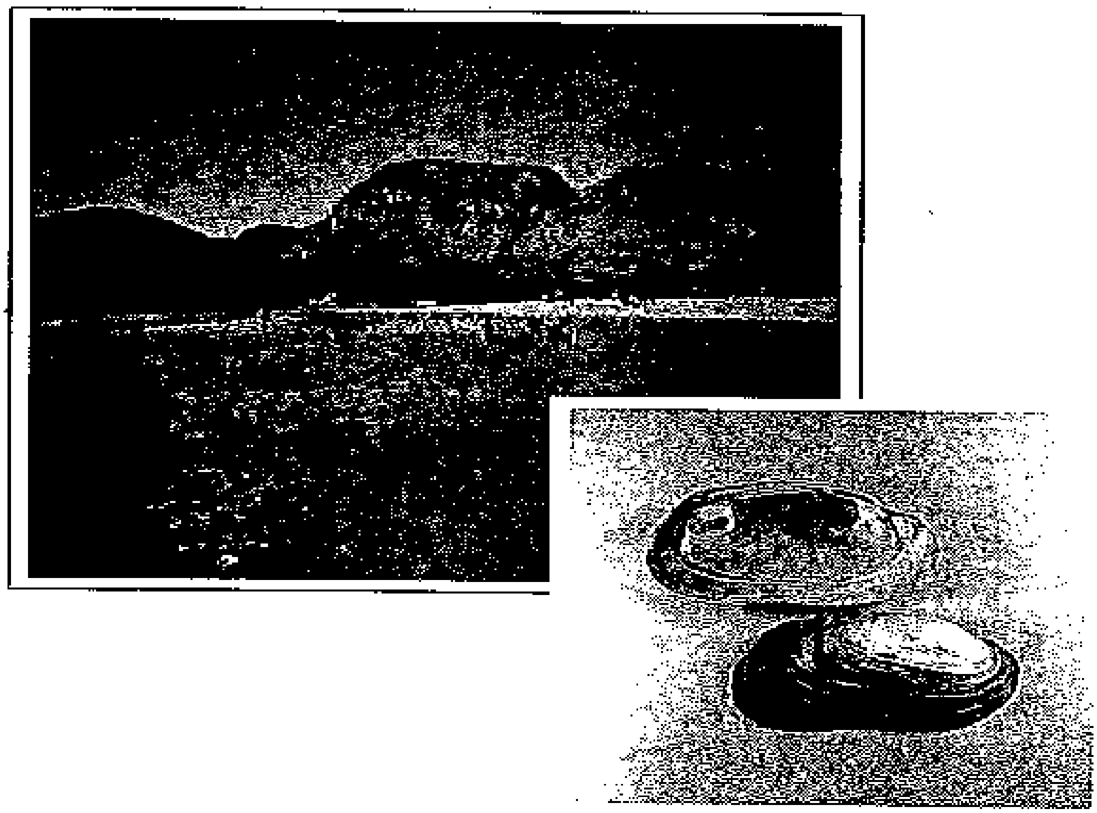
Findings.

The attached report is submitted to address the objectives of this study. It includes (1) a discussion of prior research, (2) approaches and procedures utilized, (3) a discussion of basic biology of each species of unionid, and (4) presentation of survey findings, as well as (5) comments on current status and management implications.

Genetics and reproductive biology of rare and endemic unionids in the Rio Grande were not addressed in the Texas portion of this study due to a failure to locate living specimens. Similarly, absence of living specimens also precluded discussion of physicochemical requirements related to "snap-shot" measurements associated with shells, valves, and fragments collected. Instead, long-term records of physicochemical measurements were examined to characterize temporal trends within the system.

STATUS OF FRESHWATER MUSSELS OF THE RIO GRANDE,
WITH COMMENTS ON OTHER BIVALVES

Robert G. Howells



Texas Parks and Wildlife Department
Inland Fisheries Division
4200 Smith School Road
Austin, Texas 78744

2001

ACKNOWLEDGMENTS

In addition to efforts by Texas Parks and Wildlife's (TPW) Heart of the Hills Research Station (HOH) staff, numerous other individuals assisted with work on this project. Volunteers who assisted with field surveys or provided data included Pam Baker (Kerrville, Texas), Pat Sims (Presidio High School, Presidio, Texas), and Roe Davenport (San Antonio, Texas). Raymond Skiles and other members of the Big Bend National Park staff (Big Bend National Park, Texas) assisted with field collection efforts in the Rio Grande at Big Bend National Park. Bruce Mooring, Steve Ansley, and other U.S. Geological Survey personnel (Austin, Texas) coordinated field work with HOH efforts in the upper Rio Grande of Texas and provided additional data and input. Kevin Cummings (Illinois Natural History Survey, Champaign) and Art Bogan (North Carolina State Museum of Natural Sciences, Raleigh) provided opinions on taxonomic issues related to Rio Grande unionids.

This research represented a joint effort by TPW and New Mexico Department of Game and Fish (NMDGF) and was supported by U.S. Fish and Wildlife Service funding. Brian Lang (NMDGF, Santa Fe) and Mark Gordon (New Mexico Museum of Natural History and Science, Albuquerque) provided information about findings in the Rio Grande and Pecos River Drainages of New Mexico.

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 TPW 1992-1997, and federally-funded work by TPW and NMDGF 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 10 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* was last documented in 1898. Texas hornshell *Popenaias popeii* supports a population in the Black River, New Mexico, and scattered individuals may exist in the main channel of the Rio Grande upstream of Dryden Crossing, Texas; status in Mexican waters is unknown. Rio Grande records of false spike *Quincuncina mitchelli* are generally of fossil and subfossil shells; it is likely extirpated locally. Tampico pearlymussel *Cyrtonaias tampicoensis*, paper pondshell *Utterbackia imbecillis*, and southern mapleleaf *Quadrula apiculata* are currently maintaining populations in Texas waters, as is introduced bleufer *Potamilus purpuratus*. Other species that are often abundant elsewhere, but appear to have been eliminated from the Rio Grande include yellow sandshell *Lampsilis teres* and pondhorn(s) *Uniomerus* sp(p). Giant floater *Pyganodon grandis* is present in New Mexico, but may be introduced there. Asian clams *Corbicula* spp. are widely distributed and sometimes abundant. Fingernail clams (Family Sphaeriidae) are still present, but abundance and distribution remains poorly known. Factors contributing to the decline of the unionid fauna in this system 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.

CONTENTS

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 economic importance of the region, relatively little effort has been directed at understanding freshwater mussels (Family Unionidae) of the Rio Grande (Neck and Metcalf 1988). Freshwater mussels are also 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.

Dall (1986) and others reported on early border surveys and 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 New Mexico; Metcalf (1982) discussed recent, subfossil, and fossil records; 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) addressed 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, b, c). Nonetheless, data from all these sources on the unionids of the Rio Grande was very limited.

More recently, TPW's HOH initiated statewide surveys of this group, including sites within the Rio Grande drainage (Howells 1994a, 1994b, 1995a, 1996a, 1996b, 1996c, 1997a, 1997b, 1997c, 1998a 1998b; Howells and Garrett 1995; Howells et al. 1996, 1997). In 1998, federally-funded work (termed present study herein) was jointly initiated by TPW and NMDGF to further examine the mussel fauna of the system (Howells 1999, 2000a, 2001a; Howells and Ansley 1999; Lang 1998, 2000). Johnson (1999) provided the most recent summary of the unionid fauna of the system, based on his interpretation of museum specimens and published literature. Collectively, from these sources, a picture of the unionid faunal composition, abundance, and distribution has started to emerge.

MATERIALS AND METHODS

Standard mussel sampling protocols employed in HOH work were presented in Howells (1995a, 1996a). Counting methods and estimates of shell condition follow Howells (1995a, 1996a), except in a few cases where specific authors used other terms (e.g., fresh rather than recently dead). Taxonomy follows Howells et al. (1996) and Turgeon et al. (1998), except for the common name for *Disconaias conchos* presented here. Freshwater mussel survey work by HOH 1992-1997 generally only documented Asian clams (*Corbicula* spp.; Family Corbiculidae) and fingernail clams (Family: Sphaeriidae) as present or absent, and did not record numbers. Similarly, the project title of the present study specified focus on "Unionoidea" rather than bivalves in other orders. Therefore, Asian and fingernail clams were often not identified to species or numerically counted in HOH work.

Although, the approved proposal for the present study work on the Rio Grande did not include funding for examination of museum collections, efforts were made to list historic collection records of specimens from the Rio Grande and, in some cases, eastern Mexican systems that hold Rio Grande unionid taxa. These data are listed herein as available. Also listed are published reports of bivalve and benthic invertebrate sampling sites in the drainage basin. In many cases, historic collection records were used to indicate where current efforts needed to be directed.

Global Positioning System (GPS) coordinates were obtained where possible during present study fieldwork. However, most historical and previous HOH collections lacked this information. Additionally, deep canyons of the upper Rio Grande Drainage in Texas and other confounding factors occasionally precluded obtaining GPS readings in the field. Efforts were made to obtain missing latitude and longitude data by plotting points on maps with Microsoft (2000). This was applied even to historical data wherever possible to produce at least a "best guess" set of coordinates for each collection location.

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 (October 1 of the previous year to September 30 of the year listed): 1968 (U.S. Geological Survey 1968), 1975 (U.S. Geological Survey 1975), 1986 (Buckner et al. 1986), 1996 (Gandara et al. 1996), 1999 (Gandara et al. 1999), and 2000 (Gandara et al. 2001). Reported data values from these sources were averaged by site for all years combined, by 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

Collection Records and Survey Overview

A review of selected historical sampling sites and collection records in Texas prior to the initiation of statewide freshwater mussel surveys by HOH in 1992 included approximately 100 locations (Table 1, Figs. 1 and 2). Locations in Texas examined during the 1992- 1997 surveys by HOH involved over 50 additional sites (Table 2, Figs. 3 and 4). During the present study from 1998 into 2001, HOH obtained data on nearly 130 sites (Table 3, Figs 5 and 6).

Selected historic sampling and collection sites from the Rio Grande drainage of northeastern Mexico as well as other rivers along the eastern coast of Mexico included another 45 sites (Table 4, Fig. 7). In 1994, HOH examined 20 sites on the Rio Conchos and several adjacent drainages, Chihuahua, Mexico (Table 5, Fig. 8). Finally, historic and recent unionid collection records from New Mexico for 10 sites on the Pecos River and another in the upper Rio Grande drainage are also presented (Table 6, Fig. 9). It should be noted that unpublished specimens and collection records for specimens now in museum and university collections almost certainly exist and could be added to the historic data above. Similarly, some "blanks" in Tables 1, 4, 5, and 6 where details (e.g., dates, numbers of specimens, etc.) were unavailable could often be filled by examining actual museum collections (again, not part of the original objective of this study). Additionally, work in New Mexico by NMDFG (Lang 1998, 2000) and its cooperators (Gordon 2000; Smith et al. 2000) provides a much more detailed analysis of sampling sites and collection data than is presented here, and should be consulted for information on that region.

A review of sampling and collection records from Mexico and New Mexico can be important. Most freshwater bivalves reported from the Rio Grande Drainage are not endemic and have other populations in areas to the north or south. The degree of concern about the status of Rio Grande populations may be influenced by knowledge of their total distribution and status elsewhere. For example, although both yellow sandshell and giant floater have declined in the Rio Grande and native populations may have already been eliminated, both have other populations in other drainages that are secure, if not abundant. Although it is unfortunate to have apparently lost them from the Rio Grande faunal assemblage, neither is in danger of extinction as a species. Conversely, Salina mucket *Potamilus metnecktayi* is not known to occur elsewhere, so protecting any survivors that may still remain may be critical to preventing its extinction. Additionally these data also help provide a sense of change over time also needed to put current collection data into perspective.

Past records helped focus present study efforts. For example, Metcalf (unpublished) and Davis (1980a) examined sites on the Rio Grande from Presidio upstream to El Paso, Texas. These studies provided indication that there would be little value in directing any extensive current survey efforts to that section of river. Similarly, prior HOH surveys of Las Moras Creek, Brackettville, Texas (Howells 1996b) found limited evidence of bivalves remaining in that system and downgraded need for any significant further examination.

Species Accounts

At least 16 taxa of unionids occurred in the Rio Grande drainage of Texas, New Mexico, and Mexico. Three species are endemic to this drainage basin. Among the freshwater mussels, two are apparently recent introductions, as are Asian clams. Additionally, at least four species of fingernail clams have been reported in the system, as has Atlantic rangia *Rangia cuneata* (Family Mactridae). Descriptions of freshwater mussels given below refer to conchological features of the shell unless otherwise stated. Species are arranged alphabetically by genus and species. Range maps presented were developed from data generated by this study, with additional distributional information from Murray and Leonard (1962), Brandauer and Wu (1978), Clarke (1981), Oesch (1984), Cummings and Mayer (1992), Vidrine (1993), Howells et al. (1996, 1997), Lang and Mehlhop (1996), Lang (1998, 2000), Parmalee and Bogan (1998), as well as unpublished data of the author and C.M. Mather (University of Science and Arts of Oklahoma, Chickasha; pers. comm.), where appropriate.

Tampico pearlymussel
Cyrtonaias tampicoensis
(Figs. 10-11)

Other names: Purple shell mussel, purple mussel, Concho River pearl mussel (Howells et al. 1996). Taxonomic synonyms include *Unio berlandierii, U. heermanii, U. tecomatensis,* and possibly *U. umbrosus* and *U. grandensis.* Strecker (1931) recognized three forms as subspecies (*tampicoensis, berlandierii,* and *heermanii*) in Texas; however, electrophoretic analysis of Texas populations by HOH failed to find significant differences regardless of origin or morphological appearance. A Mexican subspecies, *C. t. tecomatensis,* is listed by U.S. Fish and Wildlife Service as endangered; Simpson (1914) indicated it occurred in drainages of southeastern Mexico.

Range: The native range of Tampico pearlymussel (Fig. 12) extends from the Brazos River, Texas, (Howells et al. 1996) south to at least the Rio Papaloapan System, Vera Cruz, Mexico (Johnson 1999) and possibly Honduras (Simpson 1914), with unsuccessful introductions in the upper Trinity and Red rivers, Texas (Howells et al. 1996). Upstream records in the Rio Grande 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 counties, New Mexico (Metcalf 1982).

Description: To at least 156 mm shell length (sl); oval to subrectangular or subrhomboidal; moderately thick and solid, occasionally thinner to very thick; subcompressed to somewhat inflated; beaks elevated above hinge line and often inflated; beak sculpture consisting of only a few fine lines to absent; posterior ridge rounded, with other secondary ridges in the posterior field poorly defined; disk unsculptured; beak cavity deep; pseudocardinal teeth (two left and one right) moderately well developed; lateral teeth (two left and one right) well developed (31-36% sl) and angled downward; externally tan, yellowish-brown, grayish-brown, chestnut, dark brown, to black, rayless or with obscure green rays; Nacre often purple, but may be pink, orange, lavender, white, or bicolored, but Rio Grande and Nueces-Frio River populations are most frequently white to pastel rather than the darker hues seen in populations to the north and south (Howells et al. 1996; Howells 2000a).

Reproduction: In Texas, eggs, glochidia, or both were found in marsupia throughout the year; the smallest gravid female found was 30 mm sl (Howells 2000b). Glochidia were described by Howells et al. 1996). Fish hosts include longnose gar *Lepisosteus osseus* (Howells 1997d), as well as spotted gar *L. oculatus,* golden shiner *Notemigonus crysoleucas,* and Rio Grande cichlid *Cichlasoma cyanoguttatum* (HOH unpublished data).

Habitat: It occurs on mud, sand, gravel, and occasionally cobble in streams, rivers, canals, and adapts well to many impoundments; from very shallow water to depths of at least 15 m; lotic waters to moderately swift flows.

Status: 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 1996 also eliminated large numbers from Falcon and Amistad reservoirs when water levels fell.

Comments: Tampico pearlymussel has supported fisheries for gem-quality pearls primarily in the Brazos and

Colorado Drainage Basins of Texas since Spanish colonial times (Howells 1993, 1996c). However, no similar fishery appears to have developed in the Rio Grande.

Conchos disk
Disconaias conchos
(Figs. 13-14)

Other names: None.

Range: This species was first described by Taylor (1997) from 1969 collections near Saucillo, Rosetilla, and Julimes on the Rio Conchos, Chihuahua, and a 1937 collection at Villa Juarez on the Rio Sabinas, Coahuila, Mexico. It is apparently endemic to those systems and not known from the main channel of the Rio Grande or other tributaries (Fig. 15).

Description: To at least 124 mm sl; elongate-oval, round-pointed posterio-ventrally in some and bluntly truncate posteriorly in others (possibly sexually dimorphic); thick and solid, except thinner in smaller juveniles; beaks rise above hinge line and are set back from the anterior shell margin about 32% sl, beak sculpture exfoliated in existing specimens; posterior ridge broadly rounded; disk unsculptured; beak cavity relatively shallow; pseudocardinal teeth (two left and one tooth and one dentical right), left pair of teeth strong and almost peg-like, right anterior dentical small and oblique, right tooth much larger and triangular; lateral teeth (two left and one right) short (22-31 % sl), strong (thinner in small juveniles), and sometimes slightly curved, lateral teeth seem atypically short for such an elongate shell; externally reddish-brown in juveniles to dark brown or black in larger specimens; internally nacre white or bluish-white, with a faint salmon tint, some sun-bleached and long-dead valves in the HOH collections may have had nacre that was purple or pink in life (Taylor 1997; present study).

Reproduction: Season is unknown. Glochidia are unknown. Hosts are unknown.

Habitat: Unknown.

Status: During desert fishes surveys by the HOH staff in 1994, 10 unmatched valves were found in the Rio 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. Species status is uncertain, but the 1994 juvenile is the only suggestion the species may still survive.

Comments: This species was described from conchological shell features. Soft tissue characteristics, glochidial morphology, genetic comparisons to other unionids needed to clearly define taxonomic affinities are lacking.

Yellow sandshell
Lampsilis teres
(Fig. 16)

Other names: Thinrhine, creeper, bank creeper, banana, sandshell, sand clam, luster shell, tiger tooth; historically assigned to *Unio*; *L. anodontoides* and *L. fallaciosa* are now considered *L. teres* (Howells et al. 1996).

Range: Yellow sandshell ranges throughout much of the central U.S. (Fig. 17) and is often common elsewhere in Texas (Howells et al. 1996). In the Rio Grande drainage, it has been documented in the Pecos River upstream of the Rio Grande, Val Verde County, Texas (Johnson 1999), downstream to Cameron County, Texas (Strecker 1931), and the Rio Sabinas, Coahuila (Johnson 1999), and Rio 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.

Description: To at least 145 mm sl in Texas, occasionally larger elsewhere; oblong and elongate; sexually dimorphic with males pointed posteriorly and females truncate; most moderately thick and solid, but range from thin to rather thick; subcompressed to nearly round in cross section, with females inflated posteriorly; beaks moderately raised above the hinge, but not high; posterior ridge broad and rounded; disk unsculptured; beak cavities shallow; pseudocardinal teeth (two left and one right, occasionally with an anterior right dentical) elongate and compressed; lateral teeth (two left and one right) long, lamellar, often slightly curved; externally horn-yellow, often with darker growth-rest line, occasionally stained darker; internally very pearly-white, sometimes with a slight salmon tint dorsally (Howells et al. 1996). Rio Grande specimens do not appear to be morphologically distinct from other Texas populations (present study).

Reproduction: Females were found elsewhere in Texas with glochidia in their marsupia every month of the year except February (Howells 2000b). Descriptions of glochidia were summarized by Howells et al. (1996). At least 10 species of fishes have been identified as hosts (Watters 1994; Howells et al. 1996), many of which occur in the Rio Grande.

Habitat: This species tolerates a wide array of habitats from small to large streams, rivers, lakes, and reservoirs and slow- to fast-flow conditions and most bottom types, but avoids deep-shifting sand and deep-soft silt; though often present in shallower waters, it may occur in deeper situations as well (Howells et al. 1996).

Status: 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 2000a); and 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) found 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 found 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, and none have been located since.

Comments: It is unclear why a species that is often common to abundant elsewhere, tolerates a wide array of environmental conditions, and utilizes a large number of fish species as hosts should have declined so profoundly in the Rio Grande, even in areas where other unionids still occur.

Washboard
Megalonaias nervosa
(Fig. 18)

Other names: Giant washboard, lake board, river board, bald-pate; historically placed in the genera *Unio*, *Quadrula*, *Amblema*, and *Crenodonta* and includes species *giganteus*, *heros*, *multiplicatus*, *eightsi*, and in part *undulatus* (Howells et al. 1996).

Range: This large waterbody species occurs throughout the central United States and lower river reaches in Texas from the Red to the Nueces rivers (Howells et al. 1996) (Fig. 19). In the Rio Grande, fossil shells have been found as far upstream as 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). Mexican reports include the Rio Sabinas (Johnson 1999) and fossil material from the Rio Salado near Anahuac, Nuevo Leon, and subfossil specimens near Villa Juarez, Coahuila (Metcalf 1982).

Description: To lengths over 250 mm sl, very large and massive; quadrate to rhomboidal or oval; solid, thick, sometimes thin in small juveniles; beaks narrow and not much elevated above the hinge line; posterior ridge typically obscure; disk sculptured with long, wavy ridges extending to the posterior margin, also with cross-hatch patterns in the dorsal anterior and central disk areas (often obscure or exfoliated in large adults); beak cavities deep; pseudocardinal teeth (two left and one right) large, triangular, rough; lateral teeth (two left and one right) long and nearly straight; externally light brown to dark brown or black; internally nacre white, rarely tinted with pink or purple, often with metallic gold markings and dark splotches (Howells et al. 1996).

Reproduction: Females with glochidia were found in Texas only from November through January, with reproduction reported as early as August or September elsewhere (Howells 2000b). Descriptions of glochidia were summarized in Howells et al. (1996). Over 15 different fishes have been listed as hosts for washboard (Watters 1994; Howells et al. 1996), many of which occur in the Rio Grande.

Status: 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.

Comments: This is a large and commercially valuable species and the Rio Grande appears to be its southern range limit. It is the largest, most massive unionid in North America and its loss locally would be unfortunate.

Texas hornshell
Popenaias popeii
(Fig. 20)

Other names: Hornshell; historically placed in genera including *Unio, Margaron, Lampsilis*, and *Elliptio* (Howells et al. 1996), but apparently *U. veraepacis* (or *verae-pacis*) is not synonymous (Johnson 1999).

Range: 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 Rio Cazones, Vera Cruz (Johnson 1999) (Fig. 21). 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 (Metcalf 1982); in the Devils River nearly to Pandale, Val Verde County, Texas (Howells 2000a); 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.

Description: To at least 108 mm sl, but usually less; a report to 116 mm (Howells et al. 1996) was incorrect; elongate and trapezoidal; length to height ratio 1.8 or greater; compressed; narrowed anteriorly and centrally, but wider posteriorly; subsolid; only moderately thick; beaks low and flattened, but sharp; posterior ridge double, rounded, and flattened; disk unsculptured; beak cavities shallow; pseudocardinal teeth (two left and one right) are small to very small; lateral teeth (two left and one right) are long, low, and curved to nearly straight; externally olive-green to dark brown, occasionally faintly rayed when young; internally nacre white, bluish-white, purple-gray, often glossy, but sometimes dull (Howells et al. 1996; present study).

Reproduction: Studies in New Mexico (Lang 2000; Smith et al. 2000) found gravid females from March through August with all stages of embryos and larvae on every sampling date. Sexes were distinct and no hermaphroditism was noted (Smith et al. 2000). Glochidia were described by Smith et al. (2000). Gordon (2000) reported metamorphosed juveniles recovered from 23 fish species including longnose gar, Mexican tetra (*Astyanax mexicanus*), minnows (Cyprinidae), suckers (Catostomidae), freshwater catfishes (Ictaluridae), killifishes (Cyprinodontidae), western mosquitofish (*Gambusia affinis*), Rio Grande cichlid, sunfishes (Centrarchidae), and greenthroat darter (*Etheostoma lepidum*); transformation occurred 6-14 days after infection.

Habitat: Nearly all known habitat information originated from the recent study of the Black River population in New Mexico (Lang 2000). Texas hornshell was found at both ends of narrow, shallow runs over bedrock, but in areas where small-grained materials collected in crevices, along river banks, and at the bases of boulders. All reports appear to be from riverine areas and the species is not known from impoundments.

Status: 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 a living population surviving in the Black River (Pecos River tributary), Eddy County, New Mexico (Lang 1998, 2000). The Black River animals 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.

Comments: Since the mid-1970s, the only records of living or recently dead Texas hornshells appear to be the population in the Black River, New Mexico (Lang 2000); four preserved specimens taken in the Rio Moctezuma, San Luis Potosi, Mexico (Smith et al. 2000); and recently dead shells found in the Rio Grande between Big Bend and the San Francisco Creek, Texas (present study). Lang (2000) reported gas and oil operations in the Black River drainage were potential threats to that population, as were poor land-use practices and other environmental perturbations, muskrats *Ondatra zibethicus* that prey upon this species, and additional factors. In Texas, poor land- and water-use practices (impacts include dewatering, scouring floods, heavy siltation) and general climatic changes project a questionable future for any surviving specimens.

Salina Mucket
Potamilus metnecktayi
(Fig. 22)

Other names: Salina mucket has been included under both *Disconaias* and *Potamilus* (Howells et al. 1996). Johnson (1998) redescribed endemic animals from the Rio Grande previously referred to as *P.* or *D. salinasensis* as *P. metnecktayi* and seems to have combined a number of other related species to the south of the Rio Grande, including "*Lampsilis fimbriata*", under *Disconaias disca*.

Range: 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 Rio Salado of Tamaulipas, Coahuila, and Nuevo Leon, Mexico (Johnson 1999) (Fig. 23).

Description: To at least 135 mm sl; elongate-oval, but sexually dimorphic with males more centrally round-pointed posteriorly and females more blunt; relatively thin (in juveniles) to only moderately thick; subcompressed to slightly or moderately inflated; beaks low and sculpture largely lacking; posterior ridge low, rounded, obscure; beak cavities shallow; pseudocardinal teeth (two left and one right) thin, compressed, triangular; lateral teeth (two left and one right) relatively long and slightly curved (ca. 30% sl); externally tan to dark brown or black, some with thin, dark rays posteriorly; internally nacre white or bluish-white; sometimes with a slight salmon tint (Howells et al. 1996; Johnson 1998; present study).

Reproduction: Season is unknown. Glochidia are unknown. Hosts are unknown.

Habitat: Unknown; but not reported from reservoirs.

Status: 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 2000a). In nearly 30 years, these are the only records to suggest the Salina mucket is still extant.

Comments: See discussion under Texas hornshell in the Rio Grande, Texas.

Bleufer
Potamilus purpuratus
(Fig. 24)

Other names: Bluefer, bluffer, purple shell, purple shell mussel, pink, purple pocketbook, heelsplitter, blooper, blue mucket, blue hen; placed in genera *Unio*, *Lampsilis*, and *Proptera* and currently includes the species *coloradoensis* (Howells et al. 1996). The Central and West Texas populations, including the Rio Grande specimens, of the *coloradoensis* form may prove to be taxonomically distinct from East Texas and Mississippi River Drainage populations typical of *purpuratus* (Roe and Lydeard 1998).

Range: The native range of bleufer extends from the Guadalupe-San Antonio Drainage of Texas north and east (Howells et al. 1996) (Fig. 25). 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).

Description: To at least 265 mm sl; ovate to oblong or rectangular, but sexually dimorphic with males round pointed posteriorly and females more truncate; juveniles and males more compressed and females more inflated; occasionally somewhat alate; moderately thick to thick; solid; beaks elevated above the hinge line, but not high, sculptured with corrugated double loops, sometimes reduced to 2-5 rows of nodules or lacking entirely; posterior ridge rounded and usually not well defined, but typically with 2-3 additional ridges posterio-dorsally; disk unsculptured; beak cavity moderately deep; pseudocardinal teeth (two left and one right) erect, triangular to quadrate, somewhat compressed in smaller individuals; lateral teeth (two left and one right) short to moderately long (28-38% sl), often slightly curved, angled horizontally or upward but not downward; externally reddish-brown to black, occasionally with vague green rays; internally nacre usually purple, but more rose in Central and West Texas and in the introduced Rio Grande population, rarely orange (Howells et al. 1996; present study).

Reproduction: Females with glochidia were found from August through May in Texas; the smallest gravid female examined was 65 mm sl (Howells 2000b). Descriptions of glochidia are summarized in Howells et al. (1996). The only known host is freshwater drum *Aplodinotus grunniens* (Surber 1915).

Habitat: Bleufer occurs on mud, sand, gravel, and cobble in streams, rivers, sloughs, lakes, and reservoirs; it is occasionally found in gravel-filled cracks of bedrock bottoms; in still waters to moderately fast flows; to depths of at least 7 m (Howells et al. 1996).

Status: In the Rio Grande drainage, it is known only from Amistad Reservoir where extreme drawdowns in 2000 and 2001 almost certainly reduced its numbers.

Comments: Locally this species is an introduced exotic with limited distribution and abundance.

Giant floater
Pyganodon grandis
(Fig. 26)

Other names: Softshell, stout floater, slop bucket, hogshell, papershell; historically placed under *Anodonta* and a long list of species names (Howells et al. 1996).

Range: Though widely distributed and often common in Texas and elsewhere in the United States (Howells et al. 1996) (Fig. 27), 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); fossil material from Billingslea Draw near Toyah off the Pecos River, Reeves County, Texas (Metcalf 1982); and Granjeno Lake (Strecker 1931) and canals at Mercedes (Ellis et al. 1930), both Hidalgo County, Texas. 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 recently dead shells downstream of that impoundment, Eddy County, New Mexico.

Description: To at least 170 mm sl in Texas, larger elsewhere; elliptical to subovate, more elongate in some forms and very rounded in others; moderately to very inflated; thin; beaks often high and inflated; posterior ridge broadly rounded; disk unsculptured, sometimes subglossy; beak cavities deep; pseudocardinal and lateral teeth absent; externally tan, light brown, greenish-brown, dark brown to black, occasionally faintly rayed posteriorly; interiorly nacre white, bluish-white, occasionally with pink or salmon overtones (Howells et al. 1996).

Reproduction: In Texas, females were found carrying eggs September-October and glochidia were present in marsupia October through January, though some may retain eggs and glochidia into April (Howells 2000b). Descriptions of glochidia were summarized by Howells et al. (1996). Watters (1994) and Howells et al. (1996) summarized reports of hosts including over 35 fish species.

Habitat: Although giant floater may occur in a wide array of habitat types, it prefers soft bottoms in still and slow flow waters in ponds, lakes, reservoirs, canals, rivers, streams, and oxbows; it can often survive on softer silts and muds where heavy-shelled unionids would sink and perish (Howells et al. 1996).

Status: Metcalf and Smartt (1972) assumed 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 found recently in New Mexico (possibly non-native stock), there is no other recent confirmation of the species in the Rio Grande.

Comments: This species is occasionally so abundant elsewhere in Texas and throughout the Central U. S. that it is sometimes considered a "weed species." Why in the face of success in other areas it has declined in the Rio Grande is enigmatic.

Southern mapleleaf
Quadrula apiculata
(Fig. 28)

Other names: Greenie, mapleleaf; historically considered a subspecies of mapleleaf *Q. quadrula* and with subspecies *apiculata*, *speciosa*, *forsheyi*, and *asper* [*aspera*] (Strecker 1931).

Range: Southern mapleleaf occurs from Oklahoma south through all major drainages in Texas and east along the Gulf Coast to Alabama (Howells et al. 1996) (Fig. 29). In the Rio Grande, it is known only 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, 2000a).

Description: To at least 129 mm sl; usually quadrate, but occasionally subrectangular, ovoid, or produced posterio ventrally; moderately thick to thick; solid; inflated and globose to subcompressed; beaks elevated above the hinge, but not high; beak sculpture chevron-shaped nodular ridges; posterior rounded and obscure to slightly angular, with an obscure to well-defined sulcus; disk usually sculptured with numerous fine pimples (not large pustules or drop-shaped lunules), juveniles heavily pimpled throughout, but adults with sculpturing often restricted to dorsal areas, posterior slope with curvilinear ridges; beak cavity deep; pseudocardinal teeth (two left and one and an anterior dentical right) heavy, massive; lateral teeth (two left and one right) moderately heavy, straight to slightly curved, moderately long (38-42% sl); externally pale tan, yellow-brown, to dark brown or black, often with alternating dark and light growth-rest lines, occasionally with obscure green rays; internally nacre white (Howells et al. 1996; present study).

Reproduction: In Texas, eggs and glochidia were present in female marsupia from mid- to late May with glochidia released by mid-July; occasionally earlier in the lower Rio Grande during early spring warming; the smallest mature female found was 46 mm sl (Howells 2000b). Glochidia were described by Howells et al. (1996). Fish hosts are also unknown, but many other members of the genus utilize catfishes (Howells et al. 1996).

Habitat: Southern mapleleaf occurs on mud, sand, gravel, and occasionally cobble; in small streams and canals to larger rivers; tolerates impoundment well; lotic waters to moderately swift flows; to depths of at least 7 m (Howells et al. 1996; present study).

Status: Reservoir populations, particularly at Falcon Reservoir, were reduced in abundance in the mid- and late 1990s, 2000, and 2001 due to extensive dewatering. Unstable conditions and fluctuating water levels, agricultural and industrial impacts along with other anthropogenic factors, and exotic macrophytes threaten its survival in resacas, canals, oxbows, and other areas in the Lower Rio Grande Valley, Texas.

Comments: Although southern mapleleaf is common throughout most of Texas and other Gulf states (Howells et al. 1996), it is absent from the local fossil record (Metcalf 1982), historical, and Mexican collections from the Rio Grande. Neck and Metcalf (1988) suggested it may be an introduction. Southern mapleleafs in populations in the Rio Grande rarely grow large enough to be of interest to commercial shell harvesters.

Rio Grande monkeyface
Quadrula couchiana
(Fig. 30)

Other names: Originally described as *Unio*, otherwise, none (Howells et al. 1996).

Range: This endemic species has been reported as fossil remains as far upstream 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 at Las Moras Creek, Fort Clark (Brackettville), Kinney County, Texas (Strecker 1931) (Fig. 31). Other subfossil and fossil specimens have been found at sites in the Rio Salado, Coahuila and Nuevo Leon, Mexico (Metcalf 1982) (Fig. 31). A record from the Nueces River drainage, Zavalla County, Texas, is thought to be spurious (Johnson 1999).

Description: Reported to 58 mm sl (Metcalf 1982); subrhomboidal to nearly round or oval; solid; only slightly inflated; beaks full and elevated above the hinge but not high; posterior ridge usually moderately developed, sulcus rather shallow; disk relatively smooth (sometimes exfoliated) to covered with pustules; beak cavities deep; pseudocardinal teeth (two left and one right) somewhat less massive than many quadrulids; lateral teeth (two left and one right) nearly straight (ca. 43% sl); externally ashy-brown; greenish when young; internally nacre white (Howells et al. 1996; present study).

Reproduction: Season is unknown. Glochidia are unknown. Hosts are unknown.

Habitat: Unknown.

Status: This species may have been last seen alive or recently dead in the 1898 collections in Las Moras Creek (see Taylor 1967). Neck (1984) indicated A.L. Metcalf reported D.W. Taylor had found living specimens in the Rio 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 this century and the species may well be extinct.

False spike
Quincuncina mitchelli
(Fig. 32)

Other names: Placed in the genera *Unio*, *Elliptio*, *Quadrula*, and *Sphenonaias* and the species *taumilapanus*, *iheringii*, and *guadalupensis* (Howells et al. 1996; Johnson 1999).

Range: 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) (Fig. 33). Metcalf (1982) 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 Rio San Juan of Nuevo Leon, and Rio Salado, Nuevo Leon and Coahuila, Mexico. Johnson (1999) noted an additional collection from the Rio Salado, Tamaulipas, in the University of Michigan Museum of Zoology, but did not comment on the condition of the specimen.

Description: Reported to 132 mm sl in the Rio Grande (Metcalf 1982), smaller in Central Texas; subrhomboidal; moderately thick, thinner in smaller specimens; subsolid to solid; beaks elevated above the hinge but not high, beak sculpturing with double-looped ridges faint anteriorly but more pronounced and forming elongate chevrons posteriorly; posterior ridge broadly rounded; disk sculptured with parallel, ripple-like ridges from the posterior ridge onto the posterior slope and central region of the disk, other pustules and cross-hatching may also be present or the disk may be exfoliated; beak cavities moderately deep; pseudocardinal teeth (two left and one tooth and a large dentical right) moderately heavy and triangular (less massive than most quadrulids); lateral teeth (two left and one right) relatively short (28-33% sl) and straight; externally tawny-brown, to dark brown or black, sometimes rayed with olive-yellow or olive-green markings on the posterior slope; internally nacre white (Howells et al. 1996; present study).

Reproduction: Season is unknown. Glochidia are unknown. Hosts are unknown.

Habitats: Its ecological requirements are largely unknown; however, some specimens from Central Texas were known to inhabit gravel bars (Howells et al. 1996).

Status: Living specimens have not been found in Central Texas since the late 1970s (Howells et al. 1997) and nearly all records from the Rio Grande are Metcalf's (1982) subfossil and fossil specimens. 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 2001a) are the only suggestion the Central Texas population has not been lost as well.

Lilliput
Toxolasma parvus
(Fig. 34)

Other names: Lilliput shell, common lilliput; historically placed in *Unio*, *Lampsilis*, *Eyrynia*, and *Carunculina* (Howells et al. 1996). Taxonomic confusion among species in this genus has been problematic, particularly with historic collections.

Range: Lilliput occurs throughout most of Texas and much of the United States (Howells et al. 1996) (Fig. 35), 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).

Description: Reported to 30 mm sl (Oesch 1984), but usually much less; subelliptical to suboval; slightly compressed to nearly round in cross-section; solid; posterior margin vertically truncate, not obviously sexually dimorphic; beaks above hinge but broad, low, and flattened; posterior ridge broadly rounded and often nearly absent; disk unsculptured, but epidermis with a cloth-like or silky appearance; beak cavities shallow; pseudocardinal teeth (two left and one right) erect, triangular to peg-like, compressed; lateral teeth (two left and one right) moderately long, slightly curved, thin; externally light brown to dark brown or black, sometimes tinted green posteriorly, rayless; internally nacre white, bluish-white, or rarely blue or purple (Howells et al. 1996). Members of this genus possess two finger-like extensions of the mantle called caruncles that are used to lure potential fish hosts (Howells et al. 1996).

Reproduction: Only four living specimens taken in April in Falcon Reservoir were found during HOH work and three contained marsupial eggs (Howells 2000b); Baker (1928) reported eggs in August and glochidia May through July elsewhere. Glochidia are undescribed. Five sunfish species have been reported as hosts (Watters 1994; Howells et al. 1996).

Habitat: It prefers quiet, shallow waters with softer bottom types of mud or mud and sand (Howells et al. 1996). Vidrine (1993) characterized it primarily as a small creek species.

Status: During HOH surveys since 1992, 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 others have been documented since and recent dewatering at Falcon Reservoir was likely particularly devastating to shallow water species like lilliput.

Comments: This species is widespread in Texas, but usually much less abundant than Texas lilliput *T. texasiensis*.

Texas lilliput
Toxolasma texasiensis
(Fig. 36)

Other names: Historically placed in *Unio* and *Carunculina* and listed as a subspecies of *T. parvus*; forms called *bairdianus*, *bealii*, and *haleianus* are apparently this species as well (Howells et al. 1996); spelling *texasensis* is incorrect.

Range: Texas lilliput ranges from the Rio Grande (Howells et al. 1996) north to southern Illinois (Cummings and Mayer 1992) and east along the Gulf Coast (Vidrine 1993) (Fig. 37). Historic collections from the Rio Grande, 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).

Description: To at least 75 mm sl, but usually less; elliptical and somewhat elongate in males; strongly sexually dimorphic with males centrally-pointed posteriorly and females obliquely truncate, shorter and deeper bodied posteriorly; beaks low and flattened, only slightly elevated; posterior ridge broadly rounded and low; disk unsculptured, but epidermis often rough and flaky (not cloth-like); beak cavities shallow; pseudocardinal teeth (two left and one right) erect, peg-like to triangular, compressed; lateral teeth (two left and one right) curved or straight, moderately long (ca. 44% sl); light brown, yellowish-brown, to deep chestnut brown or black, usually unrayed; internally nacre white, but usually with yellow or salmon highlights (Howells et al. 1996). Females possess two finger-like extensions of the mantle called caruncles that are used to lure potential fish hosts (Howells et al. 1996).

Reproduction: In Texas, Howells (2000b) found females with eggs in May and June and others with glochidia from May through July. Reed and Oliver (1953) considered those in the Dallas area to be long-term brooders with a lapse in July and August; Stern and Felder (1978) reported reproductive activity from February through May. Glochidia were described by Howells et al. (1996). Two sunfishes have been described as hosts (Stern and Felder 1978).

Habitat: Texas lilliput is typical of soft bottoms and still and slow-flow waters in ponds, canals, feeder creeks, and embayments off reservoirs and lakes. Vidrine (1993) indicated it preferred larger water bodies than lilliput.

Status: Though often locally abundant in much of Texas (Howells et al. 1996), Texas lilliput has only rarely been reported in collections in the Rio Grande drainage. Texas lilliput was third in abundance in archaeological excavations along Elm Creek, Maverick County (Howells 1998c) where its sexually dimorphic shells were often readily apparent. However, it was not found in HOH survey sites throughout the basin examined during the past decade.

Comments: Although Williams et al. (1993) and Turgeon et al. (1998) acknowledged lilliput, Texas lilliput, and western lilliput (*T. mearnsi*) as valid species, genetic analysis failed to distinguish the latter as distinct from Texas lilliput (Howells 1997b) and Howells et al. (1996) included it under that species.

Mexican fawnsfoot
Truncilla cognata
(Fig. 38)

Other names: Historically placed in the genera *Unio*, *Margaron*, and *Plagiola* (Howells et al. 1996).

Range: This Rio Grande endemic has been reported from the main channel of the Rio Grande and lower Pecos River near Del Rio, Val Verde County, Texas (Metcalf 1982) downstream to Laredo, Webb County, Texas (C.M. Mather, University of Science and Arts of Oklahoma, Chickasha; pers. comm.), and in the Rio Salado of Nuevo Leon and Tamaulipas, Mexico (Johnson 1999) (Fig. 39).

Description: To at least 45 mm sl, but usually smaller; elliptical, males pointed posteriorly; relatively thin; solid; only slightly inflated; beaks moderately elevated and narrow; posterior ridge broadly rounded and flattened marginally; disk unsculptured; beak cavity shallow; pseudocardinal teeth (two left and one right) triangular and somewhat compressed; lateral teeth (two left and one right) thin, relatively short (26-36% sl); externally yellowish- or grayish-green, with darker rays, zig-zags, or chevrons, pale; internally nacre white (Howells et al. 1996; present study).

Reproduction: Season is unknown. Glochidia are unknown. Hosts are unknown.

Habitat: Unknown.

Status: This species is known only from a small number of specimens. Originally described from the Rio Salado, Nuevo Leon, Mexico in 1860, it has also been taken from the same river in Tamaulipas (U.S. National Museum; Johnson 1999) and Metcalf (1982) reported a specimen of probably fossil origin from the Rio 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 1997a) may be a misidentification. None have been otherwise documented since the 1972 Metcalf collection. However, it should be noted that during the present study, the HOH staff was unable to examine the site near Del Rio where Metcalf found the last-reported specimens.

Comments: Johnson (1999) combined Mexican fawnsfoot and Texas fawnsfoot *T. macrodon* under fawnsfoot *T. donaciformis*. However, this action was based on conchological features of a small number of Mexican fawnsfoot specimens and lacked discussions of soft tissues or genetic comparisons. Given these points, the geographic distance to the nearest Texas fawnsfoot population records in the central Colorado River drainage (several drainage basins north of the Rio Grande), and the noteworthy morphological differences between Texas and Mexican fawnsfoots, other authorities have been uninclined to support this combination of species and Mexican fawnsfoot is retained here as a valid taxon.

Pondhorn(s)
Uniomerus tetralasmus – U. declivis
(Figs. 40-42)

Other names: Pondhorn or common pondhorn *U. tetralasmus* and tapered pondhorn *U. declivis* are both presently acknowledged as valid species; historically they have been associated with *Unio*, *Margarita*, and *Elliptio* (Howells et al. 1996). A pondhorn, given as *Unio manibius*, was taken in an early border survey at Rio 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 *Uniomerus tetralasmus* and *U. declivis* to be valid species. Johnson (1999) combined them, but this has apparently not been widely accepted by unionid authorities to date. Neck (1987) considered both the Rio Agualeguas specimen and others from Baffin Bay drainage, the next system to the north, to be *U. tetralasmus*. Unfortunately many Texas *Uniomerus* populations are intermediate between the two species, as are both Rio Agualeguas and Baffin Bay examples, and true affiliation remains unclear.

Range: Outside the Rio Grande, pondhorn has been documented from the Nueces-Frio System to the Red River Drainage in northern Texas (Howells et al. 1996) and ranges northward to Illinois, Indiana, and Ohio (Vidrine 1993) (Fig. 43). Tapered pondhorn has been reported in Texas from the lower Nueces River drainage through much of Central and East Texas and eastward along the Gulf Coast at least to Alabama (Vidrine 1993) (Fig. 44).

Description: Both species can slightly exceed 120 mm sl; oblong to oblong-quadrate; relatively thin, but moderately solid; compressed to moderately inflated; beaks only slightly elevated; posterior ridge broadly rounded; disk unsculptured; beak cavity shallow; pseudocardinal teeth (two left and one right) thin, divergent, erect; lateral teeth (two left and one right) moderate in length, thin, straight or slightly curved; externally yellowish-brown to dark brown or black, rayless, occasionally with alternating dark and light (growth-rest lines); internally nacre white, rarely purple in tapered pondhorn (Howells et al. 1996). In pondhorn, the posterior margin is obliquely truncate, epidermis is subglossy and intact; and lateral teeth are nearly parallel to the ventral shell margin; in tapered pondhorn, posterior margin tapers sharply downward, the epidermis is dull and flaky, and the lateral teeth angle downward (Howells et al. 1996). But again, many Texas populations are intermediate between these two species.

Reproduction: Pondhorns have been reported gravid from February through August (Utterback 1915-16; Stern and Felder 1978; Littleton 1979). Tapered pondhorn has been found with marsupial eggs in June and July and glochidia in May and July in Texas (Howells 2000b). Pondhorn glochidia were described by Utterback (1915-16) and tapered pondhorn glochidia were described in Howells et al. (1996). Only golden shiner has been reported as a host for pondhorn (Stern and Felder 1978); hosts utilized by tapered pondhorn are unknown (Howells et al. 1996).

Habitat: Both pondhorns are typical of still and slow-flow shallow waters with soft bottoms in streams, canals, ponds (including farm ponds), oxbows and backwater arms off reservoirs and lakes; they reportedly tolerate dewatering for extended periods (Howells et al. 1996).

Status: 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. The decline of these environmentally-tolerant species in the Rio Grande Drainage when they are still abundant elsewhere in Texas is particularly puzzling and perhaps alarming.

Comments: 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 subsequently located for examination.

Paper pondshell
Utterbackia imbecillis
(Fig. 45)

Other names: Small floater, paper floater, papershell; historically placed in *Anodonta* and *Lastena*, and as *L. ohiensis* and *A. ohiensis*; use of *imbecilis* is incorrect (Howells et al. 1996).

Range: Paper pondshell is often common in most Texas drainages and elsewhere in the United States (Fig. 46). In the Rio Grande, it has been documented from Matamoras in the mid-1800s, Tamaulipas, and Rio 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 Rio 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 2000a); 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). Neck (1987) also reported paper pondshell from the San Jose River near San Rafael, Valencia County, New Mexico, upstream of El Paso off the main channel of the Rio Grande.

Description: To at least 90 mm sl in Texas, reportedly slightly larger elsewhere; oblong, elongate-oblong, or rectangular; pointed or round-pointed posteriorly; slightly compressed to moderately inflated; very thin and fragile; beaks not elevated above the hinge line; posterior ridge rounded, often with a second or third minor ridge; disk unsculptured, often glossy; beak cavity very shallow; pseudocardinal and lateral teeth absent; externally-off white, tan, lime green, greenish-brown, dark brown, black, sometimes with green or black rays posteriorly; internally nacre white or bluish-white (Howells et al. 1996).

Reproduction: In Texas, females were found carrying eggs in March-April and September-October and marsupia contained glochidia in March-April and July-November (Howells 2000b). Others have reported reproductive activity February-May (Stern and Felder 1978), winter through spring (Heard 1975), or with multiple broods (several sources). Descriptions of glochidia were given in Howells et al. (1996). Watters (1994) and Howells et al. (1996) summarized over a dozen host fishes reported for this species. Although direct transformation from the glochidial to the juvenile stage without a fish host has been suggested for this species, glochidia from Texas specimens that failed to find a host did not transform and died (Howells 1997d).

Habitat: Paper pondshell is typical of still waters and slow flows with soft to very soft bottoms in ponds, oxbows, canals, streams, and backwater arms of reservoirs and lakes; it may survive on substrates that are too soft to support other unionids with heavier shells (Howells et al. 1996).

Status: Small populations probably persist in ponds, impoundments, and backwaters from the lower Rio Grande Valley upstream to the lower Devils River and at Balmorhea off the central Pecos River drainage. Status of the species in Mexico and New Mexico is uncertain.

Comments: Some extremely deep-bodied specimens may be so inflated that the beak actually does project slightly above the hinge line; it is possible these may represent another taxon.

Species Reports of Doubtful Validity

Threeridge (*Amblema plicata*) (Fig. 47) 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*) (Fig. 48) 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 (Strecker 1931) 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* (Fig. 49), first found near El Paso in the mid-1960s (Metcalf 1966), occurs throughout the drainage basin (Howells et al. 1996) and ranges as far south along the eastern coast of Mexico as Lago de Catemaco in southeastern Veracruz (Torres-Orozco and Revueltas-Valle 1996). A second possible species in the genus has been described and has also been reported from the Rio Grande as well (Hillis and Patton 1981; Hillis and Mayden 1985) (Fig. 50). Asian clams are often considered an undesirable exotic (Howells et al. 1996). Their status in the Rio Grande remains largely undocumented.

Among the fingernail clams (Fig. 51), several have been documented including: long fingernailclam *Musculium transversum*, ubiquitous peaclam *Pisidium casertanum*, striated fingernailclam *Sphaerium striatinum*, and mottled fingernailclam *Eupera cubensis* (Metcalf, undated; Davis 1980a, b, c). Fingernail clams are even less well studied than unionids in the Rio Grande Drainage.

Atlantic rangia occurs in brackish areas at the mouth of the Rio Grande and occasionally at freshwater sites in Texas (Howells et al. 1996). Because its shells are used extensively as fill material in roads, boat ramps, and other structures, even recently dead shells are sometimes found in upstream areas even when no local population is present at that site.

Possible Reasons for Decline and Current Threats

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 earlier in this 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 have focused 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.

Climate, Weather, and Water Flow Patterns

The Rio Grande drainage basin has been evolving from a cooler, more-moist climate to a warmer and dryer situation naturally since the last geologic epic. Wilkins (1992) described a general climatic trend toward warming and drying since the last 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 for the same reason.

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) (Fig. 52). However, this pattern was less evident at Del Rio and was not found at El Paso (Fig. 52). 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 prosper and current precipitation trends are clearly unfavorable.

Nonetheless, 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 contributed to increased runoff during storms that causes additional scouring and riverbed modifications. Increased groundwater pumping, in turn, reduces spring flows and subsequently river water levels during dry periods. All 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 Rio 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 7; Fig. 53). 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 8; Figs. 54-56). 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 release below mainstem dams, that 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, except in the Rio Grande near Langtry (0.9 mg/L) (Table 7; Fig. 57). Similarly, sulfate ranged from 161 to 290 mg/L in the main channel of the Rio Grande (Table 7; Fig. 58), was low in the Devils River (9 mg/L) (Table 7; Fig. 59), but averaged over 2,000 mg/L in the upper and central Pecos River of Texas (Table 7; Fig. 59). 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 8; Figs. 60). 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 7; Figs. 61-62). Although there is little published information associating nutrient levels and freshwater mussels, it seems unlikely concentrations currently found in the Rio Grande would be problematic (but with some concern about sulfate and total phosphorus in the upper and central Pecos River).

Salinity

Chloride concentrations and associated conductivity values may, however, have a more 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 7; Figs. 63-64). In the Devils River, chloride averaged only 15 mg/L and conductivity 381 µS/cm (Table 7; Figs. 65-66). 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 7; Figs. 65). Similarly, conductivity at these same sites was 12,651, 21,585, and 34,551 µS/cm, respectively (Table 7; Fig. 66). 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, salinity of the upper and central reaches of the Pecos River in Texas is 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, this high-salinity region probably also genetically isolates the Texas hornshell population in the Black River, New Mexico, from any survivors in the Rio Grande downstream of Big Bend.

Dissolved Solids and Sediment Load

Total dissolved solids averages from El Paso to Brownsville range from 589-863 mg/L, are lower in the Devils River (214 mg/L) (Table 7; Fig 67), but dramatically elevated in the Pecos River (2,038-12,953 mg/L) (Table 7; Fig. 68). 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 7; Fig. 69). The increase in suspended sediment agrees with field observations of heavy, recent silt deposition in the Rio Grande at and upstream 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 8; Fig. 70). U.S. Geological Survey (Gandara et al. 2001) data from a sampling station in the Rio Grande just downstream of the Rio 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 Rio 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 7; Fig. 71). 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 Other Human Impacts

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 or 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 mussel 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(p)., 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 issues 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.

Exotic Species

During the present study in the Lower Rio Grande Valley, water hyacinth *Eichhornia crassipes* and hydrilla *Hydrilla verticillata* were observed in sufficient abundance at some sites that native unionids may have been displaced or eliminated. Mechanical control efforts near San Benito, Cameron County, Texas, were themselves observed to destroy some local mussels. Attempts at chemical control or with phytophagous grass carp *Ctenopharyngodon idella* could also be potentially harmful to mussels. Impacts of herbicides on unionids (a group sensitive to environmental contaminants) are largely unstudied. Excess removal of macrophytes may shift available energy in the system to undesirable phytoplankton blooms or allow erosion and silt deposition unfavorable to mussels. Dense growths of exotic macrophytes can preclude freshwater mussels, but control efforts can also be problematic.

Asian clams have frequently been blamed for declines in native mussels, but supporting evidence associated with such claims is often rather weak (Strayer 1999). Although Asian clams were sometimes locally abundant at some locations in the Rio Grande of Texas, there was little to suggest they were significantly responsible for reductions in mussel abundance, diversity, or distribution. More likely, environmental degradation and modification that negatively impacted freshwater mussels advantaged Asian clams that are often better adapted to disturbed environments.

Zebra mussel *Dreissena polymorpha* and quagga mussel *D. bugensis* are well known for their ability to reduce and eliminate native bivalve populations. Neither species is currently known in waters of Texas, New Mexico, or Mexico. Additionally, there is some question whether zebra mussels will be sufficiently heat tolerant to endure warm summer water temperatures in the Rio Grande drainage (Strayer 1991). Nonetheless, because of the ability of zebra mussels to seriously alter freshwater ecosystems, efforts should be made to prevent any introductions of this genus.

Blue tilapia *Oreochromis aureus* has been introduced into the Rio Grande and elsewhere in Texas (Howells 2001b). Its digging behavior has been implicated in unionid reproductive failure in Texas reservoirs (Howells 1995b) and potential negative impacts should be considered wherever it occurs.

MANAGEMENT RECOMMENDATIONS

State and federal regulatory agencies may wish to reevaluate the threatened-endangered status of several of the unionids found in the Rio Grande. Texas hornshell is only known from a short stretch of the Black River, New Mexico, and possibly from a small number of individuals in the Rio Grande downstream from Big Bend National Park. A limited number of recently dead shells and valves of Salina mucket from this same area downriver from Big Bend is the only suggestion this species might survive. Rio Grande monkeyface and false spike appear to be extinct in the system, and Mexican fawnfoot has not been documented alive or recently dead in nearly 30 years. Further field efforts should be mounted to examine additional sites within the basin, including in Mexican waters, to better define the status of these species.

Some aquatic organisms in the Rio Grande, particularly in upriver areas, can sometimes be successfully managed by protecting areas around spring runs and pools along with maintaining water supplies to those locations. Unfortunately, freshwater mussels rarely if ever live in headwater springs. Protecting and maintaining freshwater mussel habitat involves good land and water use practices throughout large regions of the drainage basin. Multiple state and national jurisdictions, along with varied urban, agricultural, and industrial demands for water and land, make this a formidable task. Water conservation and management practices are among the most important elements of maintaining the remaining unionids in the Rio Grande.

Human development and impacts along the Rio Grande have progressed rapidly in recent years, generally with little or no thought of impact on unionids. During surveys in the system by HOH (1992-1997) and in the present study (1998-2001), no quality mussel habitat areas were detected that could be the focus of preservation efforts. At present, even if biologists in New Mexico can successfully culture and produce Texas hornshell, no prime locations for reintroduction in Texas waters are currently known. Resource managers need to consider impacts of various activities on freshwater mussels to prevent further environmental quality degradation wherever possible.

Regulations and public education related to the introduction of potentially harmful exotic species can also be a major factor relating to the future of Rio Grande mussels. Some previous introductions of exotic species have already provoked control efforts during which impacts on unionids should be considered.

Finally, public and regulatory authority education may be the single most important issue relating to preserving the remaining mussel fauna in the Rio Grande. Few members of the general public or even regulatory authorities are aware of the status of freshwater mussels in the Rio Grande or how their actions may impact the future survival of this group. Information is not only important for individual understanding, but in gaining support for associated conservation efforts.

RECOMMENDED FUTURE WORK

During the present study, a number of factors confounded examining all areas originally planned. For example, atypical rainfall upstream in New Mexico prevented accessing several sites in the upstream reaches of the Rio Grande in Texas due to unusual flood conditions in an otherwise desert environment. Drought conditions on another occasion prompted large-volume releases from Amistad Reservoir that precluded access to a stretch of the Rio Grande near Del Rio for many months. Failure to secure permission to access private lands prevented examination of some sites and a bounty offered by a Mexican national on Border Patrol agents also kept researchers away from boundary waters for a period of time during this study. Regardless of the reason, a number of areas need to be examined or reexamined more intensely.

The lower reaches of the Rio Conchos have not been formally reviewed to date; however, channelization and agricultural runoff in the region suggest limited likelihood major mussel populations remain. The Rio Grande at and immediately downstream of the mouth of the Rio Conchos has not been surveyed in detail. Downstream, the area between Boquillas Crossing and the upper reaches of Boquillas Canyon needs to be examined with greater care to confirm whether any Salina muckets remain.

The stretch of Rio Grande between the lower reaches of Big Bend National Park and Dryden Crossing produced recently dead valves of both Texas hornshell and Salina mucket during the present study. Accessing this area requires several days by canoe and is very rigorous. Successful survey efforts also need to be coordinated with water levels most amiable to successful sampling (often difficult to achieve). Nonetheless, this area may contain the only remaining populations of these species in Texas.

The Rio Grande downstream of Amistad Dam and west of Del Rio was not surveyed during the present study due to private land access problems and high volume water releases. This location produced the last Mexican fawnsfoot specimens collected, but has not been reexamined since 1972.

A stretch of the main channel of Rio Grande between Del Rio and Laredo and the mouths of associated creeks has rarely been included in freshwater mussel collection efforts (though all of the major tributaries in Texas were examined in recent years). Lack of access across private lands and illegal border activities make working in this area difficult and dangerous. It seems unlikely this region harbors large unionid populations, but it still remains to be surveyed.

During survey efforts in the Lower Rio Grande Valley, the HOH staff was advised by local residents that several gravel bars were still present in the Rio Grande between Rio Grande City and La Grulla, Webb County, Texas. Two efforts to examine these sites were both impacted by heavy precipitation and subsequent high, fast-water conditions that limited sampling success. This area needs to be reexamined under low-flow conditions.

Deep waters of the Rio Grande in Hidalgo County, Texas, have not been studied. Rumors of washboards in this area persist, but limited access, poor water quality (e.g., potential contaminants and microorganisms that may make diving unsafe), and other factors make examining this stretch of river difficult. However, if species like washboards are still present in the Rio Grande or round pearlshells do indeed occur in the system, this location could be a logical place to expect them. This area needs to be examined.

Existing museum and university specimens need to be formally surveyed to better define historical collection sites, number of specimens found, and condition of this material.

Mexican tributaries of the Rio Grande and other systems to the south also need to be surveyed. Very little is known about the status of unionids in Mexican waters and no local biologists are currently known to be working with this group in that country.

Finally, because freshwater mussels are such important indicators of environmental health, research on the cause of their demise in the Rio Grande can have far-reaching positive impacts on other areas from angling to human health. Although freshwater mussels appear unimportant and insignificant to some, conditions that are good for unionids are also good for many other organisms, including people.

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Table 1. Selected collection locations for bivalves and sampling sites in the Rio Grande (main stem, minor tributaries, and associated waters), Pecos River, and Devils River drainage basins, Texas, reported prior to initiation of freshwater mussel surveys by Texas Parks and Wildlife in 1992. Latitude and longitude coordinates were estimated using Microsoft Streets & Trips 2001 when not otherwise reported. Museum source acronyms include: USNM = U.S. National Museum, UTEP = University of Texas at El Paso, MCZ = Museum of Comparative Zoology, ANSP = Academy of Natural Sciences of Philadelphia, TUC = Trinity University Collection (recently transferred to ANSP), and CMM = C.M. Mather (University of Arts and Sciences of Oklahoma).

Date	Location	County	Latitude	Longitude	Species	N	Condition	Source
Rio Grande Drainage								
11/--/1964	West Drain Canal (El Paso and adjacent NM)	El Paso	31°59'59"N	106°37'05"W	*Corbicula fluminea*			Metcalf 1966
1976-77	Rio Grande, at S.H. 273, El Paso	El Paso	31°48'10"N	106°32'29"W	*Corbicula* spp.			Davis 1980a
03/17/1969	El Toro Cement Agency Lake, El Paso	El Paso	31°48'15"N	106°31'04"W	*Pyganodon grandis*			USNM 681635; Johnson 1999
1976-78	Rio Grande, Zaragoza International Bridge 24.5 rkm below SH 273	El Paso	31°40'19"N	106°20'17"W				Davis 1980a
12/22/1977	Rio Grande, at drain 3.9 km SE of Esperanza	Hudspeth	31°07'58"N	105°41'46"W				Metcalf (unpublished)
12/22/1977	Rio Grande and levees, rectified end of El Paso Valley Irrigation District	Hudspeth	30°58'05"N	105°30'07"W				Metcalf (unpublished)
04/02/1978	Rio Grande, 0.6 km W of Porcher Ranch at small irrigation ditch	Hudspeth	30°56'27"N	105°28'52"W				Metcalf (unpublished)
04/02/1978	Rio Grande, below Salient Cliffs NE Little Big Bend 5.1 km SE Porcher Ranch	Hudspeth	30°55'10"N	105°26'46"W				Metcalf (unpublished)
02/04/1978	Oxbow Lake, between Rio Grande and River Road 6.8 km NW Talley Ranch	Hudspeth	30°53'32"N	105°24'14"W				Metcalf (unpublished)
02/04/1978	Rio Grande, 2.3 km NW Indian Hot Springs 1.4 km from Talley Ranch	Hudspeth	30°50'26"N	105°20'38"W				Metcalf (unpublished)
02/02/1978	Rio Grande, immediately downstream of Indian Hot Spring Crossing	Hudspeth	30°48'54"N	105°19'05"W				Metcalf (unpublished)
02/04/1978	Mason's Spring, at Indian Hot Springs	Hudspeth	30°49'34"N	105°19'00"W				Metcalf (unpublished)
11/13/1977	Rio Grande and adjacent ditches and resacas, Guerra Farm	Hudspeth	30°45'06"N	105°08'07"W				Metcalf (unpublished)
11/13/1977	Rio Grande and adjacent ponds, Bramblett Ranch headquarters	Hudspeth	30°41'02"N	105°02'02"W				Metcalf (unpublished)
11/12/1977	Rio Grande, at the "Box" 3.4 km ESE of Bramblett Ranch headquarters	Hudspeth	30°40'50"N	105°00'06"W				Metcalf (unpublished)
03/23/1978	Rio Grande, 3.2 km SE of Moody-Berman Ranch house	Presidio	30°30'27"N	104°52'22"W	*Corbicula fluminea*	0.5x1		Metcalf (unpublished)
03/23/1978	Rio Grande, Suarez Ranch house N of Ejido Pilares Road, Mexico	Presidio	30°25'49"N	104°51'34"W				Metcalf (unpublished)
1977-79	Rio Grande, between Capote Creek and McCutchenn Ranch house (3 sites)	Presidio	30°10'46"N	104°41'14"W				Metcalf (unpublished)
01/05/1978	Rio Grande, mouth of Capote Creek 3.2 km NE of Candelaria	Presidio	30°10'03"N	104°41'16"W				Metcalf (unpublished)
01/04/1978	Rio Grande, Candelaria Crossing ca 0.5 km S of Candelaria	Presidio	30°08'22"N	104°41'20"W				Metcalf (unpublished)
01/05/1978	Roadside resaca 1.8 km SE of Candelaria	Presidio	30°07'31"N	104°40'45"W				Metcalf (unpublished)
01/05/1978	Spring on Walker Ranch 2.7 km SE of Candelaria, 0.3 km E of FM 170	Presidio	30°06'13"N	104°40'33"W	*Pisidium casertanum*		live	Metcalf (unpublished)
01/05/1978	Roadside wetland 3.7 km SE of Candelaria	Presidio	30°05'38"N	104°40'58"W				Metcalf (unpublished)
01/03/1978	Spring on Nagele-Goodrich Ranch 8.5 km NNE or Ruidosa	Presidio	30°00'29"N	104°35'54"W	*Pisidium casertanum*		live	Metcalf (unpublished)
01/05/1978	Hot spring and adjacent brook, Hot Springs Resort, 8 km ENE of Ruidosa	Presidio	30°00'06"N	104°36'53"W				Metcalf (unpublished)
01/04/1978	Rio Grande and adjacent resacas and ponds, Pelton Ranch, 3.2 km N of Ruidosa	Presidio	30°00'51"N	104°41'23"W				Metcalf (unpublished)
01/03/1978	Spring on Nunez Ranch, 6.9 km SE of Ruidosa on FM 170, 3.7 km N of Presidio	Presidio	29°36'39"N	104°38'10"W				Metcalf (unpublished)
01/03/1978	Rio Grande and adjacent levees, Farquhar-Walker Ranch, 0.8 km WSW of house	Presidio	29°56'56"N	104°40'47"W				Metcalf (unpublished)
01/03-05/1979	Rio Grande and adjacent pools and springs, Chinati Ranch near FM 170	Presidio	29°50'30"N	104°36'41"W				Metcalf (unpublished)
01/02/1979	Pond adjacent to Rio Grande, W of FM 170, 1.9 km NW of Adobes	Presidio	29°46'49"N	104°34'16"W				Metcalf (unpublished)
01/--/1979	Rio Grande, 1.0-1.3 km section upstream of rectified section, Soza Farm	Presidio	29°36'33"N	104°27'59"W	*Utterbackia imbecillis*			Metcalf (unpublished)
01/--/1979	Rio Grande, 1.0-1.3 km section upstream of rectified section, Soza Farm	Presidio	29°36'33"N	104°27'59"W	*Musculium transversum*			Metcalf (unpublished)
01/--/1979	Rio Grande, 1.0-1.3 km section upstream of rectified section, Soza Farm	Presidio	29°36'33"N	104°27'59"W	*Pisidium casertanum*			Metcalf (unpublished)
01/--/1979	Rio Grande, upstream of Rio Conchos 10.5 km above Presidio	Presidio	29°35'27"N	104°25'51"W				Davis 1980a
01/07/1979	Rio Grande, rectified section at the confluence of the Rio Conchos	Presidio	29°34'27"N	104°24'11"W				Metcalf (unpublished)
01/07/1979	Marshes W of Alamito Creek	Presidio	29°31'21"N	104°17'32"W				Metcalf (unpublished)
01/07/1979	Alamito Creek, at FM 170, 8.8 km S of Presidio	Presidio	29°31'22"N	104°17'21"W				Metcalf (unpublished)
1975-77	Rio Grande, 16.3 km below Presidio	Presidio	29°28'44"N	104°13'51"W				Davis 1980a
1975-77	Rio Grande, Santa Elena Canyon mouth	Brewster	29°09'46"N	103°36'29"W				Davis 1980a
1973-74	Tornillo Creek, Big Bend National Park	Brewster	29°10'40"N	103°00'19"W				Bane and Lind 1978
1976-77	Rio Grande, at Foster Ranch upstream of Pecos River	Val Verde	29°46'38"N	101°43'16"W	*Corbicula* spp.			Davis 1980a
01/10/1972	Rio Grande, 9.7 km W of Del Rio	Val Verde	29°22'26"N	101°00'49"W	*Cyrtonaias tampicoensis*		live	Metcalf 1982
01/10/1972	Rio Grande, 9.7 km W of Del Rio	Val Verde	29°22'26"N	101°00'49"W	*Potamilus metnecktayi*			UTEP 2519, Metcalf 1982
01/10/1972	Rio Grande, 9.7 km W of Del Rio	Val Verde	29°22'26"N	101°00'49"W	*Truncilla cognata*			Metcalf 1982
01/10/1972	Rio Grande, 9.7 km W of Del Rio	Val Verde	29°22'26"N	101°00'49"W	*Lampsilis teres*		live	Metcalf 1982
01/10/1972	Rio Grande, 9.7 km W of Del Rio	Val Verde	29°22'26"N	101°00'49"W	*Popenaias popeii*		live-fresh	Metcalf 1982
1976-77	Rio Grande, Del Rio International Bridge	Val Verde	29°19'38"N	100°55'38"W	*Corbicula* spp.			Davis 1980a
1976-77	Rio Grande, Del Rio International Bridge	Val Verde	29°19'38"N	100°55'38"W	*Eupera cubensis*			Davis 1980a
	Pinto Creek	Kenney	29°11'11"N	100°42'20"W	*Cyrtonaias tampicoensis*			USNM; Strecker 1931
1892-98	Las Moras Creek, Fort Clark, Brackettville	Kenney	29°18'31"N	100°25'14"W	*Megalonaias nervosa*			Strecker 1931

Table 1. Continued.

Date	Location	County	Latitude	Longitude	Species	*N*	Condition	Source
1892-98	Las Moras Creek, Fort Clark, Brackettville	Kenney	29°18'31"N	100°25'14"W	*Uniterbackia imbecillis*			Strecker 1931
1892-98	Las Moras Creek, Fort Clark, Brackettville	Kenney	29°18'31"N	100°25'14"W	*Quadrula couchiana*			Strecker 1931
1892-98	Las Moras Creek, Fort Clark, Brackettville	Kenney	29°18'31"N	100°25'14"W	*Quadrula couchiana*			MCZ ; Johnson 1999
1892-98	Las Moras Creek, Fort Clark, Brackettville	Kenney	29°18'31"N	100°25'14"W	*Popenaias popeii*			Strecker 1931
1892-98	Las Moras Creek, Fort Clark, Brackettville	Kenney	29°18'31"N	100°25'14"W	*Popenaias popeii*			MCZ 195007; Johnson 1999
1892-98	Las Moras Creek, Fort Clark, Brackettville	Kenney	29°18'31"N	100°25'14"W	*Cyrtonaias tampicoensis*			Strecker 1931
1892-98	Las Moras Creek, Fort Clark, Brackettville	Kenney	29°18'31"N	100°25'14"W	*Lampsilis teres*			Strecker 1931
1892-98	Las Moras Creek, Fort Clark, Brackettville	Kenney	29°18'31"N	100°25'14"W	*Toxolasma texasiensis*			Strecker 1931
1892-98	Las Moras Creek, Fort Clark, Brackettville	Kenney	29°18'31"N	100°25'14"W	*Toxolasma parvus*			Strecker 1931
	Elm Creek, near Eagle Pass	Maverick	28°45'54"N	100°29'52"W	*Cyrtonaias tampicoensis*			USNM; Johnson 1999
04/17/1973	Elm Creek, Eagle Pass	Maverick	28°44'42"N	100°30'33"W	*Lampsilis teres*			living Metcalf 1982
	Rio Grande, Eagle Pass	Maverick	28°42'20"N	100°30'41"W	*Megalonaias nervosa*		fragment	Metcalf 1982
	Rio Grande, Eagle Pass	Maverick	28°42'20"N	100°30'41"W	*Truncilla cognata*		fresh	Metcalf 1982
	San Lorenzo Creek	Webb	28°03'40"N	99°57'57"W	*Uniterbackia imbecillis*			USNM; Johnson 1999
04/12/1975	Rio Grande, 72 km NW of Laredo	Webb	27°58'51"N	99°55'54"W	*Truncilla cognata*			CMM 1599
	San Isabella Creek, 18 km NW of Laredo	Webb	27°49'08"N	99°38'41"W	*Cyrtonaias tampicoensis*			MCZ; Johnson 1999
	Rio Grande, Laredo	Webb	27°29'58"N	99°30'26"W	*Lampsilis teres*			Strecker 1931
	Arroyo Veleno	Zapata	26°55'52"N	99°11'33"W	*Cyrtonaias tampicoensis*			USNM; Johnson 1999
	Falcon Reservoir	Zapata	26°48'17"N	99°14'27"W	*Quadrula apiculata*			Neck and Metcalf 1988
	Falcon Reservoir, 14.4 km S of Zapata	Zapata	26°47'10"N	99°13'50"W	*Cyrtonaias tampicoensis*			MCZ; Johnson 1999
	Falcon Reservoir, 14.4 km S of Zapata	Zapata	26°47'10"N	99°13'50"W	*Lampsilis teres*			MCZ; Johnson 1999
	Rio Grande, downstream of Falcon Dam	Starr	26°32'42"N	99°10'19"W	*Quadrula apiculata*			Metcalf 1982; Neck and Metcalf 1988
1975-76	Rio Grande, 2.3 km downstream of Falcon Dam Chapeno	Starr	25°31'54"N	99°09'18"W	*Megalonaias nervosa*		fresh	Neck and Metcalf 1988
1975-76	Rio Grande, 2.3 km downstream of Falcon Dam Chapeno	Starr	25°31'54"N	99°09'18"W	*Popenaias popeii*			Neck and Metcalf 1988
12/--/1975	Rio Grande, Chapeno gauging station	Starr	25°31'54"N	99°09'18"W	*Potamilus metnecktayi*		weathered	UTEP 4660; Neck and Metcalf 1988
12/--/1975	Rio Grande, Roma	Starr	26°24'34"N	99°01'08"W	*Potamilus metnecktayi*		weathered	UTEP 4639; Neck and Metcalf 1988
	Granjeno Lake	Hidalgo	26°07'42"N	98°17'21"W	*Pyganodon grandis*			Strecker 1931
	Granjeno Lake	Hidalgo	26°07'42"N	98°17'21"W	*Lampsilis teres*			Strecker 1931
	Arroyo Colorado, Mercedes	Hidalgo	26°08'14"N	97°55'58"W	*Cyrtonaias tampicoensis*			MCZ; USNM; Johnson 1999
	Canals, Mercedes	Hidalgo	26°07'48"N	97°54'36"W	*Pyganodon grandis*			Ellis et al. 1930; Chamberlain 1930
	Canals, Mercedes	Hidalgo	26°07'48"N	97°54'36"W	*Lampsilis teres*			Ellis et al. 1930; Chamberlain 1930
	Monte Alto Reservoir (Delta Reservoir)	Hidalgo	26°25'00"N	97°57'25"W	*Quadrula apiculata*			Metcalf 1982
	Monte Alto Reservoir (Delta Reservoir)	Hidalgo	26°25'00"N	97°57'25"W	*Cyrtonaias tampicoensis*			Murray TUC
	Monte Alto Reservoir (Delta Reservoir)	Hidalgo	26°25'00"N	97°57'25"W	*Lampsilis teres*			Murray TUC
	Monte Alto Reservoir (Delta Reservoir)	Hidalgo	26°25'00"N	97°57'25"W	*Toxolasma spp.*			Murray TUC
	Resaca de los Fresnos, San Benito	Cameron	26°08'23"N	97°37'50"W	*Quadrula apiculata*			Neck and Metcalf 1988
	Arroyo 3.6 km SW of Harlingen	Cameron	26°08'33"N	97°43'30"W	*Cyrtonaias tampicoensis*			USNM; Johnson 1999
	Pulfivare Resaca, Brownsville	Cameron			*Cyrtonaias tampicoensis*			Neck 1987
	Cottingham Resaca, ca 6 km N of Brownsville	Cameron	26°20'26"N	97°28'42"W	*Uniterbackia imbecillis*			MCZ; Johnson 1999
	Cottingham Resaca, ca 6 km N of Brownsville	Cameron	26°20'26"N	97°28'42"W	*Utterbackia* sp.			CCM 785056; Neck 1987; Neck and Metcalf 1988
	Keller Resaca, Brownsville	Cameron			*Popenaias popeii*			CCM 7850787
	Resaca del Rancho Viejo	Cameron	25°58'46"N	97°27'55"W	*Cyrtonaias tampicoensis*			Murray TUC
	Resacas of the lower Rio Grande	Cameron			*Toxolasma spp.*			Neck and Metcalf 1988
	Brownsville	Cameron			*Cyrtonaias tampicoensis*			CCM 785189
	Harlingen City Reservoir	Cameron	26°11'52"N	97°41'28"W	*Cyrtonaias tampicoensis*			Murray TUC
	Little River [sic?]	Cameron			*Cyrtonaias tampicoensis*			Murray TUC
	Rio Grande	Cameron			*Lampsilis teres*			Strecker 1931
Pecos River Drainage								
1976-77	Pecos R., SH 652 E of Orla	Reeves/ Loving	31°51'21"N	103°49'52"W				Davis 1980b
	Pecos R., 1.25 km NNE mouth of Hackberry Draw	Ward	31°22'28"N	103°06'30"W	*Quadrula couchiana*		fossil	Metcalf 1982
	Pecos R., 1.25 km NNE mouth of Hackberry Draw	Ward	31°22'28"N	103°06'30"W	*Quincuncina mitchelli*		fossil	Metcalf 1982
	Pecos R., 1.25 km NNE mouth of Hackberry Draw	Ward	31°22'28"N	103°06'30"W	*Popenaias popeii*		fossil	Metcalf 1982

Table 1. Continued.

Date	Location	County	Latitude	Longitude	Species	N	Condition	Source
	Pecos R., 1.25 km NNE mouth of Hackberry Draw	Ward	31°22'28"N	103°06'30"W	*Cyrtonaias tampicoensis*		fossil	Metcalf 1982
	Pecos R.	Ward			*Popenaias popeii*			Strecker 1931
	Pecos R., 4.8 km SW of Grandfalls SW of SH 18	Ward	31°18'24"N	102°52'36"W	*Cyrtonaias tampicoensis*		subfossil	Metcalf 1982
	Billingsley Draw near Toyah	Reeves	31°18'33"N	103°47'20"W	*Pyganodon grandis*		fossil	Metcalf 1982
	Billingsley Draw near Toyah	Reeves	31°18'33"N	103°47'20"W	*Quincuncina mitchelli*		fossil	Metcalf 1982
	Pecos R., 5.45 km NE of Imperial FM 1053 S of Pecos R.	Pecos	31°28'48"N	102°39'37"W	*Cyrtonaias tampicoensis*		fossil	Metcalf 1982
	Pecos R. 5.1 km WNW of Imperial SW of FM 11 on W bank of Pecos R.	Crane	31°17'00"N	102°44'39"W	*Cyrtonaias tampicoensis*		fossil	Metcalf 1982
	Pecos R., NW of Imperial	Crane	31°17'03"N	102°42'29"W	*Cyrtonaias tampicoensis*			Murray TUC
	Pecos R.	Crane			*Cyrtonaias tampicoensis*			Murray TUC
1976-77	Pecos R., U.S. 67 E of Girvin	Pecos/ Crockett	31°04'46"N	102°21'37"W				Davis 1980b
	Pecos R., upstream of the mouth of Big Fielder Draw	Val Verde	30°08'00"N	101°34'30"W	*Cyrtonaias tampicoensis*		living	Metcalf 1982
04/17/1973	Pecos R., ca 6 km SSW of Pandale, 0.5 km N of Pandale crossing	Val Verde	30°08'00"N	101°34'30"W	*Cyrtonaias tampicoensis*		live-fresh	Metcalf 1982
04/17/1973	Pecos R., ca 6 km SSW of Pandale, 0.5 km N of Pandale crossing	Val Verde	30°08'00"N	101°34'30"W	*Popenaias popeii*		live-fresh	Metcalf 1982
1976-77	Pecos R., US 290 SE of Sheffield	Pecos/ Crockett	30°39'35"N	101°46'12"W				Davis 1980b
1986	Pecos R., 28 km upstream of mouth	Val Verde	29°51'29"N	101°23'37"W	*Lampsilis teres*			Johnson 1999
1903	Lagoon in Deadman's Canyon, ca 21 km upstream of the Pecos R.	Val Verde	29°47'26"N	101°18'32"W	*Popenaias popeii*		living	ANSP 85268, Metcalf 1982
1903	Lagoon in Deadman's Canyon, ca 21 km upstream of the Pecos R.	Val Verde	29°47'26"N	101°18'32"W	*Cyrtonaias tampicoensis*		living	ANSP 85268, Metcalf 1982
1903	Lagoon in Deadman's Canyon, ca 21 km upstream of the Pecos R.	Val Verde	29°47'26"N	101°18'32"W	*Lampsilis teres*		living	ANSP 85268, Metcalf 1982
07/--/68	Pecos R., 1.2 km above mouth at Old US 90 (now flooded by Amistad Reservoir)	Val Verde	29°42'22"N	101°21'31"W	*Potamilus metnecktayi*		living	Metcalf 1982; Johnson 1999
07/--/68	Pecos R., 1.2 km above mouth at Old US 90 (now flooded by Amistad Reservoir)	Val Verde	29°42'22"N	101°21'31"W	*Lampsilis teres*		living	Metcalf 1982; Johnson 1999
07/--/68	Pecos R., 1.2 km above mouth at Old US 90 (now flooded by Amistad Reservoir)	Val Verde	29°42'22"N	101°21'31"W	*Cyrtonaias tampicoensis*			Metcalf 1982; Johnson 1999
07/--/68	Pecos R., 1.2 km above mouth at Old US 90 (now flooded by Amistad Reservoir)	Val Verde	29°42'22"N	101°21'31"W	*Popenaias popeii*			Metcalf 1982; Johnson 1999
07/--/68	Pecos R., 1.2 km above mouth at Old US 90 (now flooded by Amistad Reservoir)	Val Verde	29°42'22"N	101°21'31"W	*Truncilla cognata*			Metcalf 1982; Johnson 1999
1976-77	Pecos R., at Shumla	Val Verde	29°47'26"N	101°23'41"W	*Corbicula* spp.			Davis 1980b
1976-77	Pecos R., at Shumla	Val Verde	29°47'26"N	101°23'41"W	*Sphaerium striatinum*			Davis 1980b
	Pecos R., 1.28 km upstream of the mouth	Val Verde	29°42'24"N	101°21'23"W	*Cyrtonaias tampicoensis*		living	Metcalf 1982
	Pecos R.	Val Verde			*Cyrtonaias tampicoensis*			Murray TUC
	Pecos R., mouth	Val Verde	29°42'03"N	101°22'13"W	*Cyrtonaias tampicoensis*			Strecker 1931
Devils River Drainage								
	Beaver Lake, on the Devils R. 5.4 km N of Juno	Val Verde	30°10'32"N	101°03'03"W	*Utterbackia imbecillis*			Strecker 1931
1976-77	Devils R., at Paffords Crossing	Val Verde	29°40'48"N	101°00'09"W	*Corbicula* spp.			Davis 1980c
1976-77	Devils R. at Paffords Crossing	Val Verde	29°40'48"N	101°00'09"W	*Eupera cubensis*			Davis 1980c
	Devils R.	Val Verde	29°33'12"N	100°56'46"W	*Quadrula couchiana*			USNM; Johnson 1999
	Devils R.	Val Verde	29°33'12"N	100°56'46"W	*Popenaias popeii*			USNM; UMMZ; Strecker 1931; Johnson 1999
	Devils R.	Val Verde	29°35'12"N	100°56'46"W	*Toxolasma texasiensis*			USNM; Johnson 1999
	Devils R.	Val Verde			*Utterbackia imbecillis*			Strecker 1931
	Blaine's Lake	Val Verde	29°34'09"N	100°58'49"W	*Cyrtonaias tampicoensis*			Strecker 1931
	Devils R., Blaine's Lake, lower end	Val Verde	29°33'16"N	100°59'07"W	*Popenaias popeii*			Strecker 1931
	Devils R., mouth	Val Verde	29°32'10"N	100°58'58"W	*Cyrtonaias tampicoensis*			Strecker 1931

Table 2. Freshwater bivalve survey sites examined by Texas Parks and Wildlife during annual surveys from 1992 through 1997 in the Rio Grande, Pecos River, and Devils River drainages, Texas. BBNP = Big Bend National Park.

Date	Location	County	Latitude	Longitude	Species	N	Condition	Source
Rio Grande Drainage								
02/08-12/1993	Rio Grande, lower reaches of BBNP	Brewster	28°58'17"N 29°22'02"N	103°09'15"W to 102°50'44"W				Howells 1995
07/25/1994	Rio Grande, Mexican side opposite BBNP downstream boundary	Brewster	29°22'33"N	102°50'37"W	*Cyrtonaias tampicoensis*	0.5x1	relatively-recently dead	Howells 1996a
07/25/1994	Rio Grande, Mexican side opposite BBNP downstream boundary	Brewster	29°22'33"N	102°50'37"W	*Corbicula* spp.			Howells 1996a
01/06/1992	Rio Grande, mouth of San Francisco Creek	Brewster/ Terrell	29°52'45"N	102°19'13"W	*Popenaias popeii*	1	recently dead	Howells 1994a
01/06/1992	Rio Grande, ca 14 km downstream of San Francisco Creek, Dryden Crossing	Terrell	29°47'15"N	102°03'19"W	*Potamilus metnecktayi*	1.0+0.5x1	recently dead	Howells 1994a
01/06/1992	Rio Grande, ca 14 km downstream of San Francisco Creek, Dryden Crossing	Terrell	29°47'15"N	102°03'19"W	*Cyrtonaias tampicoensis*	1	recently dead	Howells 1994a
12/12/1994	Amistad Reservoir, at confluence of Devils R.	Val Verde	29°33'18"N	100°58'51"W				Howells 1996a
12/20/1994	Amistad Reservoir, at confluence of Devils R.	Val Verde	29°33'18"N	100°58'51"W				Howells 1996a
05/25/1995	Amistad Reservoir, at confluence of Devils R.	Val Verde	29°33'18"N	100°58'51"W				Howells 1996b
09/20/1995	Amistad Reservoir, Salem Point off Box Canyon Road	Val Verde	29°30'51"N	101°09'53"W	*Cyrtonaias tampicoensis*	present	live - recently dead	Howells 1996b
05/25/1994	Amistad Reservoir, Long Point and San Pedro Canyon (4 sites combined)	Val Verde	29°30'54"N	100°56'11"W	*Cyrtonaias tampicoensis*	0.5x2	long dead	Howells 1996a
12/12/1994	Amistad Reservoir, Long Point and San Pedro Canyon (4 sites combined)	Val Verde	29°30'54"N	100°56'11"W	*Potamilus purpuratus*	2+0.5x2	relatively-recently - long dead	Howells 1996a
12/20/1994	Amistad Reservoir, Long Point and San Pedro Canyon (4 sites combined)	Val Verde	29°30'54"N	100°56'11"W	*Cyrtonaias tampicoensis*	13+0.5x51	live - long dead	Howells 1996a
12/20/1994	Amistad Reservoir, Long Point and San Pedro Canyon (4 sites combined)	Val Verde	29°30'54"N	100°56'11"W	*Potamilus purpuratus*	6	relatively-recently - long dead	Howells 1996a
01/11/1995	Amistad Reservoir, Long Point and San Pedro Canyon (4 sites combined)	Val Verde	29°30'54"N	100°56'11"W	*Cyrtonaias tampicoensis*	90+0.5x12	live - recently dead	Howells 1996b
01/11/1995	Amistad Reservoir, Long Point and San Pedro Canyon (4 sites combined)	Val Verde	29°30'54"N	100°56'11"W	*Potamilus purpuratus*	3+0.5x3	live - recently dead	Howells 1996b
09/20/1995	Amistad Reservoir, Cardo Canyon	Val Verde	29°31'53"N	101°04'52"W	*Cyrtonaias tampicoensis*	present	live - recently dead	Howells 1996b
04/19/1994	San Felipe Creek, Del Rio City Park	Val Verde	29°22'17"N	100°53'03"W				Howells 1996a
04/19/1994	Zorro Creek, at US 277	Val Verde	29°19'29"N	100°49'50"W				Howells 1996a
04/19/1994	Sycamore Creek, at US 277	Val Verde/ Kinney	29°15'15"N	100°45'03"W	*Corbicula* spp.			Howells 1996a
04/19/1994	Sycamore Creek, at US 90	Val Verde/ Kinney	29°23'21"N	100°42'26"W	*Corbicula* spp.			Howells 1996a
04/19/1994	Mud Creek, US 90	Val Verde/ Kinney	29°22'44"N	100°40'22"W	*Corbicula* spp.			Howells 1996a
04/19/1994	Pinto Creek, US 277	Kinney	29°11'30"N	100°42'18"W	*Corbicula* spp.			Howells 1996a
04/26/1995	Lindsey Creek, US 90, E of Brackettville	Kinney	29°17'34"N	100°22'18"W				Howells 1996b
04/26/1995	Elm Creek, US 90, E of Brackettville	Kinney	29°16'45"N	100°19'29"W				Howells 1996b
04/26/1995	Brackettville Reservoir, NW of Brackettville, Las Moras Creek drainage	Kinney	29°20'55"N	100°25'36"W				Howells 1996b
04/26/1995	Las Moras Creek, Brackettville, upstream of Fort Clark Springs	Kinney	29°18'55"N	100°25'10"W				Howells 1996b
04/26/1995	Las Moras Creek, Brackettville, Fort Clark Springs	Kinney	29°18'34"N	100°25'14"W				Howells 1996b
04/26/1995	Las Moras Creek, Brackettville, swimming pool below Fort Clark Springs	Kinney	29°18'31"N	100°25'14"W				Howells 1996b
04/26/1995	Las Moras Creek, Brackettville, bulkheaded area below swimming pool	Kinney	29°18'28"N	100°25'09"W				Howells 1996b
04/26/1995	Las Moras Creek, Brackettville, natural bank downstream of bulkheaded area	Kinney	29°18'23"N	100°25'01"W				Howells 1996b
04/26/1995	Las Moras Creek, at Southern Pacific RR E of Ranch Road 3384	Kinney	29°13'17"N	100°29'31"W	*Corbicula* spp.			Howells 1996b
04/26/1995	Las Moras Creek, SH 1908 E of Ranch Road 3384	Kinney	29°07'41"N	100°32'16"W				Howells 1996b
04/26/1995	Las Moras Creek, Ranch Road 1908 N of Maverick Co. line	Kinney	29°05'39"N	100°33'06"W				Howells 1996b
04/26/1995	Las Moras Creek, Ranch Road 1908 S of Maverick Co. line, Salado Cr. tributary	Maverick	29°04'02"N	100°33'22"W				Howells 1996b
04/19/1994	Las Moras Creek, US 277	Maverick	29°00'18"N	100°23'03"W				Howells 1996a
04/26/1995	Las Moras Creek, US 277	Maverick	29°00'18"N	100°23'03"W	*Corbicula* spp.			Howells 1996b
04/26/1995	Canyon Grande Creek, US 277 at Quemado City Park	Maverick	28°55'36"N	100°36'52"W	*Corbicula* spp.			Howells 1996b
12/13/1992	Elm Creek, Eagle Pass, US 277 and Ranch Road 1589 (combined)	Maverick	28°46'10"N 28°45'01"N	100°29'53"W to 100°30'24"W	*Cyrtonaias tampicoensis*	1	recently dead	Howells 1994a
12/13/1992	Elm Creek, Eagle Pass, US 277 and Ranch Road 1589 (combined)	Maverick	28°46'10"N 28°45'01"N	100°29'53"W to 100°30'24"W	*Lampsilis teres*	1	recently dead	Howells 1994a
12/13/1992	Elm Creek, Eagle Pass, US 277 and Ranch Road 1589 (combined)	Maverick	28°46'10"N	100°29'53"W	*Rangia cuneata*	1	recently dead	Howells 1994a
07/01-02/1996	Elm Creek, Eagle Pass, US 277	Maverick	28°46'10"N	100°29'53"W				Howells 1997a

Table 2. Continued.

Date	Location	County	Latitude	Longitude	Species	*N*	Condition	Source
07/01-02/ 1996	Elm Creek, Eagle Pass, Ranch Road 1589	Maverick	28°45'01"N	100°30'24"W				Howells 1997a
09/06/1994	Lake Casa Blanca	Webb	27°32'47"N	99°26'05"W	*Cyrtonaias tampicoensis*	0.5x2	relatively-recently dead	Howells 1996a
09/06/1994	Lake Casa Blanca	Webb	27°32'47"N	99°26'05"W	*Quadrula apiculata*	1	relatively-recently dead	Howells 1996a
09/06/1994	Lake Casa Blanca	Webb	27°32'47"N	99°26'05"W	*Corbicula* spp.			Howells 1996a
10/05/1994	Lake Casa Blanca	Webb	27°32'47"N	99°26'05"W	*Cyrtonaias tampicoensis*	10+0.5x2	live – relatively-recently dead	Howells 1996a
10/05/1994	Lake Casa Blanca	Webb	27°32'47"N	99°26'05"W	*Quadrula apiculata*	20+0.5x1	recently dead	Howells 1996a
10/05/1994	Lake Casa Blanca	Webb	27°32'47"N	99°26'05"W	*Toxolasma parvus*	0.5x1	relatively-recently dead	Howells 1996a
10/05/1994	Lake Casa Blanca	Webb	27°32'47"N	99°26'05"W	*Utterbackia imbecillis*	3	recently dead	Howells 1996a
10/05/1994	Lake Casa Blanca	Webb	27°32'47"N	99°26'05"W	*Corbicula* spp.			Howells 1996a
08/12/1996	Lake Casa Blanca	Webb	27°32'47"N	99°26'05"W	*Cyrtonaias tampicoensis*	4+0.5x28	live-relatively recently dead	Howells 1997a
08/12/1996	Lake Casa Blanca	Webb	27°32'47"N	99°26'05"W	*Utterbackia imbecillis*	1	relatively long dead	Howells 1997a
08/12/1996	Lake Casa Blanca	Webb	27°32'47"N	99°26'05"W	*Corbicula* spp.			Howells 1997a
07/01-02/ 1996	Rio Grande, first access road upstream of Falcon Reservoir	Zapata	26°58'14"N	99°23'41"W	*Cyrtonaias tampicoensis*	many	dead	Howells 1997a
07/01-02/ 1996	Rio Grande, first access road upstream of Falcon Reservoir	Zapata	26°58'14"N	99°23'41"W	*Quadrula apiculata*	many	dead	Howells 1997a
07/01-02/ 1996	Falcon Reservoir, at county road from Zapata to the reservoir	Zapata	26°52'44"N	99°18'21"W	*Cyrtonaias tampicoensis*	many	dead	Howells 1997a
07/01-02/ 1996	Falcon Reservoir, at county road from Zapata to the reservoir	Zapata	26°52'44"N	99°18'21"W	*Quadrula apiculata*	many	dead	Howells 1997a
04/11/1995	Falcon Reservoir, embayment at Zapata and US 83	Zapata	26°53'06"N	99°15'27"W	*Cyrtonaias tampicoensis*	17+0.5x5	live - recently dead	Howells 1996b
04/11/1995	Falcon Reservoir, embayment at Zapata and US 83	Zapata	26°53'06"N	99°15'27"W	*Quadrula apiculata*	10	live – very-recently dead	Howells 1996b
04/11/1995	Falcon Reservoir, embayment at Zapata and US 83	Zapata	26°53'06"N	99°15'27"W	*Utterbackia imbecillis*	3	live - recently dead	Howells 1996b
04/11/1995	Falcon Reservoir, embayment at Zapata and US 83	Zapata	26°53'06"N	99°15'27"W	*Corbicula* spp.			Howells 1996b
04/17/1995	Falcon Reservoir, embayment at Zapata and US 83	Zapata	26°53'06"N	99°15'27"W	*Cyrtonaias tampicoensis*	16	live	Howells 1996b
04/17/1995	Falcon Reservoir, embayment at Zapata and US 83	Zapata	26°53'06"N	99°15'27"W	*Quadrula apiculata*	22	live – relatively-recently dead	Howells 1996b
04/17/1995	Falcon Reservoir, embayment at Zapata and US 83	Zapata	26°53'06"N	99°15'27"W	*Toxolasma parvus*	4	live	Howells 1996b
04/17/1995	Falcon Reservoir, embayment at Zapata and US 83	Zapata	26°53'06"N	99°15'27"W	*Utterbackia imbecillis*	9	live - recently dead	Howells 1996b
04/17/1995	Falcon Reservoir, embayment at Zapata and US 83	Zapata	26°53'06"N	99°15'27"W	*Corbicula* spp.			Howells 1996b
07/01-02/ 1996	Falcon Reservoir, between Zapata and Arroyo Leon	Zapata	26°48'57"N	99°13'56"W	*Cyrtonaias tampicoensis*	many	dead	Howells 1997a
07/01-02/ 1996	Falcon Reservoir, between Zapata and Arroyo Leon	Zapata	26°48'57"N	99°13'56"W	*Quadrula apiculata*	many	dead	Howells 1997a
07/01-02/ 1996	Falcon Reservoir, upstream of Arroyo del Tigre	Zapata	26°44'25"N	99°12'39"W	*Cyrtonaias tampicoensis*	many	dead	Howells 1997a
07/01-02/ 1995	Falcon Reservoir, upstream of Arroyo del Tigre	Zapata	26°44'25"N	99°12'39"W	*Quadrula apiculata*	1+many	1 live, many dead	Howells 1997a
07/01-02/ 1996	Falcon Reservoir, Arroyo del Tigre	Zapata	26°41'36"N	99°06'39"W	*Cyrtonaias tampicoensis*	7+0.5x2	relatively-recently dead	Howells 1997a
07/01-02/ 1996	Falcon Reservoir, Arroyo del Tigre	Zapata	26°41'36"N	99°06'39"W	*Quadrula apiculata*	12+0.5x2	relatively-recently dead	Howells 1997a
07/01-02/ 1996	Falcon Reservoir, Arroyo del Tigre	Zapata	26°41'36"N	99°06'39"W	*Toxolasma parvus*	0.5x1	relatively-long dead	Howells 1997a
07/01-02/ 1996	Falcon Reservoir, county road access upstream of New Falcon	Zapata	26°36'15"N	99°09'59"W	*Cyrtonaias tampicoensis*	1+0.5x10	relatively-recently dead	Howells 1997a
07/01-02/ 1996	Falcon Reservoir, county road access upstream of New Falcon	Zapata	26°36'15"N	99°09'59"W	*Quadrula apiculata*	6+0.5x4	relatively-recently dead	Howells 1997a
03/22-23/ 1994	Falcon Reservoir, at Falcon State Park	Zapata	26°34'20"N	99°08'37"W	*Cyrtonaias tampicoensis*	2+0.5x10	long dead	Howells 1996a
03/22-23/ 1994	Falcon Reservoir, at Falcon State Park	Zapata	26°34'20"N	99°08'37"W	*Quadrula apiculata*	2+0.5x3	recently dead	Howells 1996a

Table 2. Continued.

Date	Location	County	Latitude	Longitude	Species	*N*	Condition	Source
3/22-23/ 1994	Falcon Reservoir, at Falcon State Park	Zapata	26°34'20"N	99°08'37"W	*Utterbackia imbecillis*	1	relatively-recently dead	Howells 1996a
01/13/1995	Falcon Reservoir, at Falcon State Park	Zapata	26°34'20"N	99°08'37"W	*Cyrtonaias tampicoensis*	5	recently dead	Howells 1996b
01/13/1995	Falcon Reservoir, at Falcon State Park	Zapata	26°34'20"N	99°08'37"W	*Quadrula apiculata*	4+0.5x2	relatively-recently dead	Howells 1996b
01/13/1995	Falcon Reservoir, at Falcon State Park	Zapata	26°34'20"N	99°08'37"W	*Utterbackia imbecillis*	2	recently dead	Howells 1996b
07/01-02/ 1996	Falcon Reservoir, at Falcon State Park	Zapata	26°34'20"N	99°08'37"W	*Cyrtonaias tampicoensis*	4+0.5x11	relatively-recently dead	Howells 1997a
07/01-02/ 1996	Falcon Reservoir, at Falcon State Park	Zapata	26°34'20"N	99°08'37"W	*Quadrula apiculata*	1	relatively-recently dead	Howells 1997a
03/03/1993	Rio Grande, islands below Falcon Dam	Starr	26°33'07"N	99°09'59"W	*Corbicula* spp.			Howells 1995
03/02/1994	Rio Grande, Falcon dam to 24 km downstream	Starr	26°33'24"N 26°24'18"N	99°09'47"W 99°01'11"W	*Corbicula* spp.			Howells 1996a
03/22-23/ 1994	Rio Grande, Falcon dam to 24 km downstream	Starr	26°33'24"N 26°24'18"N	99°09'47"W 99°01'11"W	*Cyrtonaias tampicoensis*	14	subfossil	Howells 1996a
03/22-23/ 1994	Rio Grande, Falcon dam to 24 km downstream	Starr	26°33'24"N 26°24'18"N	99°09'47"W 99°01'11"W	*Lampsilis teres*	0.5x5	subfossil	Howells 1996a
03/22-23/ 1994	Rio Grande, Falcon dam to 24 km downstream	Starr	26°33'24"N 26°24'18"N	99°09'47"W 99°01'11"W	*Megalonaias nervosa*	1	very-long dead	Howells 1996a
03/22-23/ 1994	Rio Grande, Falcon dam to 24 km downstream	Starr	26°33'24"N 26°24'18"N	99°09'47"W 99°01'11"W	*Quadrula apiculata*	3+0.5x2	long dead	Howells 1996a
03/22-23/ 1994	Rio Grande, Falcon dam to 24 km downstream	Starr	26°33'24"N 26°24'18"N	99°09'47"W 99°01'11"W	*Corbicula* spp.			Howells 1996a
07/01-02/ 1996	Rio Grande, Falcon dam to 24 km downstream	Starr	26°33'24"N 26°24'18"N	99°09'47"W 99°01'11"W	*Quadrula apiculata*	4	very-long dead	Howells 1997a
07/01-02/ 1996	Rio Grande, Falcon dam to 24 km downstream	Starr	26°33'24"N 26°24'18"N	99°09'47"W 99°01'11"W	*Utterbackia imbecillis*	0.5x1	very-long dead	Howells 1997a
07/01-02/ 1996	Rio Grande, Falcon dam to 24 km downstream	Starr	26°33'24"N 26°24'18"N	99°09'47"W 99°01'11"W	*Corbicula* spp.			Howells 1997a
03/24/1992	Harlingen City Reservoir	Cameron	26°11'54"N	98°41'30"W	*Cyrtonaias tampicoensis*	several	recently dead	Howells 1994a
04/09/1992	Resaca del Rancho Viejo, Dana Ave., Brownsville	Cameron	25°58'46"N	97°27'56"W	*Cyrtonaias tampicoensis*	numerous	relatively-long dead	Howells 1994a
Pecos River Drainage								
09/--/1993	Pecos R., Grandfalls	Crane/Pecos	31°18'17"N	102°52'28"W	*Cyrtonaias tampicoensis*	0.5x7	subfossil	Howells 1995
02/16/1995	Lake Balmorhea, Balmorhea State Park	Reeves	30°57'59"N	103°43'21"W				Howells 1996b
08/26/1997	Lake Balmorhea, Balmorhea State Park	Reeves	30°57'59"N	103°43'21"W				Howells 1998a
08/26/1997	Lake Balmorhea, Balmorhea State Park	Reeves	30°57'59"N	103°43'21"W	*Utterbackia imbecillis*	2	recently dead	Howells 1998a
08/26/1997	Lake Balmorhea, Balmorhea State Park	Reeves	30°57'59"N	103°43'21"W	*Corbicula* spp.			Howells 1998a
02/16/1995	San Solomon Springs, run downstream of Lake Balmorhea	Reeves	30°57'57"N	103°42'16"W				Howells 1996b
Devils River Drainage								
05/21/1995	Devils R., at Dolan Springs	Val Verde	29°53'09"N	100°55'50"W				Howells 1996b
04/19/1994	Devils R., Satans Canyon and Rough Canyon (combined)	Val Verde	29°35'24"N	100°59'24"W	*Utterbackia imbecillis*	17	live – very-recently dead	Howells 1996a
04/19/1994	Devils R., Satans Canyon and Rough Canyon (combined)	Val Verde	29°35'24"N	100°59'24"W	*Corbicula* spp.			Howells 1996a
12/20/1994	Devils R., upstream of Recreation Road	Val Verde	29°35'34"N	100°58'54"W				Howells 1996a
01/11/1995	Devils R., upstream of Amistad Reservoir	Val Verde	29°34'04"N	100°59'08"W				Howells 1996b

Table 3. Freshwater bivalve survey sites examined during the present study in the Rio Grande, Pecos River, Devils River, and associated waters of those drainages Texas, 1998-2001. Texas Parks and Wildlife (TPW) staff was assisted by U.S. Geological Survey and Big Bend National Park personnel as well as several volunteers who assisted with collection efforts and provided data. BBNP = Big Bend National Park; LRGNWR = Lower Rio Grande National Wildlife Refuge; CWD = Cameron County Water District office; below = downstream; above = upstream. These data have also been presented in Howells 1999 (for 1998), Howells 2000a (1999), and Howells 2001a (2000).

Field N	Site N	Date	Location	County	Latitude	Longitude	Species	N	Condition
Rio Grande Drainage									
TPW-001	1	8/10/99	Rio Grande, at the Rio Conchos	Presidio	29°35'10"N	104°25'22"W			
TPW-002	2	8/10/99	Rio Grande, at Alamido Creek	Presidio	29°31'17"N	104°17'34"W			
TPW-003	3	8/10/99	Alamido Creek, just upstream of the Rio Grande	Presidio	29°31'18"N	104°17'26"W			
TPW-004	4	3/--/99	Rio Grande upstream of Colorado Canyon	Presidio	29°17'52"N	103°57'10"W	*Musculium transversum*		alive
TPW-004	4	3/--/99	Rio Grande, upstream of Colorado Canyon	Presidio	29°22'00"N	104°05'56"W	*Corbicula* spp.		alive
TPW-005	5	8/15/98	Rio Grande, at Colorado Canyon access 37 km above Lajitas	Presidio	29°21'27"N	103°54'28"W			
TPW-006	6	8/15/98	Rio Grande, Madera Canyon access 17.9 km above Lajitas	Presidio	29°17'37"N	103°56'23"W			
TPW-007	7	8/15/98	Rio Grande, Grassy Banks access 17.4 km above Lajitas	Presidio	29°17'28"N	103°55'53"W			
TPW-008	8	8/14/98	Rio Grande, Santa Elena takeout 12.9 km above Castolon, BBNP	Brewster	29°09'31"N	103°36'04"W			
TPW-009	9	3/--/99	Rio Grande, Santa Elena takeout area, BBNP	Brewster	29°09'20"N to 29°09'12"N	103°35'53"W to 103°35'48"W			
TPW-010	10	8/14/98	Rio Grande at Castolon camp grounds, BBNP	Brewster	29°08'01"N	103°31'29"W			
TPW-011	11	8/14/98	Rio Grande, Santa Elena Crossing, BBNP	Brewster	29°07'17"N	103°31'15"W	*Corbicula* spp		dead
TPW-012	12	3/--/99	Rio Grande, USBWC gage downstream of Castolon, BBNP	Brewster	29°02'05"N to 29°01'55"N	103°23'23"W to 103°23'11"W			
TPW-013	13	2/09/99	Rio Grande, Solis canoe takeout, BBNP	Brewster	29°02'38"N	103°06'19"W	*Corbicula* spp.		alive
TPW-014	14	2/09/99	Rio Grande, San Vicente Crossing, BBNP	Brewster	29°07'48"N	103°10'19"W			
TPW-015	15	2/08/99	Rio Grande, Hot Springs area, BBNP	Brewster	29°10'46"N	102°59'39"W			
TPW-016	16	2/08/99	Rio Grande, below Rio Grande Village pumping station, BBNP	Brewster	29°10'55"N	102°58'03"W			
TPW-017	17	3/31/98	Rio Grande, gravel bar at Rio Grande Village, BBNP	Brewster	29°10'34"N	102°57'11"W	*Corbicula* spp.		dead
TPW-018	18	4/01/98	Rio Grande, river at Rio Grande Village, BBNP	Brewster	29°10'34"N	102°57'11"W	*Corbicula* spp.		dead
TPW-019	19	4/01/98	Rio Grande, gravel bar upstream of Boquillas Crossing, BBNP	Brewster	29°11'29"N	102°56'04"W	*Corbicula* spp.		dead
TPW-020	20	3/--/99	Rio Grande, upstream of Boquillas Canyon, BBNP	Brewster	29°11'31"N to 29°11'32"N	102°55'15"W to 102°55'04"W	*Corbicula* spp.		dead
TPW-020	20	3/--/99	Rio Grande, upstream of Boquillas Canyon, BBNP	Brewster	29°11'31"N to 29°11'32"N	102°55'15"W to 102°55'04"W	*Potamilus metnecktayi*	0.5x1	relatively-recently dead
TPW-021	21	2/07/99	Rio Grande, Black Gap Wildlife Management Area	Brewster	29°35'35"N to 29°35'46"N	103°46'02"W to 103°46'05"W	*Corbicula* spp.		alive
TPW-022	22	2/28/98	Rio Grande, at La Linda, Ranch Road 2627	Brewster	29°27'01"N	102°49'17"W			
TPW-023	23	2/28/98	Rio Grande, at Horse Canyon	Brewster	29°28'24"N	102°48'57"W			
TPW-024	24	2/28/98	Rio Grande, at Maravillas	Brewster	29°34'29"N	102°45'50"W			
TPW-025	25	3/01/98	Rio Grande, at Maravillas Ridge	Brewster	29°35'28"N	102°46'01"W			
TPW-026	26	3/01/98	Rio Grande, at El Sombrero (Castle Buttes)	Brewster	29°39'35"N	102°42'46"W			
TPW-027	27	3/01/98	Rio Grande, below El Sombrero	Brewster	29°40'16"N	102°44'25"W			
TPW-028	28	3/01/98	Rio Grande, Mexican side opposite Black Gap shelters 19-20	Brewster	29°41'42"N	102°41'48"W			
TPW-029	29	3/01/98	Rio Grande, at El Rocendo Creek (Mexican side)	Brewster	29°44'47"N	102°32'42"W	*Cyrtonaias tampicoensis*	0.5x1	long dead
TPW-030	30	3/02/98	Rio Grande, 2.2 km above Oso Canyon	Brewster	29°45'18"N	102°34'51"W			
TPW-031	31	3/02/98	Rio Grande, at Oso Canyon (Bear Canyon)	Brewster	29°46'17"N	102°34'06"W			
TPW-032	32	3/02/98	Rio Grande, at La Yegua Creek (Mexican side)	Brewster	29°45'28"N	102°33'27"W			
TPW-033	33	3/02/98	Rio Grande, hot springs opposite Silber Canyon	Brewster	29°44'46"N	102°32'47"W			
TPW-034	34	3/02/98	Rio Grande, below hot springs opposite Silber Canyon	Brewster	29°44'55"N	102°32'27"W			
TPW-035	35	3/03/98	Rio Grande, upstream of Bullis Gap	Brewster	29°46'04"N	102°30'49"W			
TPW-036	36	3/03/98	Rio Grande, at Bullis Fold (Dean Canyon)	Brewster	29°46'47"N	102°31'06"W	*Popenaias popeli*	0.5x1	long dead
TPW-036	36	3/03/98	Rio Grande, at Bullis Fold (Dean Canyon)	Brewster	29°46'47"N	102°31'06"W	*Popenaias popeli*	1	recently dead
TPW-036	36	3/03/98	Rio Grande, at Bullis Fold (Dean Canyon)	Brewster	29°46'47"N	102°31'06"W	*Potamilus metnecktayi*	0.5x1	long dead
TPW-036	36	3/03/98	Rio Grande, at Bullis Fold (Dean Canyon)	Brewster	29°46'47"N	102°31'06"W	*Potamilus metnecktayi*	1	relatively-recently dead

Table 3. Continued.

Field N	Site N	Date	Location	County	Latitude	Longitude	Species	N	Condition
TPW-037	37	3/03/98	Rio Grande, 2.93 km upstream of Rodeo Rapids	Brewster	29°46'52"N	102°27'41"W			
TPW-038	38	3/03/98	Rio Grande, 1.47 km downstream of Rodeo Rapids	Brewster	29°46'29"N	102°26'31"W	*Potamilus metnecktayi*	0.5x1	long dead
TPW-038	38	3/03/98	Rio Grande, 1.47 km downstream of Rodeo Rapids	Brewster	29°46'29"N	102°26'31"W	*Potamilus metnecktayi*	0.5x1	relatively-recently dead
TPW-039	39	3/04/98	Rio Grande, at Mal Paso Creek (Mexican side)	Brewster	29°45'57"N	102°24'41"W	Popenaias popeii	1	recently dead
TPW-040	40	3/04/98	Rio Grande, between Upper and Lower Madison Rapids	Brewster	29°51'06"N	102°21'21"W			
TPW-041	41	3/04/98	Rio Grande, downstream of Lower Madison Rapids	Brewster	29°51'50"N	102°20'56"W			
TPW-042	42	3/04/98	Rio Grande, downstream of Panther Canyon	Brewster	29°52'26"N	102°20'36"W			
TPW-043	43	3/04/98	Rio Grande, 2.93 km above San Francisco Creek	Brewster	29°52'05"N	102°16'24"W	*Potamilus metnecktayi*	0.5x3	long dead
TPW-043	43	3/04/98	Rio Grande, 2.93 km above San Francisco Creek	Brewster	29°52'05"N	102°19'24"W	*Popenaias popeii*	1	recently dead
TPW-043	43	3/04/98	Rio Grande, 2.93 km above San Francisco Creek	Brewster	29°52'05"N	102°19'24"W	*Potamilus metnecktayi*	4	recently dead
TPW-044	44	3/04/98	Rio Grande, Mexican side opposite San Francisco Canyon	Brewster	29°52'45"N	102°16'13"W	*Potamilus metnecktayi*	0.5x1	recently dead
TPW-045	45	3/05/98	Rio Grande, mouth of San Francisco Canyon	Brewster	29°52'45"N	102°19'13"W			
TPW-046	46	3/05/98	Rio Grande, 2.2 km below San Francisco Creek	Terrell	29°52'40"N	102°18'09"W			
TPW-047	47	3/05/98	Rio Grande, 4.4 km below San Francisco Creek	Terrell	29°51'50"N	102°16'58"W	*Potamilus metnecktayi*	1+0.5x2	recently dead
TPW-048	48	3/05/98	Rio Grande, at Los Pomas Creek (Mexican side)	Terrell	29°52'45"N	102°16'41"W	*Potamilus metnecktayi*	0.5x1	long dead
TPW-048	48	3/05/98	Rio Grande, at Los Pomas Creek (Mexican side)	Terrell	29°52'45"N	102°16'41"W	*Potamilus metnecktayi*	0.5x1	recently dead
TPW-049	49	3/05/98	Rio Grande, island off Los Pomas Creek	Terrell	29°52'45"N	102°15'52"W	*Potamilus metnecktayi*	0.5x1	very-long dead
TPW-050	50	3/05/98	Rio Grande, below Los Pomas Creek	Terrell	29°50'52"N	102°14'38"W			
TPW-051	51	3/06/98	Rio Grande, Middle Watering Beach (Mexican side)	Terrell	29°50'49"N	102°14'28"W			
TPW-052	52	3/06/98	Rio Grande, at Paso Colorado (Mexican side)	Terrell	29°50'23"N	102°12'12"W	*Popenaias popeii*	0.5x1	subfossil
TPW-053	53	3/20/98	Rio Grande, just below Sanderson Canyon	Terrell	29°49'45"N	102°10'50"W	*Popenaias popeii*	0.5x1	relatively-long dead
TPW-054	54	3/06/98	Rio Grande, at Dryden Crossing (John's Marina)	Terrell	29°47'15"N	102°03'19"W			
TPW-055	55	9/06/98	Amistad Reservoir, at US 277	Val Verde	29°29'28"N	100°54'14"W	*Corbicula* spp.		
TPW-056	56	9/06/98	Amistad Reservoir, at SH 454 east side	Val Verde	29°28'82"N	100°57'06"W	*Corbicula* spp.		
TPW-056	56	9/06/98	Amistad Reservoir, at SH 454 east side	Val Verde	29°28'82"N	100°57'06"W	*Cyrtonaias tampicoensis*	0.5x1	relatively-recently dead
TPW-056	56	9/06/98	Amistad Reservoir, at SH 454 east side	Val Verde	29°28'82"N	100°57'06"W	*Potamilus purpuratus*	0.5x2	relatively-recently – long dead
TPW-057	57	9/06/98	Amistad Reservoir, at SH 454 west side	Val Verde	29°28'49"N	100°57'03"W	*Corbicula* spp.		
TPW-058	58	7/05/99	Los Olmos Creek, Rio Grande City, at US Customs Office	Starr	26°22'03"N	98°48'53"W			
TPW-059	59	7/05/99	Rio Grande, at La Grulla access road	Starr	26°15'59"N	98°37'59"W			
TPW-060	60	7/05/99	Rio Grande, at Los Ebanos Crossing	Hidalgo	26°14'43"N	98°33'29"W			
TPW-061	61	6/16/99	Walker Lake, southeast side of La Joya	Hidalgo	26°14'19"N	98°24'44"W	*Corbicula* spp.		alive
TPW-061	61	6/16/99	Walker Lake, southeast side of La Joya	Hidalgo	26°14'19"N	98°24'44"W	*Cyrtonaias tampicoensis*	10	alive
TPW-061	61	6/16/99	Walker Lake, southeast side of La Joya	Hidalgo	26°14'19"N	98°24'44"W	*Quadrula apiculata*	8	alive
TPW-062	62	6/16/99	Rio Grande, at the intake of the Edinburg Canal	Hidalgo	26°13'25"N	98°26'58"W	*Corbicula* spp.		alive
TPW-063	63	6/16/99	Edinburg Canal, mouth near the Rio Grande	Hidalgo	26°13'31"N	98°26'55"W	*Corbicula* spp.		alive
TPW-064	64	6/16/99	Edinburg Canal, source at Zamora St., Penitas	Hidalgo	26°13'47"N	98°26'31"W	*Corbicula* spp.		alive
TPW-064	64	6/16/99	Edinburg Canal, source at Zamora St., Penitas	Hidalgo	26°13'47"N	98°26'31"W	*Cyrtonaias tampicoensis*	0.5x1	relatively-long dead
TPW-064	64	6/16/99	Edinburg Canal, source at Zamora St., Penitas	Hidalgo	26°13'47"N	98°26'31"W	*Cyrtonaias tampicoensis*	2	alive
TPW-064	64	6/16/99	Edinburg Canal, source at Zamora St., Penitas	Hidalgo	26°13'47"N	98°26'31"W	*Quadrula apiculata*	0.5x1	relatively-long dead
TPW-065	65	6/16/99	Cemetery Pond, Penitas, SE of Edinburg Canal, N of RR tracks	Hidalgo	26°13'44"N	98°26'31"W	*Corbicula* spp.		dead
TPW-065	65	6/16/99	Cemetery Pond, Penitas, SE of Edinburg Canal, N of RR tracks	Hidalgo	26°13'44"N	98°26'31"W	*Cyrtonaias tampicoensis*	8+0.5x9	relatively-recently dead
TPW-066	66	6/16/99	Bentsen State Park Lake, Bentsen State Park	Hidalgo	26°01'36"N	98°23'34"W	*Corbicula* spp.		
TPW-066	66	6/16/99	Bentsen State Park Lake, Bentsen State Park	Hidalgo	26°10'36"N	98°23'34"W	*Cyrtonaias tampicoensis*	1	relatively-recently dead
TPW-067	67	7/06/99	Rio Grande, at Chimney Park boat ramp	Hidalgo	26°09'17"N	98°20'11"W			

Table 3. Continued.

Field *N*	Site *N*	Date	Location	County	Latitude	Longitude	Species	*N*	Condition
TPW-068	68	7/06/99	Rio Grande, overflow site at Anzalduas Park	Hidalgo	26°08'35"N	98°19'35"W			
TPW-069	69	6/15/99	Rio Grande, Anzalduas Reservoir, upstream of dam	Hidalgo	26°08'27"N	98°19'54"W			
TPW-070	69	1/10/01	Rio Grande, Anzalduas Reservoir, upstream of dam	Hidalgo	26°08'27"N	98°19'54"W	*Corbicula* spp.		
TPW-071	69	1/26/01	Rio Grande, Anzalduas Reservoir, upstream of dam	Hidalgo	26°08'27"N	98°19'54"W			
TPW-072	70	2/10/01	Canal at the north side of Anzalduas Park	Hidalgo	26°08'38"N	98°19'35"W			
TPW-073	71	7/06/99	Canal at the west side of Anzalduas Park	Hidalgo	26°08'29"N	98°19'21"W	*Cyrtonaias tampicoensis*	2	alive
TPW-074	71	7/06/99	Canal at the west side of Anzalduas Park	Hidalgo	26°08'29"N	98°19'21"W	*Corbicula* spp.		
TPW-074	71	7/06/99	Canal at the west side of Anzalduas Park	Hidalgo	26°08'29"N	98°19'21"W	*Cyrtonaias tampicoensis*	7+0.5x4	relatively-recently dead
TPW-075	72	7/06/99	Rio Grande, below Anzalduas Dam	Hidalgo	26°08'05"N	98°19'56"W	*Corbicula* spp.		
TPW-076	72	2/10/01	Rio Grande, below Anzalduas Dam	Hidalgo	26°08'05"N	98°19'56"W	*Corbicula* spp.		
TPW-076	72	2/10/01	Rio Grande, below Anzalduas Dam	Hidalgo	26°08'05"N	98°19'56"W	*Quadrula apiculata*	0.5x1	relatively-recently dead
TPW-077	73	6/15/99	Canal adjacent to the Pharr Settling Basin	Hidalgo	26°04'56"N	98°14'57"W	*Corbicula* spp.		alive
TPW-078	74	6/15/99	Pharr Settling Basin	Hidalgo	26°04'48"N	98°14'42"W	*Corbicula* spp.		alive
TPW-079	75	6/15/99	Oxbow Pond, La Coma Tract LRGNWR	Hidalgo	26°03'16"N	98°03'49"W	*Corbicula* spp.		alive
TPW-079	75	6/15/99	Oxbow Pond, La Coma Tract LRGNWR	Hidalgo	26°03'16"N	98°03'49"W	*Cyrtonaias tampicoensis*	0.5x1	long dead
TPW-079	75	6/15/99	Oxbow Pond, La Coma Tract LRGNWR	Hidalgo	26°03'16"N	98°03'49"W	*Cyrtonaias tampicoensis*	2	alive
TPW-079	75	6/15/99	Oxbow Pond, La Coma Tract LRGNWR	Hidalgo	26°03'16"N	98°03'49"W	*Lampsilis teres*	0.5x1	very-long dead
TPW-079	75	6/15/99	Oxbow Pond, La Coma Tract LRGNWR	Hidalgo	26°03'16"N	98°03'49"W	*Utterbackia imbecillis*	0.5x4	relatively-recently – very long dead
TPW-080	76	6/15/99	Dry Oxbow Pond, La Coma Tract LRGNWR	Hidalgo	26°03'34"N	98°03'54"W	*Cyrtonaias tampicoensis*	5+0.5x2	long dead
TPW-081	77	6/15/99	Rio Grande, downstream of Retamal Dam	Hidalgo	26°03'03"N	98°02'04"W	*Corbicula* spp.		alive
TPW-082	78	2/10/01	Ditch at FM 494 ca 0.4 km north of FM 1016	Hidalgo	26°09'22"N	98°17'41"W	*Corbicula* spp.		
TPW-083	79	7/05/99	Sapo Lake	Hidalgo	26°24'16"N	98°14'42"W	*Corbicula* spp.		
TPW-083	79	7/05/99	Sapo Lake	Hidalgo	26°24'16"N	98°14'42"W	*Cyrtonaias tampicoensis*	1	recently dead
TPW-083	79	7/05/99	Sapo Lake	Hidalgo	26°24'16"N	98°14'42"W	*Cyrtonaias tampicoensis*	7	alive
TPW-083	79	7/05/99	Sapo Lake	Hidalgo	26°24'16"N	98°14'42"W	*Quadrula apiculata*	1	alive
TPW-083	79	7/05/99	Sapo Lake	Hidalgo	26°24'16"N	98°14'42"W	*Quadrula apiculata*	1	recently dead
TPW-083	79	7/05/99	Sapo Lake	Hidalgo	26°24'16"N	98°14'42"W	*Utterbackia imbecillis*	1	recently dead
TPW-084	80	6/16/99	Lake Edinburg	Hidalgo	26°22'46"N	98°10'13"W	*Corbicula* spp.		alive
TPW-084	80	6/16/99	Lake Edinburg	Hidalgo	26°22'46"N	98°10'13"W	*Cyrtonaias tampicoensis*	2	alive
TPW-084	80	6/16/99	Lake Edinburg	Hidalgo	26°22'46"N	98°10'13"W	*Cyrtonaias tampicoensis*	4+0.5x1	recently dead – subfossil
TPW-084	80	6/16/99	Lake Edinburg	Hidalgo	26°22'46"N	98°10'13"W	*Quadrula apiculata*	5	relatively-recently – relatively-long dead
TPW-085	81	6/16/99	Delta Lake (Monte Alto Reservoir)	Hidalgo	26°24'37"N	97°57'28"W	*Corbicula* spp.		alive
TPW-085	81	6/16/99	Delta Lake (Monte Alto Reservoir)	Hidalgo	26°24'37"N	97°57'28"W	*Cyrtonaias tampicoensis*	0.5x10	long dead
TPW-085	81	6/16/99	Delta Lake (Monte Alto Reservoir)	Hidalgo	26°24'37"N	97°57'28"W	*Cyrtonaias tampicoensis*	4	alive
TPW-085	81	6/16/99	Delta Lake (Monte Alto Reservoir)	Hidalgo	26°24'37"N	97°57'28"W	*Quadrula apiculata*	0.5x1	long dead
TPW-086	82	7/06/99	Llano Grande Lake (Main Floodway Canal)	Hidalgo	26°07'12"N	98°57'38"W			
TPW-087	83	7/06/99	Main Floodway Canal, at Mercedes	Hidalgo	26°08'13"N	97°55'59"W	*Corbicula* spp.		
TPW-088	84	7/06/99	Arroyo Colorado, at Florida Ave., Mercedes	Hidalgo	26°07'44"N	97°54'32"W	*Corbicula* spp.		
TPW-088	84	7/06/99	Arroyo Colorado, at Florida Ave., Mercedes	Hidalgo	26°07'44"N	97°54'32"W	*Cyrtonaias tampicoensis*	2	recently dead
TPW-088	84	7/06/99	Arroyo Colorado, at Florida Ave., Mercedes	Hidalgo	26°07'44"N	97°54'32"W	*Cyrtonaias tampicoensis*	20	alive
TPW-089	85	7/06/99	Moon Lake, at Progresso Lakes	Hidalgo	26°03'55"N	98°57'45"W			
TPW-090	86	7/06/99	Lion Lake, at Progresso Lakes	Hidalgo	26°04'22"N	98°58'00"W			
TPW-091	87	7/06/99	Mercedes Settling Basin	Hidalgo	26°03'55"N	97°53'36"W			
TPW-092	88	7/06/99	Oxbow Lake, at US 281 west of Santa Maria	Hidalgo	26°05'05"N	97°52'05"W	*Corbicula* spp.		
TPW-093	89	6/14/99	La Feria Reservoir	Cameron	26°08'16"N	98°49'27"W			

Table 3. *Continued.*

Field *N*	Site *N*	Date	Location	County	Latitude	Longitude	Species	*N*	Condition
TPW-094	90	6/14/99	Adams Garden Reservoir	Cameron	26°06'23"N	97°47'09"W	*Corbicula* spp.		relatively-long dead
TPW-094	90	6/14/99	Adams Garden Reservoir	Cameron	26°06'23"N	97°47'09"W	*Cyrtonaias tampicoensis*	2+0.5x14	relatively-long + very-long dead
TPW-095	91	6/14/99	Confluence of canal and Reservoir I, Los Indios	Cameron	26°03'09"N	97°44'10"W	*Corbicula* spp.		alive
TPW-095	91	6/14/99	Confluence of canal and Reservoir I, Los Indios	Cameron	26°03'09"N	97°44'10"W	*Cyrtonaias tampicoensis*	18	alive
TPW-095	91	6/14/99	Confluence of canal and Reservoir I, Los Indios	Cameron	26°03'09"N	97°44'10"W	*Cyrtonaias tampicoensis*	6+0.5x9	very-recently – very-long dead
TPW-095	91	6/14/99	Confluence of canal and Reservoir I, Los Indios	Cameron	26°03'09"N	97°44'10"W	*Quadrula apiculata*	1	relatively-long dead
TPW-095	91	6/14/99	Confluence of canal and Reservoir I, Los Indios	Cameron	26°03'09"N	97°44'10"W	*Quadrula apiculata*	7	alive
TPW-096	92	12/13/00	North Floodway Canal, at US 77 south of Sebastian	Cameron	26°18'34"N	97°46'36"W			
TPW-097	93	6/14/99	Dixieland Reservoir, Harlingen	Cameron	26°09'59"N	97°43'09"W	*Corbicula* spp.		alive
TPW-097	93	6/14/99	Dixieland Reservoir, Harlingen	Cameron	26°09'59"N	97°43'09"W	*Cyrtonaias tampicoensis*	1	alive
TPW-097	93	6/14/99	Dixieland Reservoir, Harlingen	Cameron	26°09'59"N	97°43'09"W	*Cyrtonaias tampicoensis*	2	relatively-recently dead
TPW-097	93	6/14/99	Dixieland Reservoir, Harlingen	Cameron	26°09'59"N	97°43'09"W	Quadrula apiculata	1	alive
TPW-098	94	6/14/99	Harlingen City Reservoir, Harlingen	Cameron	26°11'54"N	98°41'30"W			
TPW-099	95	6/15/99	Resaca de los Fresnos, northeast of San Benito	Cameron	26°09'47"N	97°36'22"W	*Corbicula* spp.		alive
TPW-099	95	6/15/99	Resaca de los Fresnos, northeast of San Benito	Cameron	26°09'47"N	97°36'22"W	*Cyrtonaias tampicoensis*	3	alive
TPW-099	95	6/15/99	Resaca de los Fresnos, northeast of San Benito	Cameron	26°09'47"N	97°36'22"W	*Cyrtonaias tampicoensis*	4+0.5x1	relatively-long dead
TPW-099	95	6/15/99	Resaca de los Fresnos, northeast of San Benito	Cameron	26°09'47"N	97°36'22"W	*Quadrula apiculata*	0.5x1	relatively-recently dead
TPW-100	96	7/07/99	Resaca del Rancho Viejo, southeast of Rancho Viejo	Cameron	25°58'46"N	97°31'13"W			
TPW-101	97	7/07/99	Resaca del Rancho Viejo, SH 3248, Brownsville	Cameron	25°58'28"N	97°30'25"W			
TPW-102	98	7/07/99	Lake at SH 1732 west of Olmito	Cameron	26°00'56"N	97°32'16"W			
TPW-103	99	7/07/99	Sweeney Lakes	Cameron	26°10'02"N	97°29'14"W			
TPW-104	100	6/15/99	Canal downstream of Sweeney Lakes at FM 1847	Cameron	26°09'52"N	97°28'04"W			
TPW-105	101	6/15/99	Resaca de los Cuates, FM 803 north of SH 100	Cameron	26°05'31"N	97°31'18"W	*Corbicula* spp.		
TPW-105	101	6/15/99	Resaca de los Cuates, FM 803 north of SH 100	Cameron	26°05'31"N	97°31'18"W	*Cyrtonaias tampicoensis*	1	relatively-recently dead
TPW-105	101	6/15/99	Resaca de los Cuates, FM 803 north of SH 100	Cameron	26°05'31"N	97°31'18"W	*Cyrtonaias tampicoensis*	many	long dead
TPW-106	102	7/07/99	Indian Lake, east of FM 803 and Cameron CWD office	Cameron	26°05'14"N	97°30'12"W	*Corbicula* spp.		
TPW-107	103	7/07/99	Resaca de los Cuates, at Cameron Co. W.D. office	Cameron	26°05'04"N	97°31'23"W	*Cyrtonaias tampicoensis*	0.5x2	very-long dead
TPW-108	104	1/26/01	Resaca de los Cuates, FM 1421 west of US 77/83	Cameron	26°04'50"N	97°34'57"W			
TPW-109	105	1/26/01	Resaca at FM 1421 1.6 km north of FM 1731	Cameron	26°01'30"N	97°35'16"W			
TPW-110	106	6/15/99	Loma Alta Lake	Cameron	26°59'19"N	97°25'58"W			
TPW-111	107	6/15/99	Rio Grande, access off SH 4 at Border Patrol Sta.	Cameron	25°55'39"N	97°20'59"W			
TPW-112	108	1/12/01	Rio Grande, mouth	Cameron	26°57'07"N	97°09'46"W			
Pecos River Drainage									
TPW-113	109	5/30/00	Delaware River, at Ranch Road 652 west of Orla	Culberson	31°53'49"N	103°54'54"W			
TPW-114	110	5/30/00	Red Bluff Reservoir, southwest side	Reeves	31°53'53"N	103°55'08"W			
TPW-115	111	5/30/00	Red Bluff Reservoir, southwest side near dam	Reeves	31°53'47"N	103°54'55"W			
TPW-116	112	5/30/00	Pecos River, below Red Bluff Dam	Reeves	31°53'50"N	103°54'06"W	Unidentified fragments	0.5x2	subfossil
TPW-117	113	5/30/00	Pecos River, Ranch Road 652 east of Orla	Reeves	31°52'21"N	103°49'56"W			
TPW-118	114	7/02/98	Lake Balmorhea, Balmorhea State Park	Reeves	30°57'59"N	103°43'21"W	Utterbackia imbecillis	1	alive
TPW-119	115	5/20/00	Pecos River, at SH 302 west of Mentone	Loving	31°40'37"N	103°37'35"W			
TPW-120	116	7/28/99	Pecos River, from US 190 upstream ca 0.5 km	Crockett/Pecos	30°54'17"N	101°52'45"W			
TPW-121	117	7/28/99	Pecos River, low-water crossing ca 1 km below US 190	Crockett/Pecos	30°53'16"N	101°53'23"W			
TPW-122	118	7/28/99	Pecos River, low-water crossing at Deer Canyon Road	Crockett/Pecos	30°47'19"N	101°50'05"W	Unidentified fragments	0.5x3	long dead – subfossil

Table 3. Continued.

Field *N*	Site *N*	Date	Location	County	Latitude	Longitude	Species	*N*	Condition
TPW-123	119	7/28/99	Pecos River, 1st access below TPW-123 (Site 118)	Crockett/Pecos	30°45'27"N	101°49'23"W	Unidentified fragments	0.5x4	long dead – subfossil
TPW-124	120	7/28/99	Pecos River, 2nd access below TPW-123 (Site 118)	Crockett/Pecos	30°44'49"N	101°48'50"W			
TPW-125	121	7/28/99	Pecos River, 1st low-water crossing below US 290	Crockett/Terrell	30°37'01"N	101°39'27"W	Unidentified fragments	0.5x3	subfossil
TPW-126	122	10/16/99	Pecos River, 5.9 km below Pandale	Val Verde	30°07'27"N	101°31'52"W	*Popenaias popeii*	2	relatively-long dead
TPW-127	123	10/19/99	Pecos River, 59.3 km below Pandale	Val Verde	29°53'38"N	101°29'47"W	*Popenaias popeii*	2	relatively-long dead
TPW-128	124	10/20/99	Pecos River, 63.1 km below Pandale	Val Verde	29°57'24"N	101°27'44"W	*Popenaias popeii*	0.5x1	relatively-long dead
Devils River Drainage									
TPW-129	125	7/12/00	Devils River, ca 8 km above Dolan Springs	Val Verde	29°53'36"N	101°03'54"W	*Popenaias popeii*	0.5x1	subfossil
TPW-130	126	5/27/98	Devils River, at Baker's Bridge	Val Verde	29°57'50"N	101°08'41"W			
TPW-131	127	5/27/98	Devils River, at Finnegan Springs	Val Verde	29°54'16"N	101°00'08"W			
TPW-132	128	5/27/98	Phillips Creek, upstream of Devils River	Val Verde	29°57'11"N	101°06'47"W			
TPW-133	129	5/27/98	Dolan Creek, upstream of Devils River	Val Verde	29°53'48"N	101°59'03"W			

Table 4. Selected sampling and collection locations of freshwater bivalves in Mexican tributaries of the Rio Grande and other river systems in eastern Mexico. Museum source acronyms include: LACM = Los Angles County Museum, MCZ = Museum of Comparative Zoology, ANSP = Academy of Natural Sciences of Philadelphia, UMMZ = University of Michigan Museum of Zoology, USNM = U.S. National Museum.

Date	Location	State	Latitude	Longitude	Species	*N*	Condition	Source
Rio Grande Drainage								
	Rio Conchos, 15 km NE of Saucillo	Chihuahua	27°20'36"N	104°52'14"W	*Disconaias conchos*		worn valves	LACM 69-240.2; Taylor 1998
	Rio Conchos, 1.5 km NW of Rosetilla	Chihuahua	28°15'56"N	105°18'14"W	*Disconaias conchos*		worn valves	LACM 69-243.1; Taylor 1998
	Rio Conchos, 1.2 km E of Julimes	Chihuahua	28°25'05"N	105°26'18"W	*Disconaias conchos*			LACM 69-239.1; Taylor 1998
	Rio Salado, canal ca 34 km WNW Anahuac	Nuevo Leon	27°20'16"N	100°28'11"W	*Uniterbackia imbecillis*			MCZ; Johnson 1999
05/--/1976	Rio Salado, bank sediments, Municipio Villa Juarez 0.9 km NE Presa don Martin	Coahuila	27°31'10"N	100°36'30"W	*Megalonaias nervosa*		subfossil	Metcalf 1982
05/--/1976	Rio Salado, bank sediments, Municipio Villa Juarez 0.9 km NE Presa don Martin	Coahuila	27°31'10"N	100°36'30"W	*Quadrula couchiana*		subfossil	Metcalf 1982
05/--/1976	Rio Salado, bank sediments, Municipio Villa Juarez 0.9 km NE Presa don Martin	Coahuila	27°31'10"N	100°36'30"W	*Quincuncina mitchelli*		subfossil	Metcalf 1982
05/--/1976	Rio Salado, bank sediments, Municipio Villa Juarez 0.9 km NE Presa don Martin	Coahuila	27°31'10"N	100°36'30"W	*Popenaias popeii*		subfossil	Metcalf 1982
05/--/1976	Rio Salado, bank sediments, Municipio Villa Juarez 0.9 km NE Presa don Martin	Coahuila	27°31'10"N	100°36'30"W	*Cyrtonaias tampicoensis*		subfossil	Metcalf 1982
05/--/1976	Rio Salado, bank sediments, Municipio Villa Juarez 0.9 km NE Presa don Martin	Coahuila	27°31'10"N	100°36'30"W	*Potamilus metnecktayi*		subfossil	Metcalf 1982
	Rio Sabinas	Coahuila	26°31'25"N	101°13'26"W	*Cyrtonaias tampicoensis*			MCZ; USNM; Johnson 1999
	Rio Sabinas	Coahuila	26°31'25"N	101°13'26"W	*Lampsilis teres*			MCZ; Johnson 1999
"1855"	Rio Agualeguas, Puntiagudo, ca 4.8 km NE of General Trevino	Nuevo Leon	26°15'39"N	99°26'40"W	*Uniomerus* sp.?			MCZ 169447-8; Gould 1855; Johnson 1999
05/--/1976	Rio Salado, 24 km S of Anahuac	Nuevo Leon	27°08'20"N	99°57'30"W	*Megalonaias nervosa*		fossil	Metcalf 1982
05/--/1976	Rio Salado, 24 km S of Anahuac	Nuevo Leon	27°08'20"N	99°57'30"W	*Quadrula couchiana*		fossil	Metcalf 1982
05/--/1976	Rio Salado, 24 km S of Anahuac	Nuevo Leon	27°08'20"N	99°57'30"W	*Popenaias popeii*		fossil	Metcalf 1982
05/--/1976	Rio Salado, 24 km S of Anahuac	Nuevo Leon	27°08'20"N	99°57'30"W	*Lampsilis teres*		fossil	Metcalf 1982
05/--/1976	Rio Salado, 24 km S of Anahuac	Nuevo Leon	27°08'20"N	99°57'30"W	*Truncilla cognata*		fossil	Metcalf 1982
05/--/1976	Rio Salado, 24 km S of Anahuac	Nuevo Leon	27°08'20"N	99°57'30"W	*Quincuncina mitchelli*		fossil	Metcalf 1982
	Rio Salado, Anahuac	Nuevo Leon	27°14'04"N	100°08'08"W	*Cyrtonaias tampicoensis*			MCZ; Johnson 1999
	Rio Salado, Lampazos	Nuevo Leon			*Cyrtonaias tampicoensis*			ANSP 4201; Johnson 1999
	Rio Salado, Lampazos	Nuevo Leon			*Potamilus metnecktayi*			ANSP 44200; Johnson 1999
	Rio San Juan, Monterrey	Nuevo Leon	25°40'46"N	100°16'05"W	*Cyrtonaias tampicoensis*			UMMZ; Johnson 1999
05/--/1976	Rio San Juan, 3.5 km NE of Municipio China	Nuevo Leon	25°43'40"N	99°13'08"W	*Popenaias popeii*		fossil	Metcalf 1982
	Rio San Juan, China	Nuevo Leon	25°42'27"N	99°14'07"W	*Cyrtonaias tampicoensis*		fossil	Metcalf 1982
	Rio San Juan, China	Nuevo Leon	25°42'27"N	99°14'07"W	*Quincuncina mitchelli*		fossil	Metcalf 1982
01/--/1984	Rio San Juan, at Castillos	Nuevo Leon	25°33'00"N	100°01'00"W	*Corbicula fluminea*			Hillis and Mayden 1984
01/--/1984	Rio San Juan, at Castillos	Nuevo Leon	25°33'00"N	100°01'00"W	*Corbicula* sp. (purple)			Hillis and Mayden 1984
	Rio Salado	Nuevo Leon	26°59'45"N	99°57'42"W	*Quadrula couchiana*			USNM; Johnson 1999
	Rio Salado	Nuevo Leon	26°59'45"N	99°57'42"W	*Popenaias popeii*			USNM; Johnson 1999
	Rio Salado	Nuevo Leon	26°59'45"N	99°57'42"W	*Truncilla cognata*			USNM 85004-holotype; Johnson 1999
	Rio Sabinas(?)	Nuevo Leon			*Megalonaias nervosa*			USNM 83991; Johnson 1999
	Rio Sabinas, Villa Juarez	Coahuila	27°36'07"N	100°43'02"W	*Disconaias conchos*			LACM 95117; Taylor 1998
	Rio Salado, 7.2 km S of Nuevo Laredo	Tamaulipas	26°49'06"N	99°32'22"W	*Quincuncina mitchelli*			UMMZ; Johnson 1999
	Rio Salado, 7.2 km S of Nuevo Laredo	Tamaulipas	26°49'06"N	99°32'22"W	*Cyrtonaias tampicoensis*			UMMZ; Johnson 1999
07/--/1929	Rio Salado, 7.2 km S of Nuevo Laredo	Tamaulipas	26°49'06"N	99°32'22"W	*Potamilus metnecktayi*			UMMZ 66993; Johnson 1999
	Rio Salado, near Nuevo Laredo	Tamaulipas	26°49'06"N	99°32'22"W	*Truncilla cognata*			USNM 85004a; Johnson 1999
	Rio Salado, near Nuevo Laredo	Tamaulipas	26°49'06"N	99o32'22"W	*Truncilla cognata*			USNM 257105; Johnson 1999
	Rio San Juan, Camargo	Tamaulipas	26°14'33"N	98°52'39"W	*Cyrtonaias tampicoensis*			USNM; Johnson 1999
	Matamoros	Tamaulipas	25°52'36"N	97°35'56"W	*Uniterbackia imbecillis*			USNM; Johnson 1999

Table 4. Continued.

Date	Location	State	Latitude	Longitude	Species	N	Condition	Source
Rio San Fernando Drainage								
01/--/1984	Rio San Fernando = Rio Conchos (general)	Tamaulipas	24°53'59"N	98°13'38"W				Hillis and Mayden 1985
	Rio Conchos (= Rio Fernando)	Tamaulipas			*Cyrtonaias tampicoensis*			USNM; LACM 105551; Johnson 1999
Rio Sota la Marina Drainage								
	Rio Corona, 5.6 km E of Guemez	Tamaulipas			*Popenaias popeii*			UMMZ; Johnson 1999
	Rio Purificacion, near Padilla	Tamaulipas	24°00'27"N	98°46'36"W	*Popenaias popeli*			MCZ; Johnson 1999
01/--/1984	Rio Purificacion branch of Sota la Marina	Tamaulipas	24°40'07"N	98°58'07"W				Hillis and Mayden 1985
	Rio Sota la Marina, 6.4 km W of Padilla	Tamaulipas	23°55'32"N	98°33'00"W	*Popenaias popeli*			MCZ; Johnson 1999
01/--/1984	Rio Corona tributary (unnamed), 3 km S of Rio Corona and Mexican Hwy 101	Tamaulipas	23°57'00"N	98°57'00"W	*Corbicula fluminea*			Hillis and Mayden 1985
01/--/1984	Rio Corona tributary (unnamed), 3 km S of Rio Corona and Mexican Hwy 101	Tamaulipas	23°57'00"N	98°57'00"W	*Corbicula* sp. (purple)			Hillis and Mayden 1985
Rio Carrizal Drainage								
12/29-30/ 1974	Rio Carrizal, ca 48 km S of Hwy 180 and 70 at Sota la Marina	Tamaulipas	23°20'46"N	98°00'43"W	*Popenaias popeli*	1	recently dead	Howells (unpublished)
04/--/1982	Rio Carrizal, at Mexican Hwy 180	Tamaulipas	23°20'46"N	98°00'43"W	*Corbicula fluminea*		living	Hillis and Mayden 1985
Rio Tamesi Drainage								
	Rio Sabinas, E of Gomez Farias	Tamaulipas	23°30'00"N	99°50'40"W	*Popenaias popeli*			UMMZ; Johnson 1999
	Rio Sabinas, E of Gomez Farias	Tamaulipas	23°30'00"N	99°50'40"W	*Cyrtonaias tampicoensis*			UMMZ; Johnson 1999
	Rio Guayalejo, 30.6 km ENE of Cuidad Mante	Tamaulipas	22°46'46"N	98°39'25"W	*Popenaias popeli*			MCZ; Johnson 1999
	Rio Guayalejo, 30.6 km ENE of Cuidad Mante	Tamaulipas	22°46'46"N	98°39'25"W	*Cyrtonaias tampicoensis*			MCZ; Johnson 1999
	Rio Guayalejo, near Magiscatzin	Tamaulipas			*Popenaias popeli*			MCZ; Johnson 1999
	Rio Frio (*Rio Panuco System*), 4.3 km from Rescon	San Luis Potosi	22°06'12"N	99°17'08"W	*Popenaias popeli*			MCZ; Johnson 1999
	Valles River (Rio Panuco System), Micos Falls, Micos	San Luis Potosi	22°11'14"N	99°12'43"W	*Popenaias popeli*			MCZ; Johnson 1999
	Valles River (Rio Panuco System), between Valles and Pojal	San Luis Potosi	21°58'44"N	99°01'29"W	*Popenaias popeli*			MCZ; Johnson 1999
	Valles River	San Luis Potosi	22°03'04"N	99°03'08"W	*Popenaias popeli*			MCZ; Johnson 1999
	Rio Panuco, Panuco	Veracruz	22o30'31"N	98°10'09"W	*Popenaias popeli*			INHS 21699
	Rio Tampico (Panuco?)	Veracruz	22°13'29"N	97°52'56"W	*Cyrtonaias tampicoensis*			MCZ; Johnson 1999
03/25/1986	Rio Moctezuma, Tamuzenchale	San Luis Potosi	21°15'55"N	98°47'24"W	*Cyrtonaias tampicoensis* / *Popenaias popeii*	4	living	USNM; Johnson 1999 / Smith et al. 2000
Rio Cazones Drainage								
	Rio Cazones, WSW of Poza Rica	Veracruz	20°06'27"N	97°28'56"W	*Popenaias popeii*			MCZ; Johnson 1999
Rio Cotaxtla Drainage								
	Rio Dedelfin, 16 km S of Veracruz	Veracruz	19°02'30"N	96°08'20"W	*Cyrtonaias tampicoensis*			USNM; Johnson 1999
Rio San Juan Drainage and Lago de Catemaco								
	Rio Tecomate, near Tlacotalpan	Veracruz	18°36'11"N	95°39'59"W	*Cyrtonaias tampicoensis*			USNM; Johnson 1999
	Lago de Catemaco	Veracruz	18°21'00"N	95°02'00"W	*Corbicula fluminea*			Torres-Orozco and Tevuelnas-Valle 1996

Table 5. Locations sampled and bivalves collected during desert fishes surveys by Texas Parks and Wildlife personnel in the Rio Conchos and adjacent drainages, Chihuahua, Mexico, 1994 (Howells 1996a).

Date	Location	State	Latitude	Longitude	Species	*N*	Condition
08/03/1994	Rio Conchos, headwater at Cuchillo de Parado	Chihuahua	29°31'20"N	104°53'15"W			
08/05/1994	Rio Conchos, downstream of Julimes	Chihuahua	28°25'16"N	105°26'19"W	*Disconaias conchos*	0.5x10	relatively-recently – long dead
08/06/1994	Rio Conchos, near Valle de Zaragosa	Chihuahua	27°27'40"N	105°48'54"W			
08/04/1994	Rio Chuviscar, near San Diego de Alcala	Chihuahua	28°35'09"N	105°33'59"W			
08/04/1994	Hot springs, near San Diego de Alcala, low-water crossing	Chihuahua	28°35'05"N	105°34'23"W			
10/--/1994	Hot springs, at San Diego de Alcala, low-water crossing	Chihuahua	28°35'05"N	105°34'23"W			
08/06/1994	Ojo de Talmantes (Rio Florido tributary), at Balneario	Chihuahua	27°34'00"N	104°59'05"W			
08/06/1994	Rio San Pedro, south of Satevo at Highway 24	Chihuahua	27°53'59"N	106°06'55"W			
08/07/1994	Rio Santa Isabela, upstream of Rive Palacio	Chihuahua	28°33'25"N	106°30'58"W			
08/07/1994	Rio Santa Isabela, at Rive Palacio	Chihuahua	28°32'28"N	106°30'09"W			
08/10/1994	Ojo del Rey, near Angostura	Chihuahua	30°02'16"N	107°35'37"W			
08/10/1994	Rio Papagochi, below Matachic	Chihuahua	28°50'52"N	107°45'59"W	*Anodonta* sp.[1]	0.5x1	long dead
08/10/1994	Rio Papagochi, below Matachic	Chihuahua	28°50'52"N	107°45'59"W	Sphaeriidae	several	alive
08/09/1994	Rio at Basaseachic	Chihuahua					
08/11/1994	Rio Palangana, at Mata Ortiz	Chihuahua	30°10'34"N	108°00'57"W			
10/21-24/1994	Ojo del Alamo, NW of Coyame	Chihuahua	29°28'42"N	105°06'53"W			
10/--/1994	Rio Coyame	Chihuahua	29°27'53"N	105°05'22"W			
10/--/1994	Hot springs, at Coyame	Chihuahua	29°27'29"N	105°05'36"W			
10/--/1994	Ojo del Laguna, endorheic waters N of Ciudad Chihuahua	Chihuahua	29°27'44"N	106°18'12"W			
10/--/1994	Rio Chuviscar, headwater (two sites combined)	Chihuahua	28°41'51"N	105°37'42"W			
10/--/1994	Rio Chuviscar, at San Diego de Alcala	Chihuahua	28°41'51"N	105°37'42"W			

[1] Possibly *Anodonta dejecta*

Table 6. Freshwater mussel collection locations reported in New Mexico, including both historic records and recent data from New Mexico Department of Game and Fish obtained in the present study (Lang 1998, 2000). USNM = U.S. National Museum. ANSP = Academy of Natural Sciences of Philadelphia.

Date	Location	County	Latitude	Longitude	Species	Condition	Source
Rio Grande Drainage							
"1987"	San Jose River, near San Rafael	Valencia	35°09'04"N	107°50'33"W	*Utterbackia imbecillis*		Neck 1987
Pecos River Drainage							
	Rio Felix, 3.2 km N, 0.8 km E of center of Hagerman, N bank	Chaves	33°08'37"N	104°19'04"W	*Cyrtonaias tampicoensis*	subfossil	Metcalf 1982
	Rio Felix, 3.2 km N, 0.8 km E of center of Hagerman, N bank	Chaves	33°08'37"N	104°19'04"W	*Popenaias popeii*	subfossil	Metcalf 1982
1902	North Spring River, near Roswell	Chaves	33°26'05"N	104°26'56"W	*Popenaias popeii*	fresh	Cockerell 1902; USNM 168765; ANSP 91432
	Pecos River, 7.2 km NE of Roswell	Chaves	33°29'39"N	104°23'10"W	*Popenaias popeii*		Johnson 1999; USNM
	Pecos River, below McMillan Reservoir, Dam to 1 km downstream	Eddy	32°35'22"N 32°35'47"N	104°21'05"W to 104°21'35"W	*Cyrtonaias tampicoensis*	fossil	Metcalf 1982
	Pecos River, below McMillan Reservoir, Dam to 1 km downstream	Eddy	32°35'22"N 32°35'47"N	104°21'05"W to 104°21'35"W	*Megalonaias nervosa*	fossil	Metcalf 1982
	Pecos River, below McMillan Reservoir, Dam to 1 km downstream	Eddy	32°35'22"N 32°35'47"N	104°21'05"W to 104°21'35"W	*Potamilus metnecktayi*	fossil	Metcalf 1982
	Pecos River, below McMillan Reservoir, Dam to 1 km downstream	Eddy	32°35'22"N 32°35'47"N	104°21'05"W to 104°21'35"W	*Popenaias popeii*	fossil	Metcalf 1982
	Pecos River, below McMillan Reservoir, Dam to 1 km downstream	Eddy	32°35'22"N 32°35'47"N	104°21'05"W to 104°21'35"W	*Quadrula couchiana*	fossil	Metcalf 1982
	Pecos River, below McMillan Reservoir, Dam to 1 km downstream	Eddy	32°35'22"N 32°35'47"N	104°21'05"W to 104°21'35"W	*Quincuncina mitchelli*	fossil	Metcalf 1982
02/2000	Pecos River, upstream of Avalon Reservoir (site BKL00-004)	Eddy	32°31'12"N	104°17'34"W	*Pyganodon grandis*	live	Lang 2000
02/2000	Pecos River, below Avalon Dam, ca 4.8 km N of Carlsbad (site BK99-034)	Eddy	32°28'28"N	104°15'47"W	*Pyganodon grandis*	recently dead	Lang 2000
1937	Pecos River, Carlsbad	Eddy	32°24'30"N	104°13'25"W	*Popenaias popeii*		Johnson 1999; ANSP 174028
	Pecos River, quarry immediately below Fishing Rock E of low bridge	Eddy	32°13'07"N	104°00'06"W	*Cyrtonaias tampicoensis*	fossil	Metcalf 1982
	Pecos River, quarry immediately below Fishing Rock E of low bridge	Eddy	32°13'07"N	104°00'06"W	*Megalonaias nervosa*	fossil	Metcalf 1982
	Pecos River, quarry SE side of Pierce Crossing E&W of road	Eddy	32°11'17"N	103°58'38"W	*Cyrtonaias tampicoensis*	fossil	Metcalf 1982
	Pecos River, quarry SE side of Pierce Crossing E&W of road	Eddy	32°11'17"N	103°58'38"W	*Megalonaias nervosa*	fossil	Metcalf 1982
	Pecos River, quarry SE side of Pierce Crossing E&W of road	Eddy	32°11'17"N	103°58'38"W	*Popenaias popeii*	fossil	Metcalf 1982
	Pecos River, quarry SE side of Pierce Crossing E&W of road	Eddy	32°11'17"N	103°58'38"W	*Quadrula couchiana*	fossil	Metcalf 1982
	Pecos River, quarry SE side of Pierce Crossing E&W of road	Eddy	32°11'17"N	103°58'38"W	*Quincuncina mitchelli*	fossil	Metcalf 1982
1997-2000	Black River, Black River Village to US 285	Eddy	32°12'04"N 32°14'10"N	104°14'59"W to 104°04'47"W	*Popenaias popeii*	live	Lang 1998, 2000
1998	Delaware River, Texas border to the Pecos River	Eddy	32°00'04"N 32°02'00"N	104°05'47"W to 104°01'24"W	*Popenaias popeii*	subfossil	Lang 1998

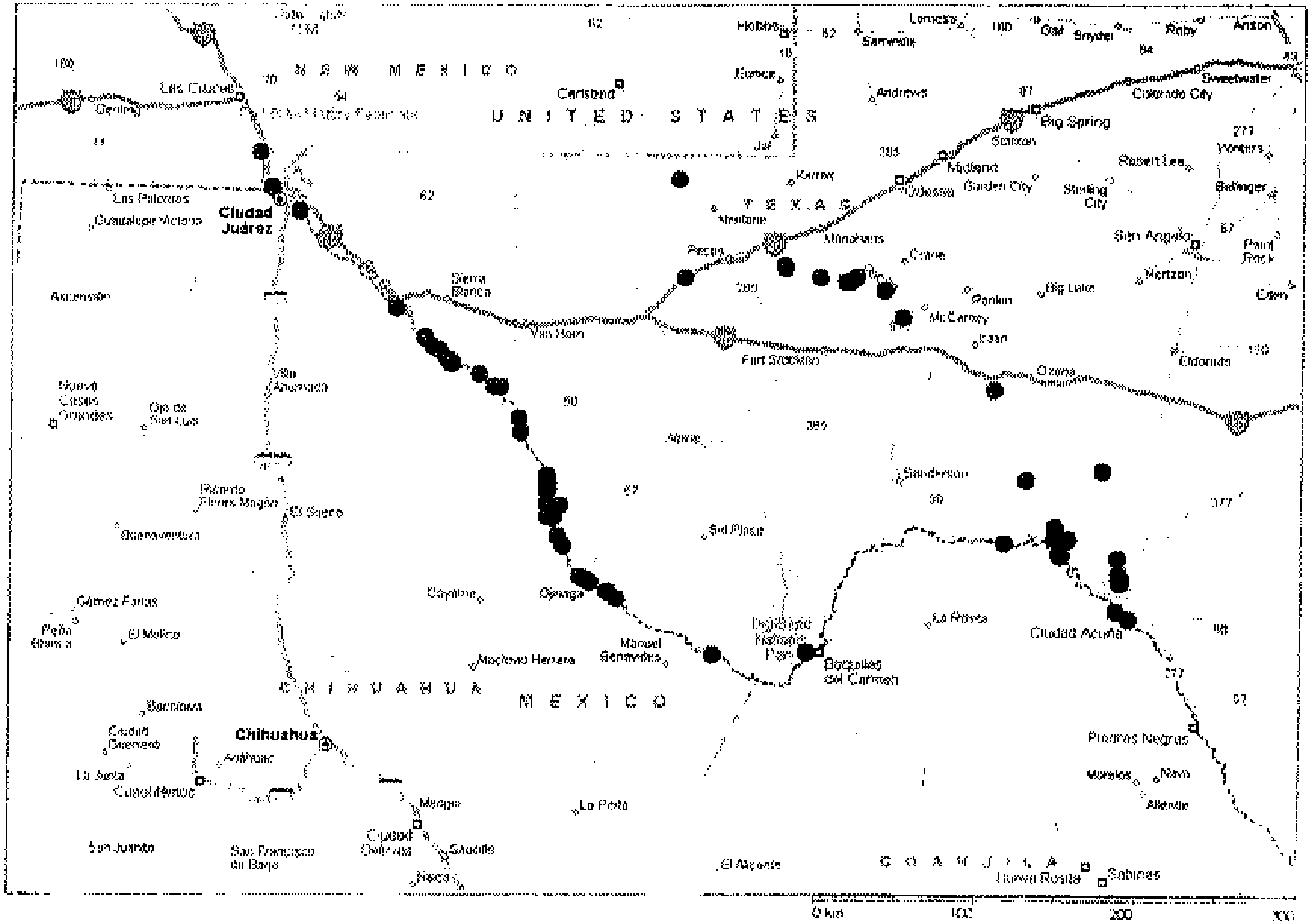
Table 7. Mean values for selected physicochemical parameters at locations on the Rio Grande, Pecos River, and Devils River, Texas, obtained from measurements presented in U.S. Geological Survey reports for water years 1968 (USGS 1968), 1975 (USGS 1975), 1986 (Buckner et al. 1986), 1996 (Gandara et al. 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	Anzal-duas Dam	Browns-ville
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)	1,368	1,214	1,103	959	971	1,065	1,020	1,322
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)	2,012	3,477	467	9
Nitrate (mg/L)			0.92	0.94
Chloride (mg/L)	3,477	5,818	777	15
Conductivity (µS/cm)	12,651	21,585	34,551	381
Suspended sediments (mg/L)			12	22
Dissolved solids (mg/L)	9,742	12,953	2,038	214
Turbidity (NTU)			10	5

Table 8. 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 (Buckner 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	2,364	4,113	3,609
Rio Grande - Falcon Dam			122	29	19	20
Rio Grande – Brownsvilte			120	63	47	64



Figu[re] Selected historic collection and sampling sites related to freshwater bivalves prior to 1992 on the upper Rio Grande Drainage, Texas

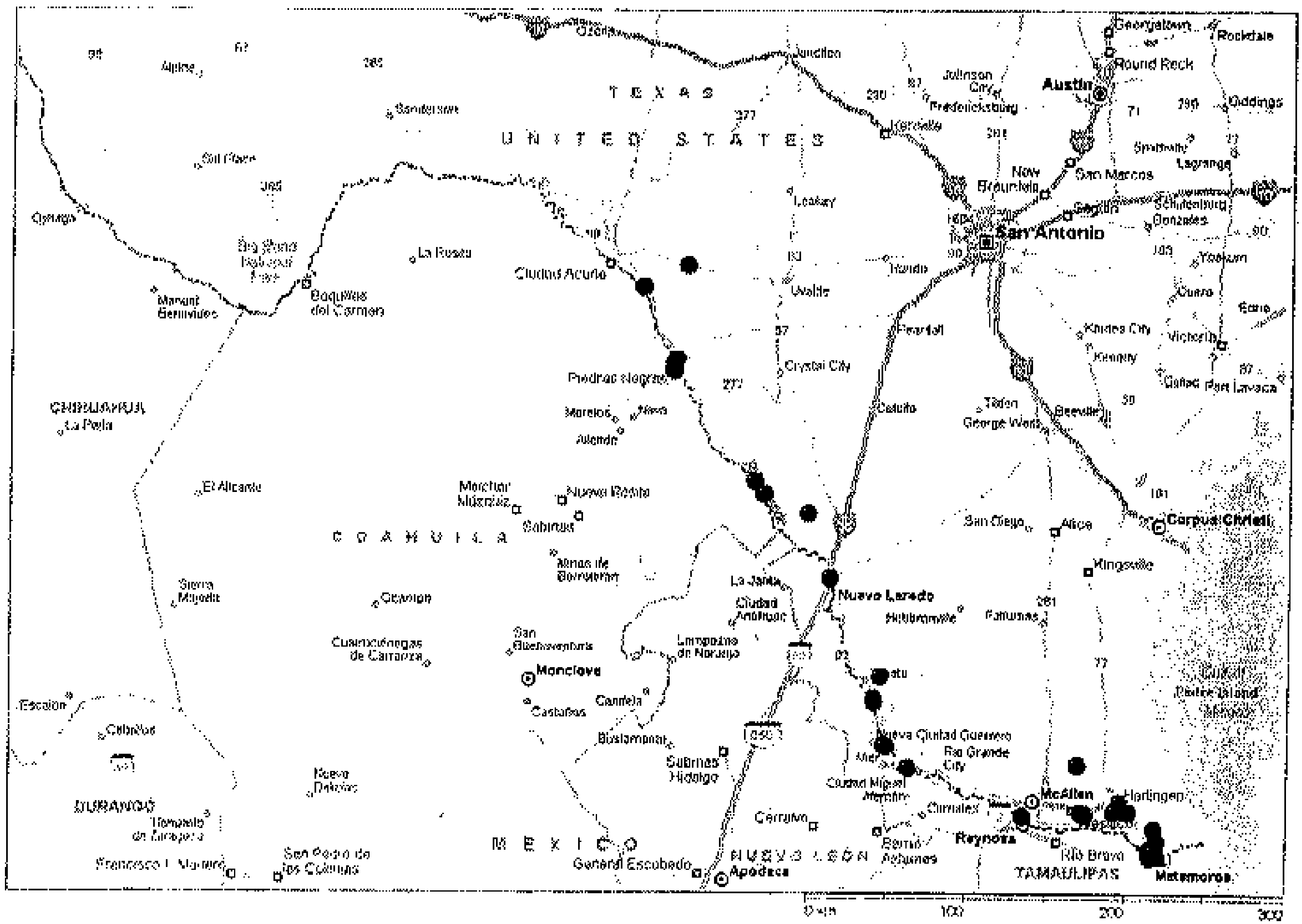


Figure 2. Selected historic collection and sampling sites related to freshwater bivalves prior to 1992 on the lower Río Grande Drainage, Texas.

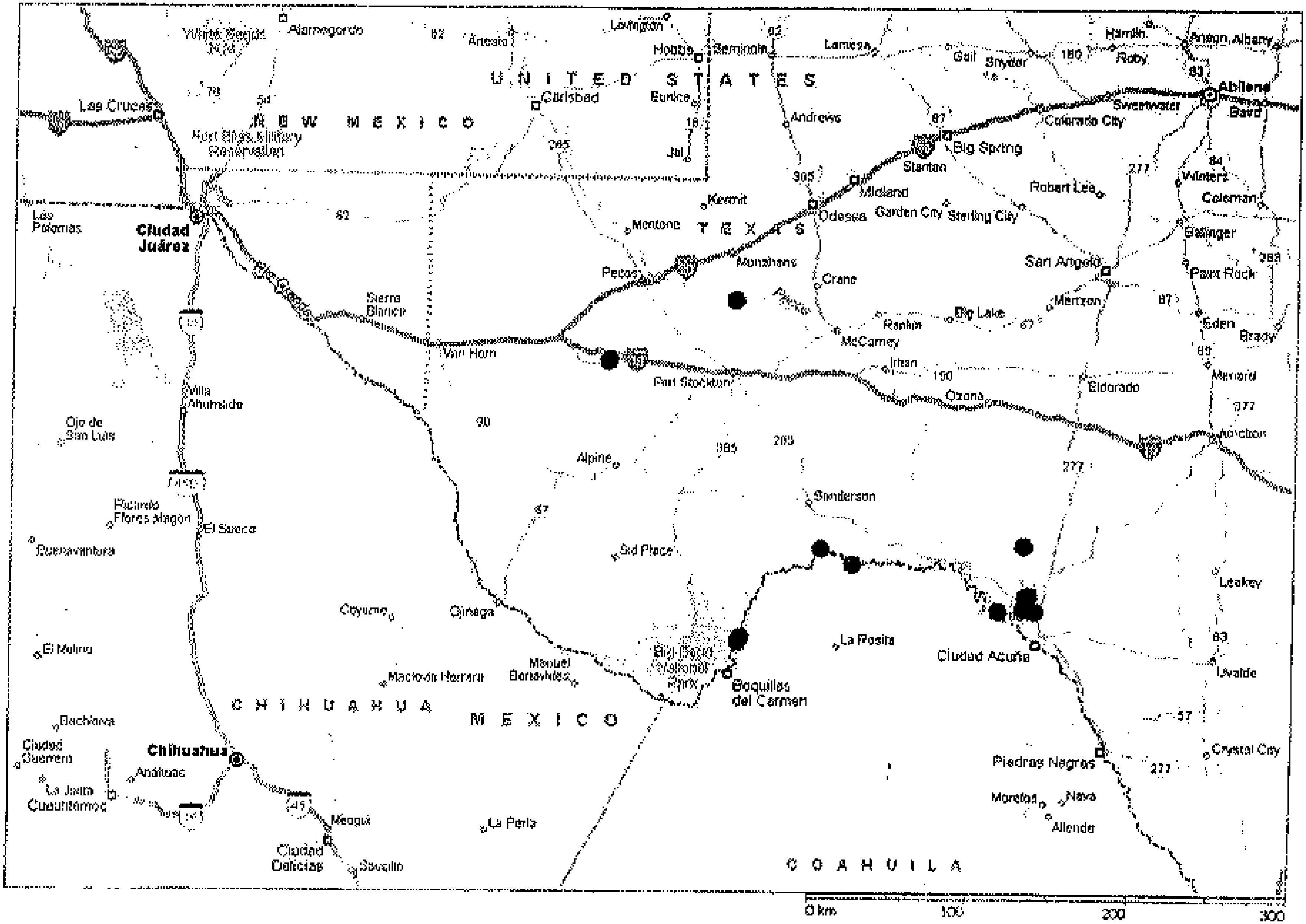


Figure 5 Freshwater mussel survey sites on the upper Rio Grande Drainage, Texas, documented by Texas Parks and Wildlife's Heart of the Hills Research Station, 1992-1997

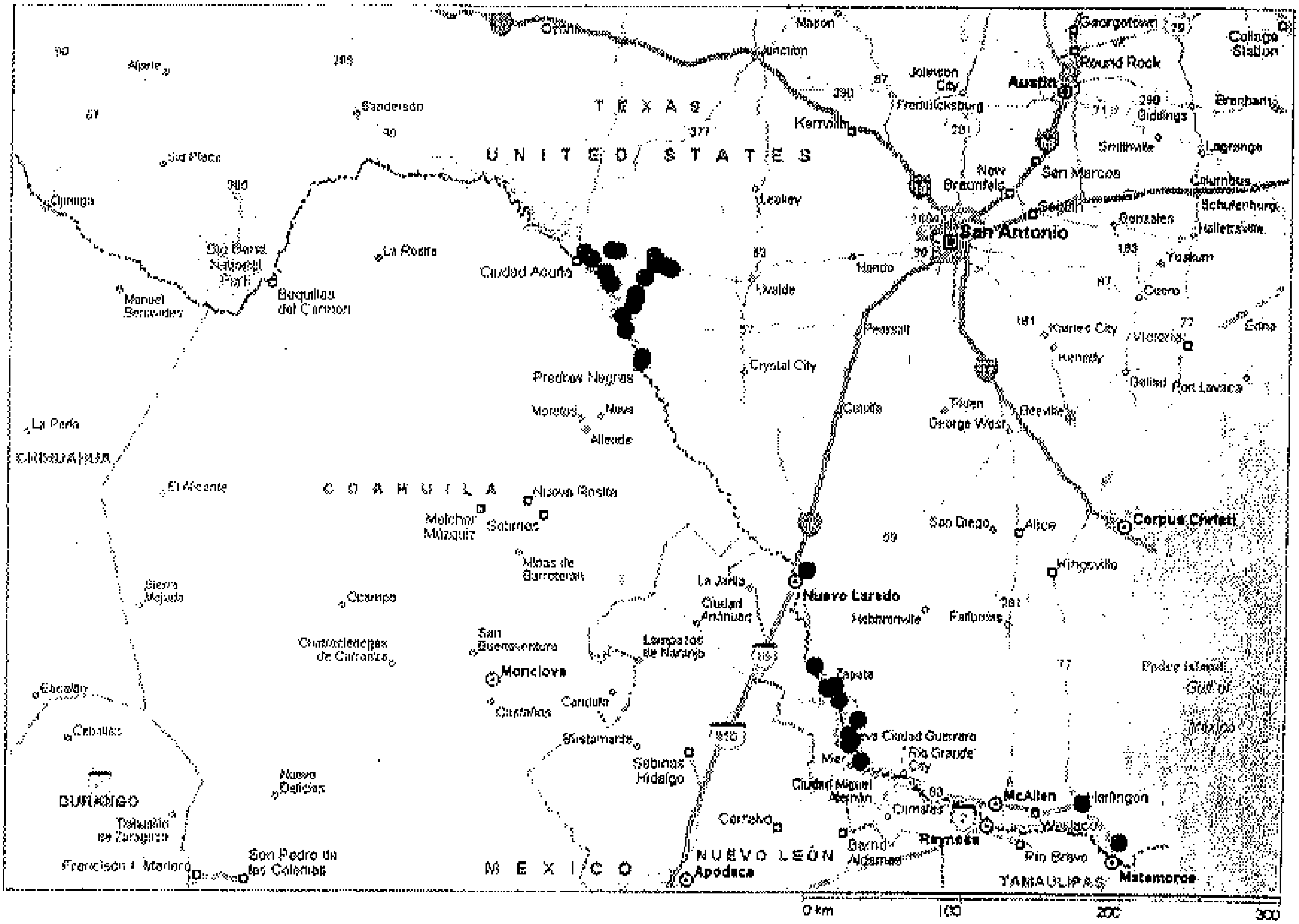


Figure 4. Freshwater mussel survey sites on the lower Rio Grande Drainage, Texas, documented by Texas Parks and Wildlife's Heart of the Hills Research Station, 1992-1997

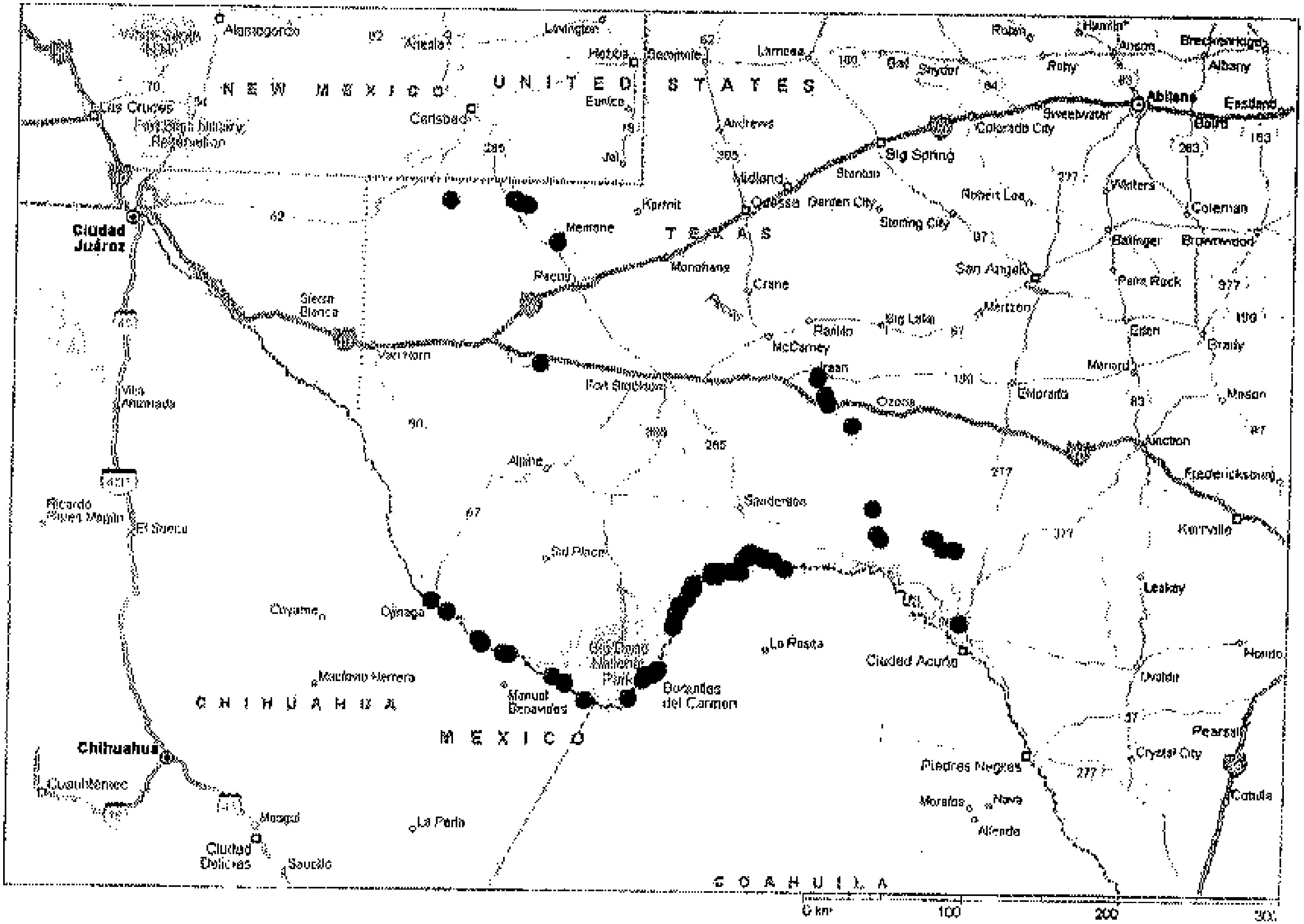


Figure 5 Freshwater mussel survey sites on the upper Rio Grande Drainage, Texas, documented by Texas Parks and Wildlife's Heart of the Hills Research Station, 1997-2001 (present study)

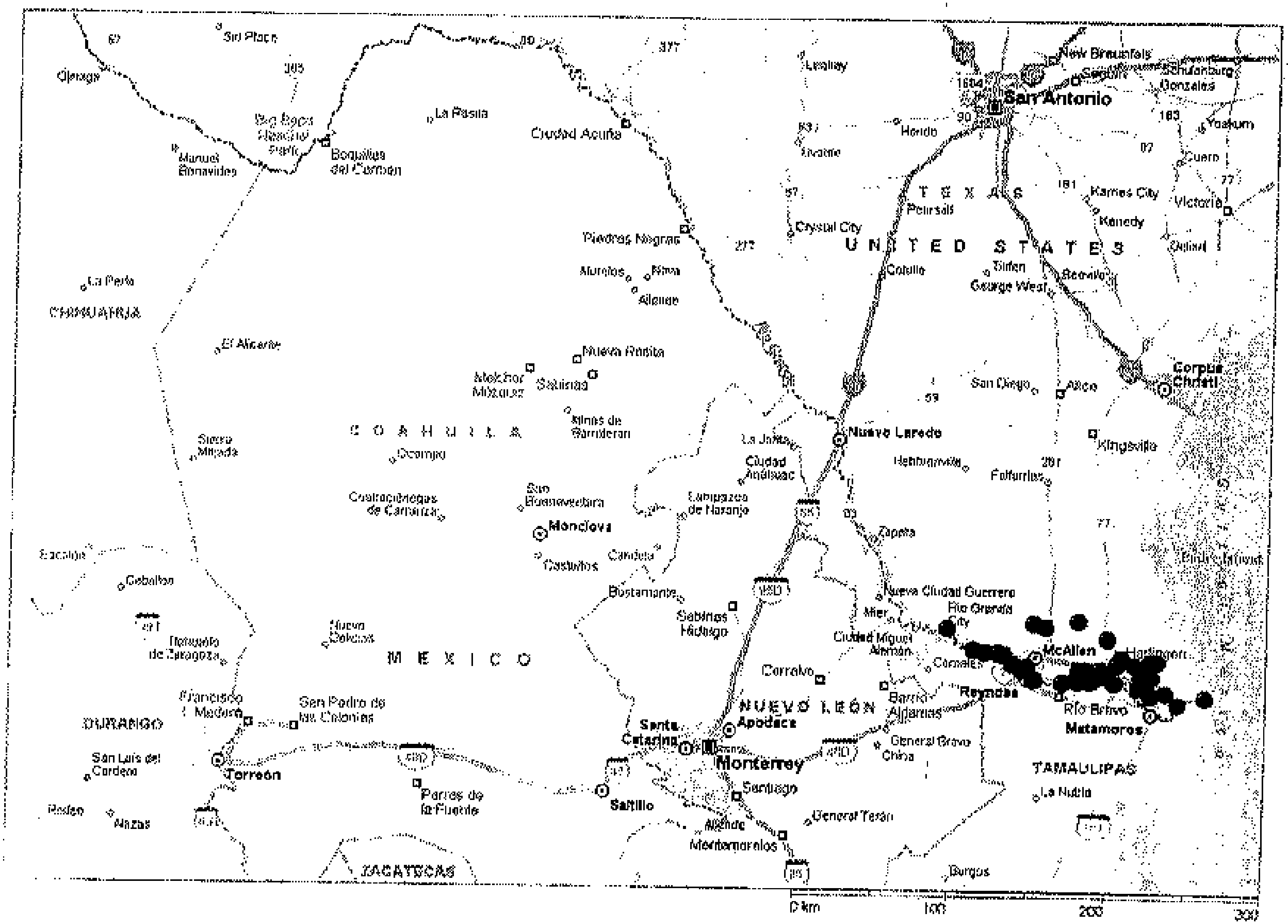


Figure 6. Freshwater mussel survey sites on the lower Rio Grande Drainage, Texas, documented by Texas Parks and Wildlife's Heart of the Hills Research Station, 1997-2001 (present study)

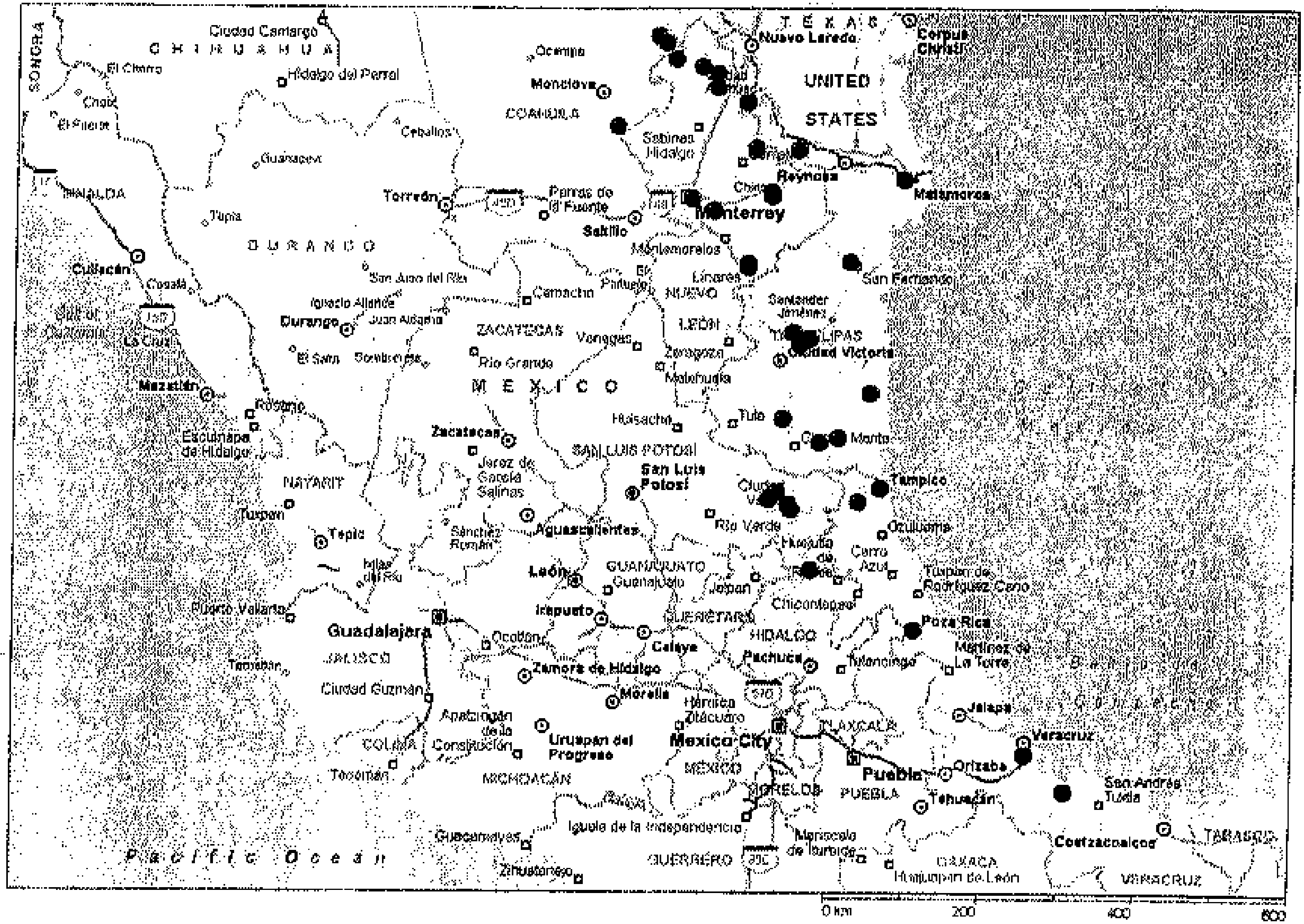


Figure 7. Selected historic collection and sampling sites related to freshwater bivalves in the lower Rio Grande Drainage and Gulf of Mexico tributaries, Mexico.

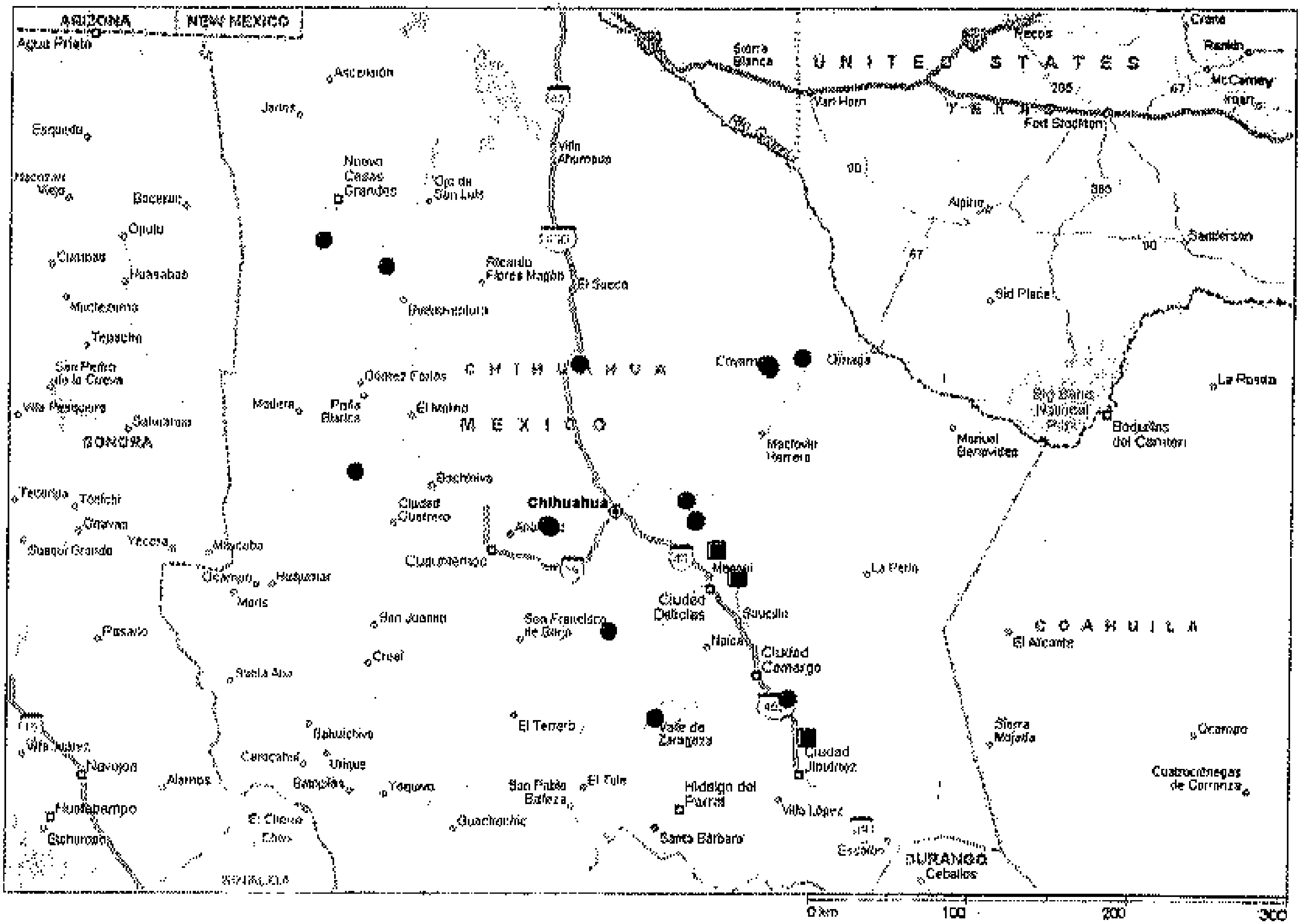


Figure 8. Collection sites (squares) reported by Taylor (1997) and sampling and collection sites (circles) examined by Texas Parks and Wildlife's Heart of the Hills Research Station in 1994 in the Rio Conchos and adjacent drainages, Chihuahua, Mexico.

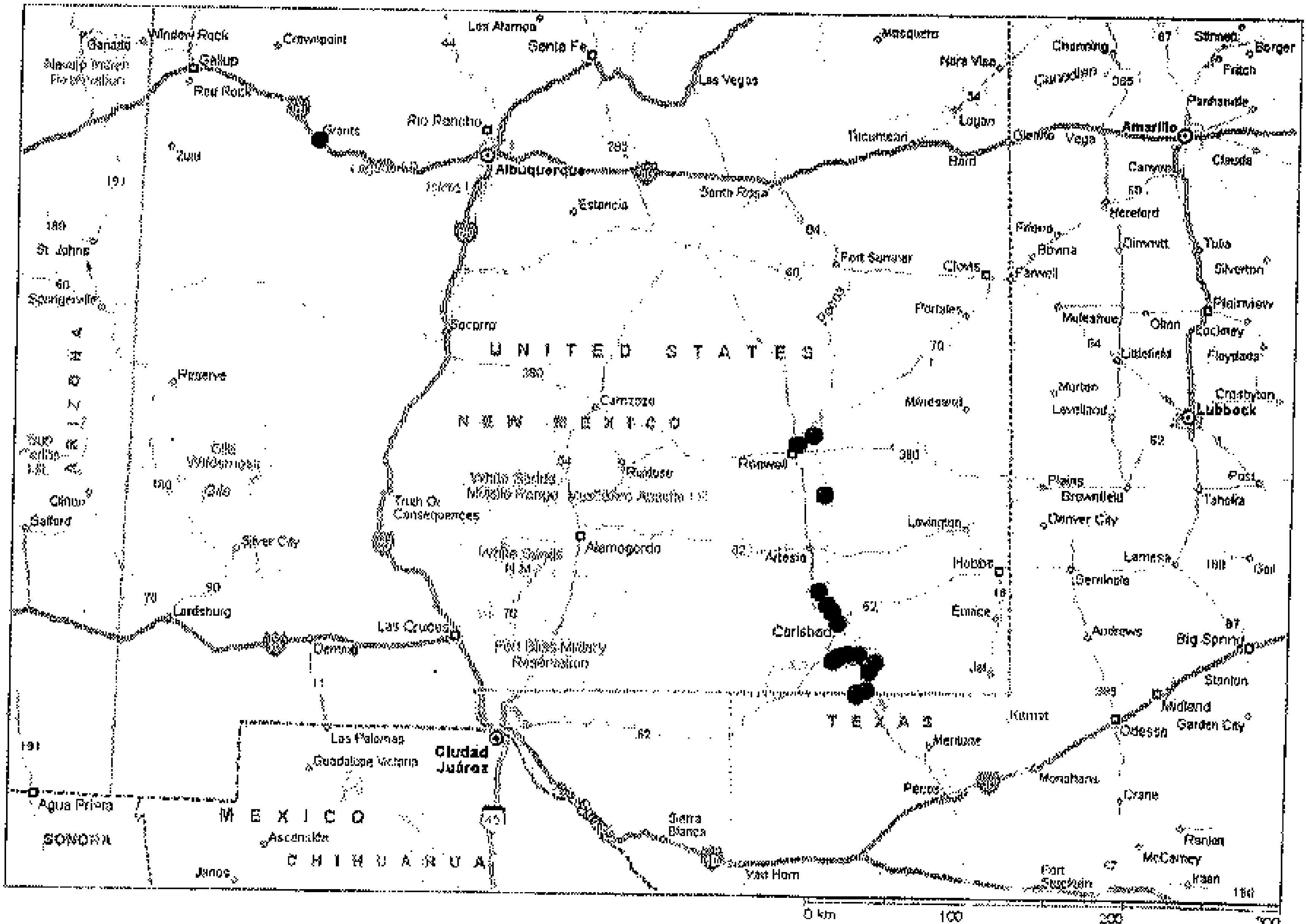


Figure 9. Selected historic freshwater mussel collection sites and locations reported by Lang (1998, 2000) in the upper Rio Grande Drainage, New Mexico.

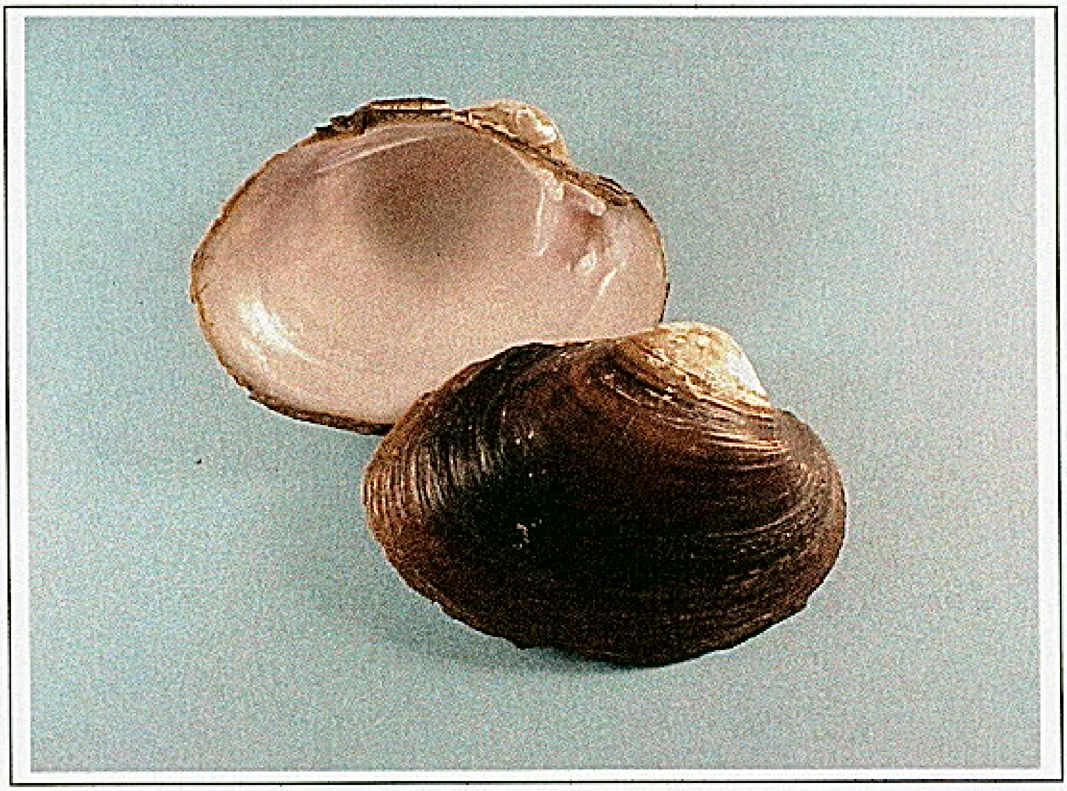


Figure 10. Tampico pearlymussel *Cyrtonaias tampicoensis*: Amistad Reservoir, Val Verde County, Texas, 20 September 1995, 89 mm shell length. Specimen has pale nacre typical of Rio Grande populations. Photo by R.G. Howells.

Figure 11. Tampico pearlymussel *Cyrtonaias tampicoensis*: Stillhouse Hollow Reservoir, Bell County, Texas, 7 August 1996, 101 mm shell length. Specimen has dark nacre typical of Central Texas populations. Photo by R.G. Howells.

Figure 12. Historic distribution of Tampico pearlymussel *Cyrtonaias tampicoensis*. Dots represent unsuccessful introductions in the Trinity and Red rivers.

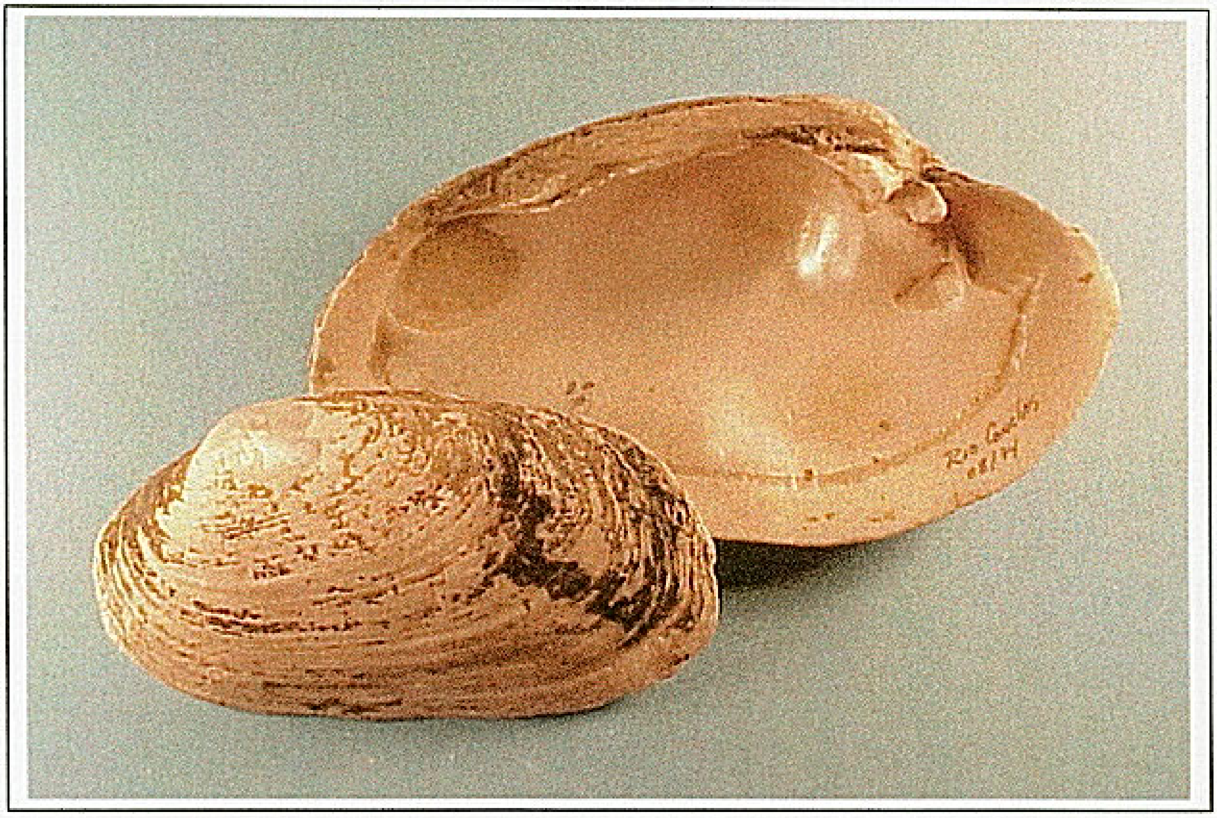


Figure 13. Conchos disk *Disconaias conchos*: Rio Conchos near Julimes, Chihuahua, Mexico, 6 August 1994, 149 and 115 mm shell length. Photo by R.G. Howells.

Figure 14. Conchos disk *Disconaias conchos*: Rio Conchos near Julimes, Chihuahua, Mexico, 6 August 1994, 75 mm shell length. Photo by R.G. Howells.

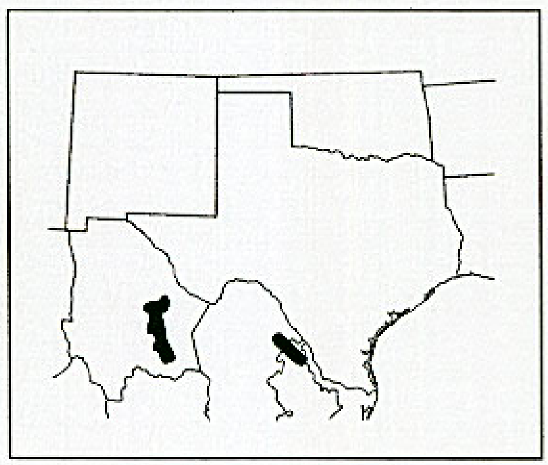


Figure 15. Approximate known range of Conchos disk *Disconaias conchos*.

Figure 16. Yellow sandshell *Lampsilis teres*: Lake Corpus Christi, Live Oak County, Texas, July 1996, 82 and 95 mm shell length. Male bottom left; female top right. Photo by R.G. Howells.

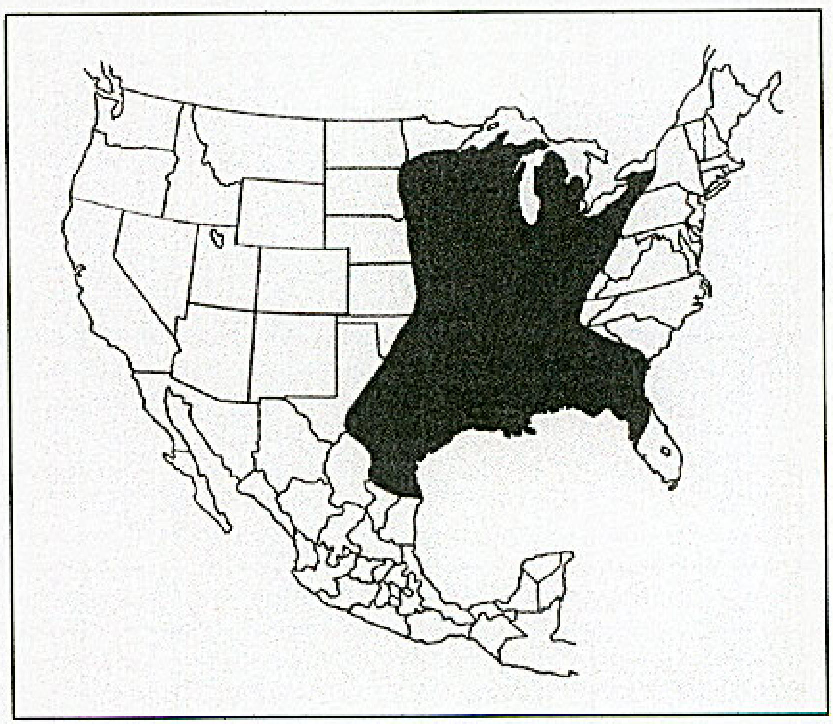


Figure 17. Historic range of yellow sandshell *Lampsilis teres*.

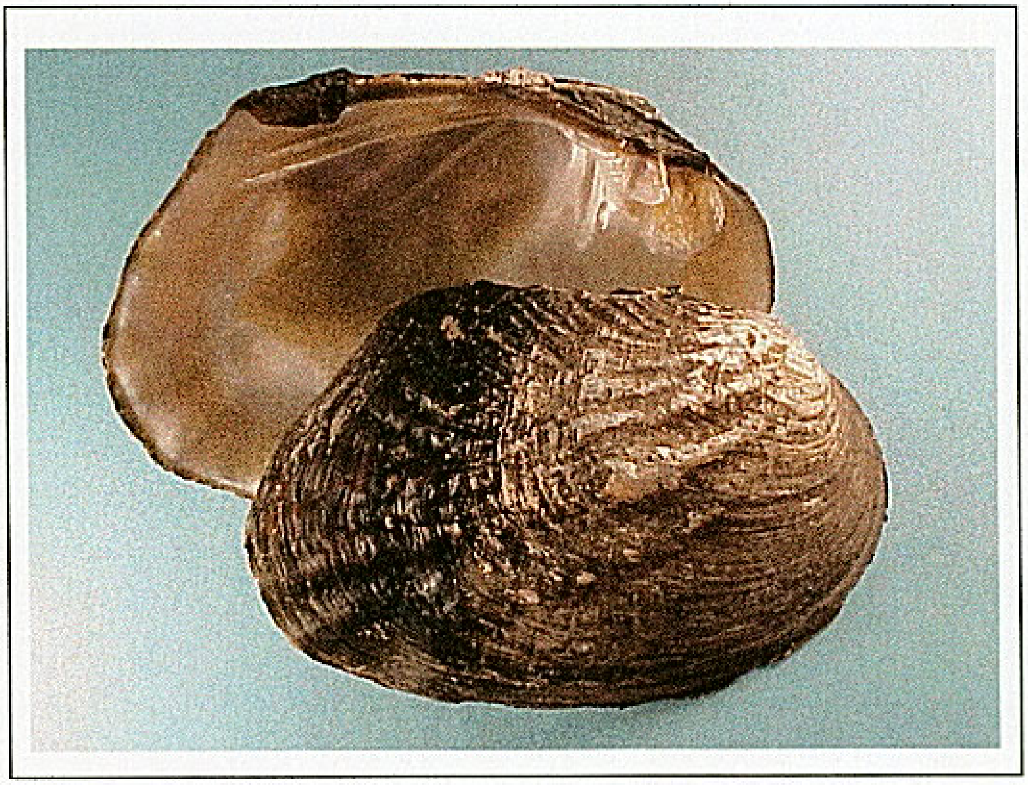


Figure 18. Washboard *Megalonaias nervosa*: Guadalupe River, Gonzales County, Texas, 22 May 1996, 153 mm shell length. Photo by R.G. Howells.

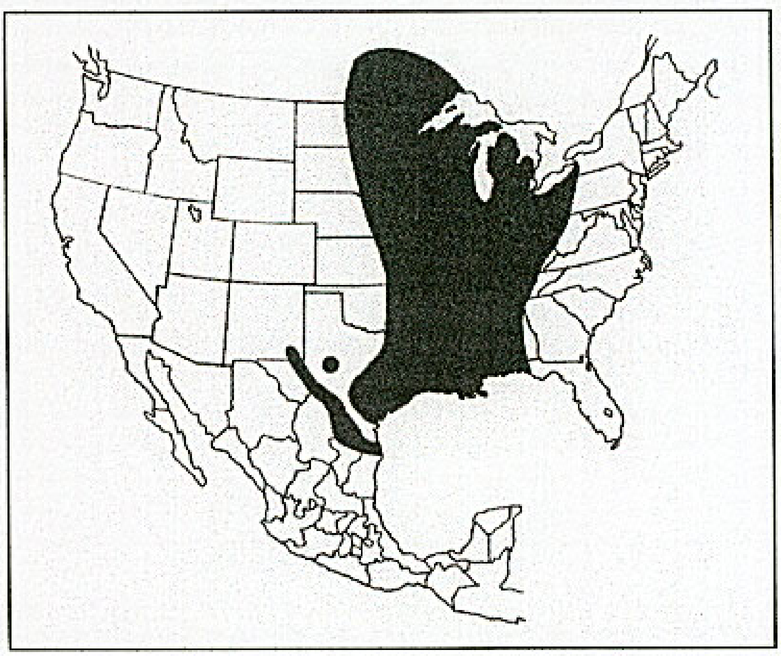


Figure 19. Historic range of washboard *Megalonaias nervosa*. Dot represents an introduction in Nasworthy Reservoir, Tom Green County, Texas.

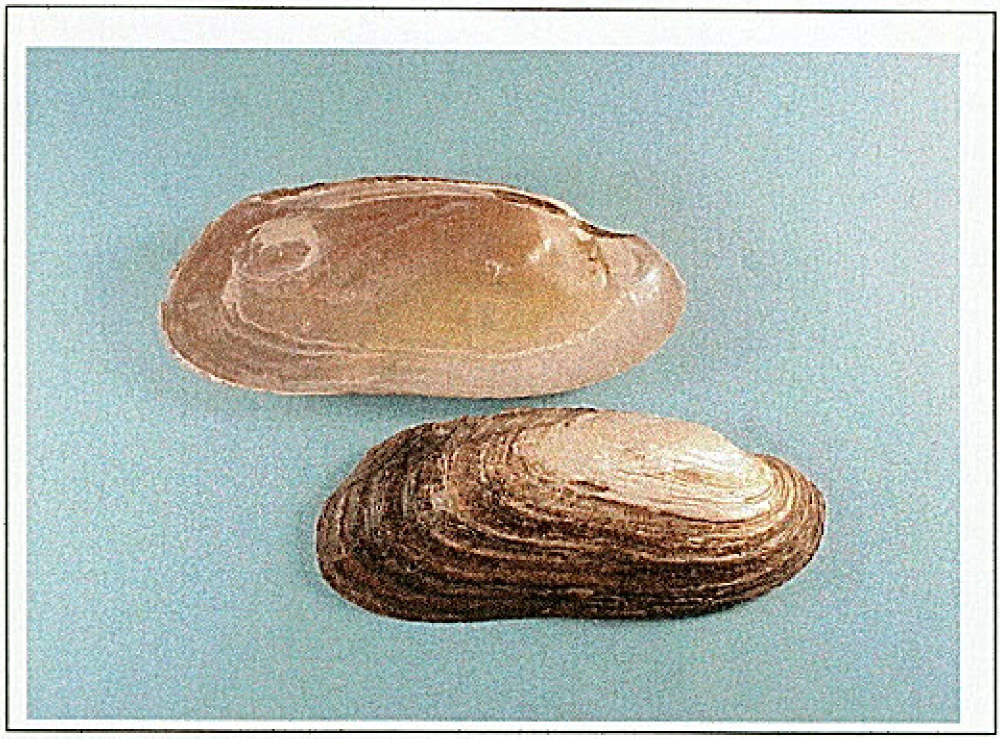


Figure 20. Texas hornshell *Popenaias popeii*: Rio Grande at the mouth of San Francisco Creek, Brewster/Terrell Counties, Texas, 6 January 1992, 108 mm shell length. Photo by R.G. Howells.

Figure 21. Historic range of Texas hornshell *Popenaias popeii*. Dots represent single-specimen collections on the South Concho River, Tom Green County, and Llano River, Llano County, Texas.

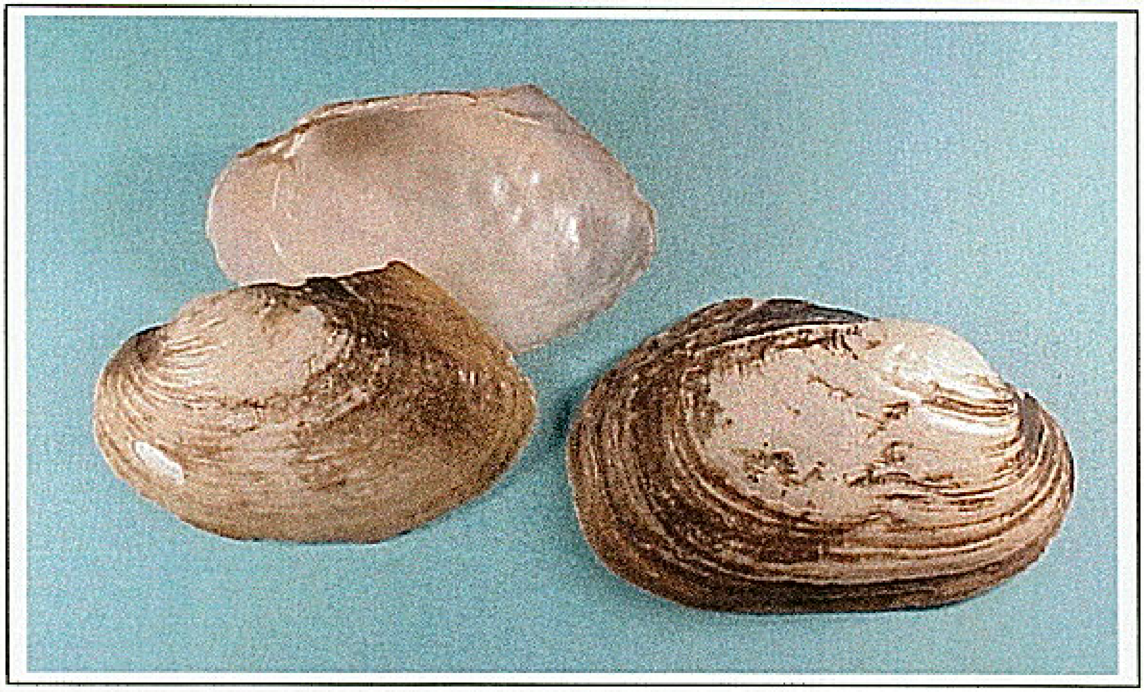


Figure 22. Salina mucket *Potamilus metnecktayi*: Rio Grande at Dryden Crossing, Terrell County, Texas, 6 January 1992, 79 and 92 mm shell length. Photo by R.G. Howells.

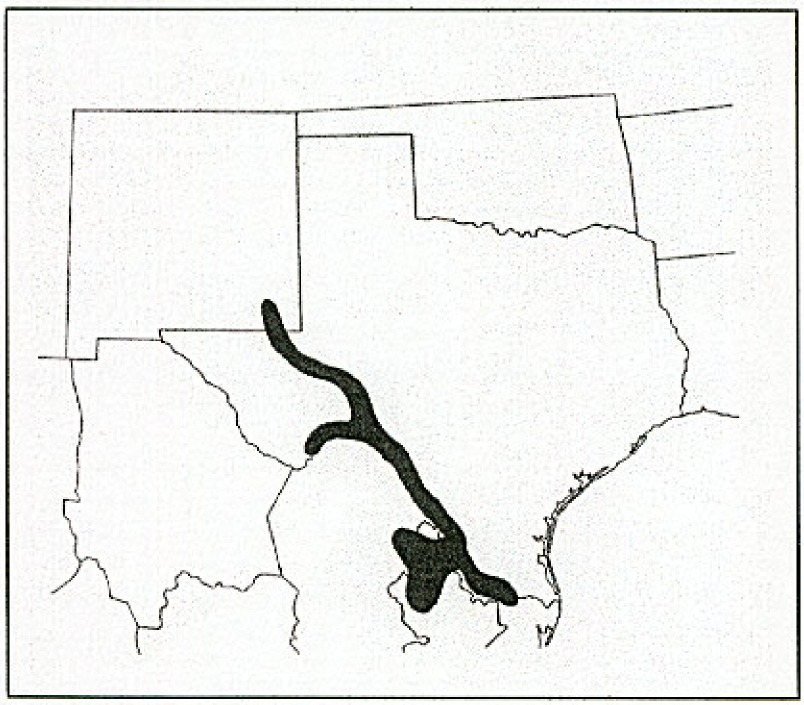


Figure 23. Historic range of Salina mucket *Potamilus metnecktayi*.

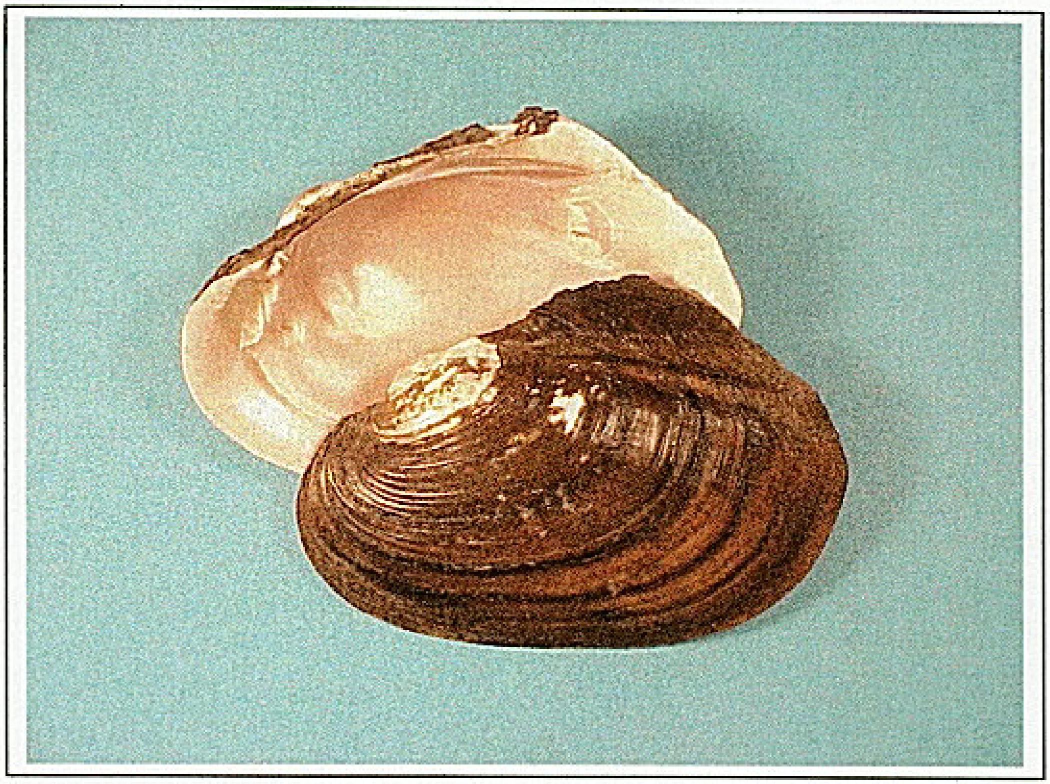


Figure 24. Bleufer *Potamilus purpuratus*: Amistad Reservoir, Val Verde County, Texas, 21 December 1994, 129 mm shell length. Nacre color in fresh specimens is more rosy-purple than in the bleached specimen shown. Photo by R.G. Howells.

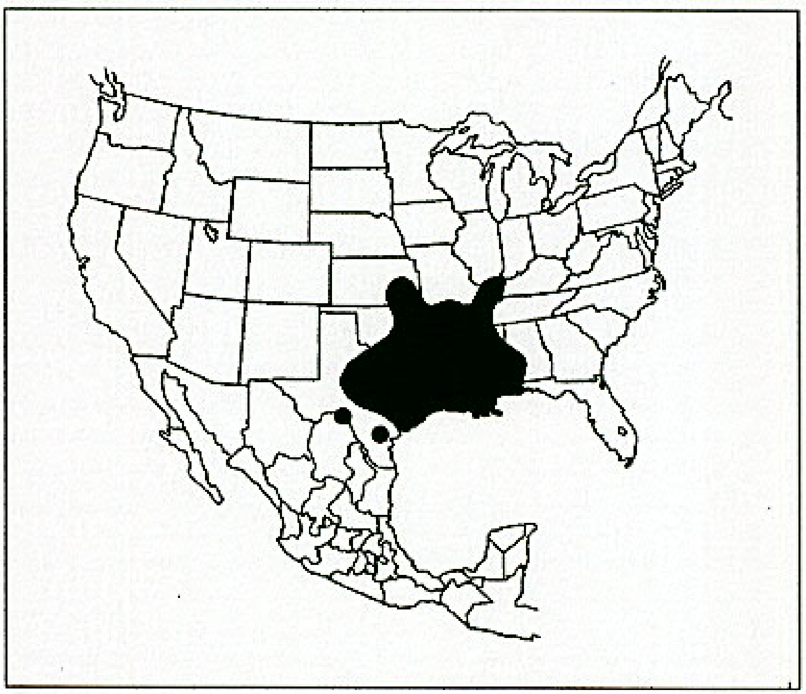


Figure 25. Historic range of bleufer *Potamilus purpuratus*. Dots represent introductions in Lake Corpus Christi, Live Oak County, and Amistad Reservoir, Val Verde County, Texas.

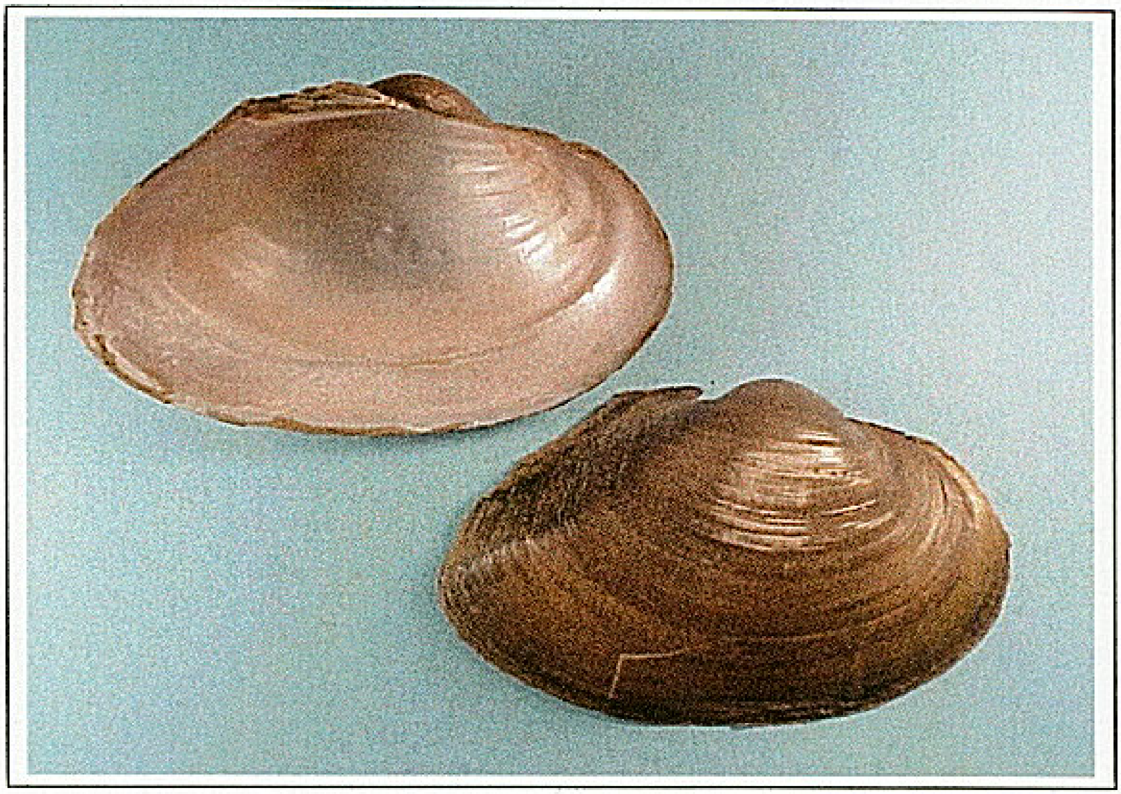


Figure 26. Giant floater *Pyganodon grandis*: Joe Pool Reservoir, Tarrant County, Texas, 16 September 1998, 125 mm shell length. Photo by R.G. Howells.

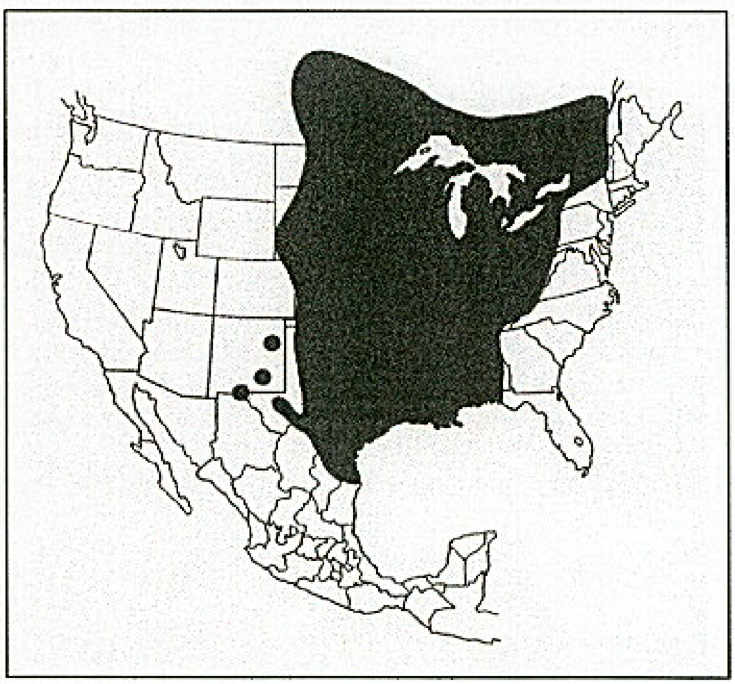


Figure 27. Historic range of giant floater *Pyganodon grandis*. Dots represent introductions in El Paso, Texas, and in the upper Pecos and Canadian rivers, New Mexico.

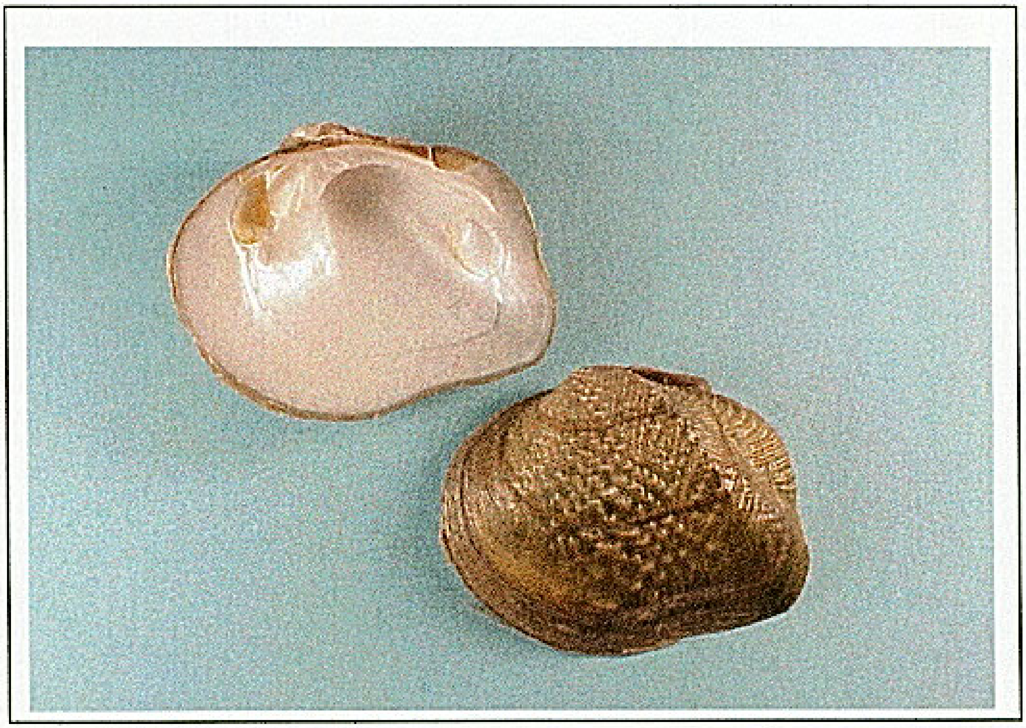
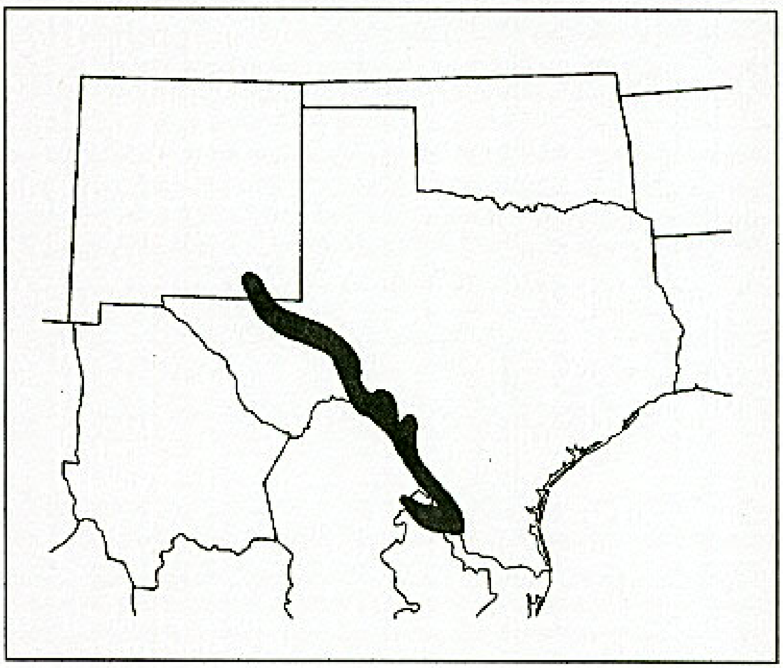


Figure 28. Southern mapleleaf *Quadrula apiculata*: Falcon Reservoir, Zapata County, Texas, 17 April 1995, 65 mm shell length. Photo by R.G. Howells.

Figure 24. Historic distribution of southern mapleleaf *Quadrula apiculata*. An introduced population in Tennessee is indicated.

Figure 30. Rio Grande monkeyface *Quadrula couchiana*: Las Moras Creek, Kinney County, Texas, May 1898, 31 mm shell length. Photo by R.G. Howells.



Figurer 31. Historic range of Rio Grande monkeyface *Quadrula couchiana*.

Figure 32. False spike *Quincuncina mitchelli*: left center – Leon River, Bell County, Texas, 6 October 1983, 61 mm shell length (sl); bottom right – Lampasas River, Bell County, Texas, 16 December 1980, 41 mm sl; top right (an elongate, gravel-bar morph) Llano River, Kimble County, Texas, 7 September 1974, 73 mm sl. Photo by R.G. Howells.

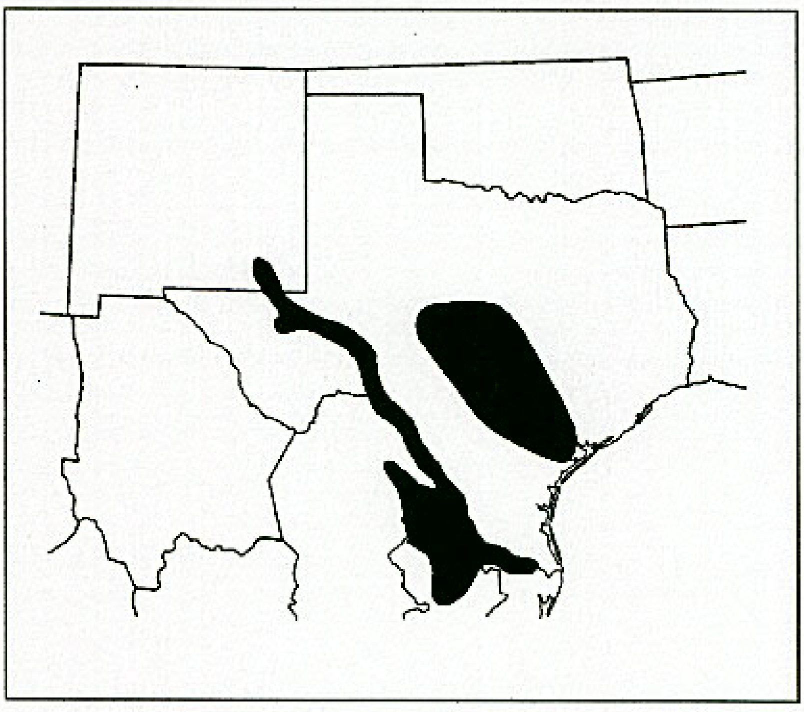


Figure 33. Historic distribution of false spike *Quincuncina mitchelli*.

Figure 34. Lilliput *Toxolasma parvus.* Falcon Reservoir, Zapata County, Texas, 17 April 1995, 27 mm shell length. Photo by R.G. Howells.

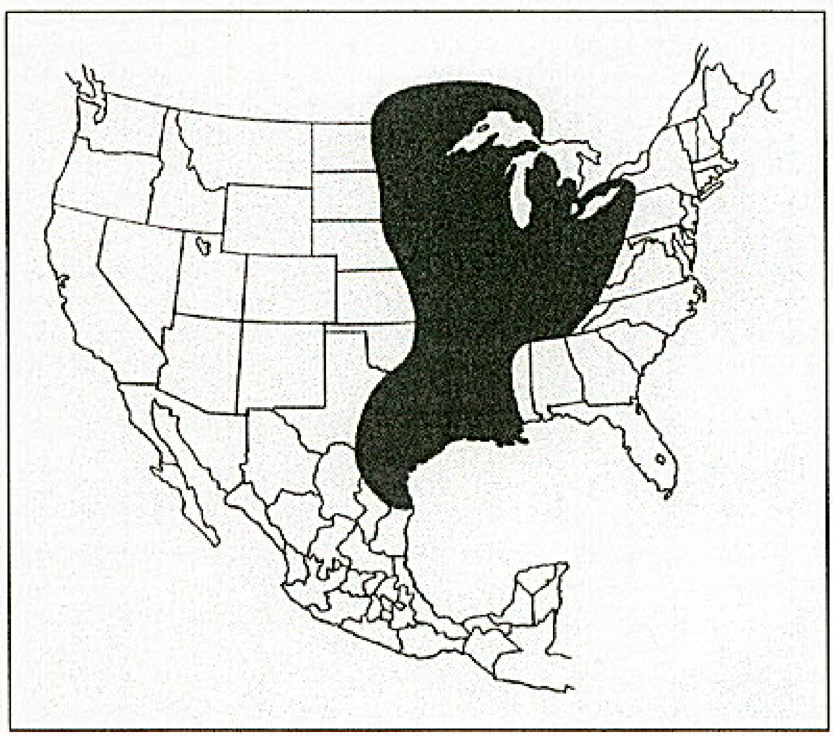


Figure 35. Historic distribution of lilliput *Toxolasma parvus.*

Figure 36. Texas lilliput *Toxolasma texasiensis*: Lake Livingston, Trinity County, Texas, 30 July 1996, 45 and 55 mm shell length; male above; female below. Photo by R.G. Howells.

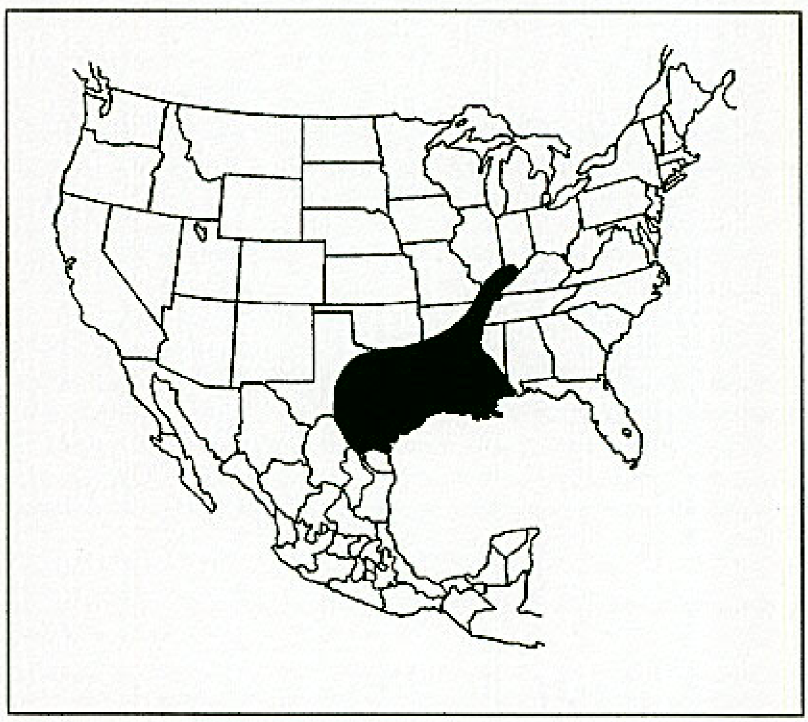


Figure 37. Historic range of Texas lilliput *Toxolasma texasiensis*.

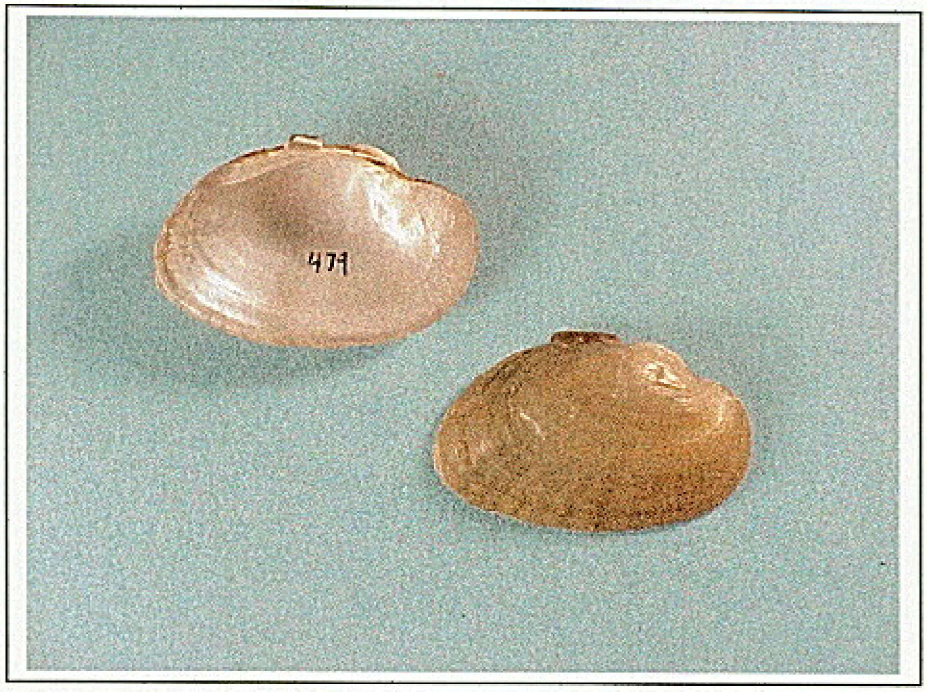


Figure 38. Mexican fawnsfoot *Truncilla cognata*: Rio Grande, Val Verde County, Texas, 10 June 1992; 36 mm shell length. Photo by R.G. Howells.

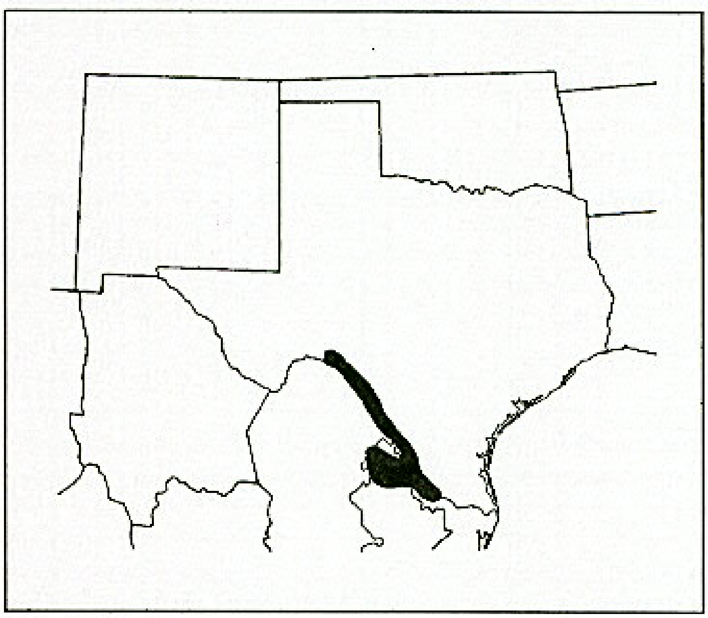


Figure 39. Historic distribution of Mexican fawnsfoot *Truncilla cognata*.

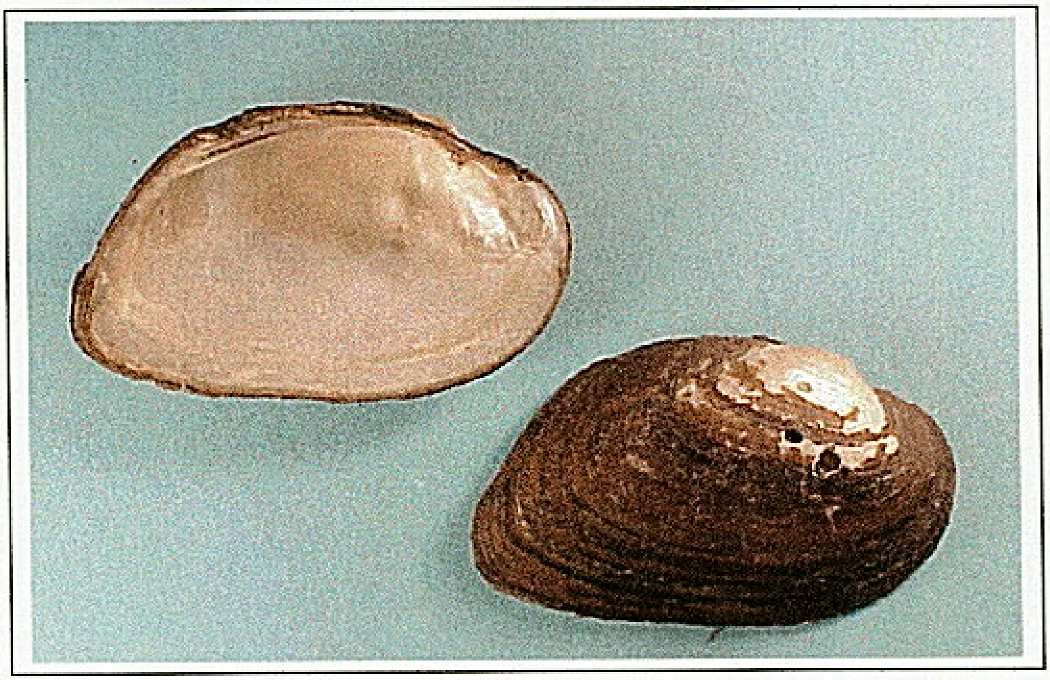


Figure 40. Pondhorn sp. *Uniomerus* sp. Agua Dulce Creek, Jim Wells County, Texas, 26 March 2001, 77 mm shell length. This specimen from the Baffin Bay Drainage immediately north of the Rio Grande is similar to material from the lower Rio Grande Valley. Photo by R.G. Howells.

Figure 41. Pondhorn *Uniomerus tetralasmus*: Boy Scout Lakes, Robertson County, Texas, May 1992, 75 mm shell length. Photo by R.G. Howells.

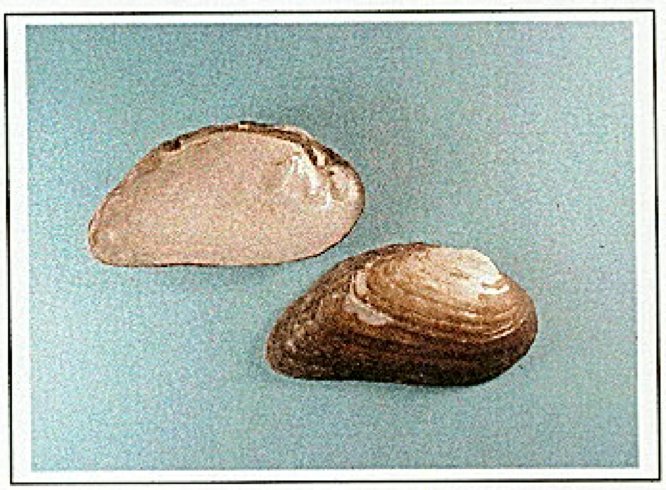


Figure 42. Tapered pondhorn *Uniomerus declivis*: Pond Creek, Falls County, Texas, 10 August 1994, 102 mm shell length. Photo by R.G. Howells.

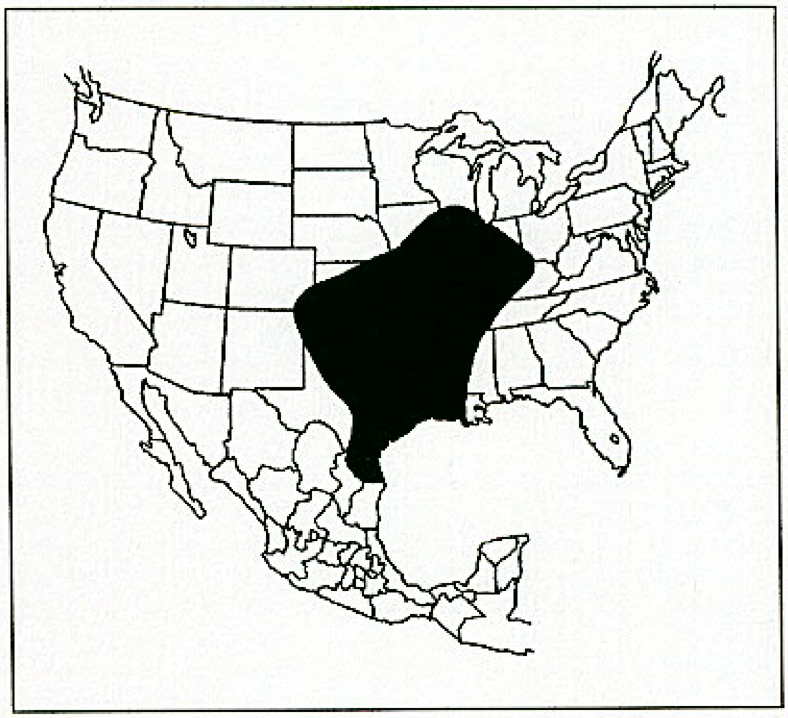


Figure 43. Historic distribution of pondhorn *Uniomerus tetralasmus*.

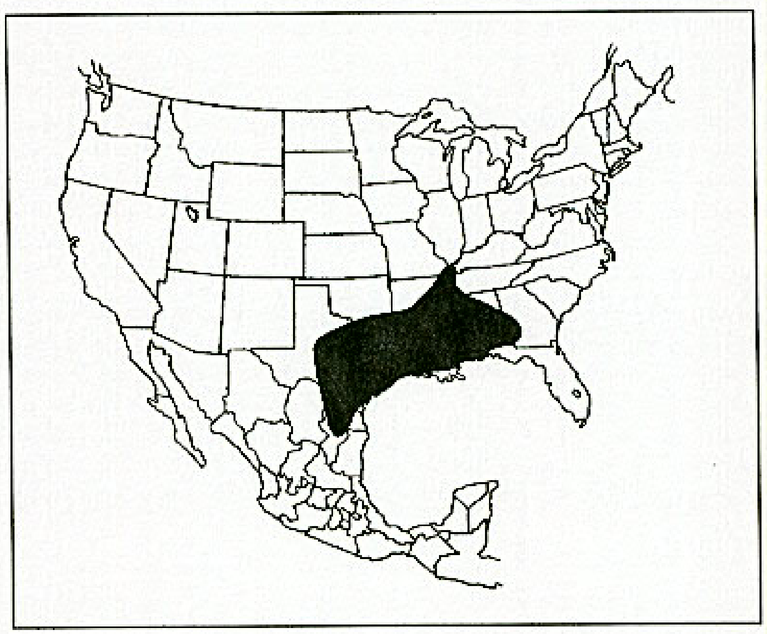


Figure 44. Historic distribution of tapered pondhorn *Uniomerus declivis*.

Figure 45. Paper pondshell *Utterbackia imbecillis*: San Miguel Creek, McMullen County, Texas, 26 July 1994, 75 mm shell length. Photo by R.G. Howells.

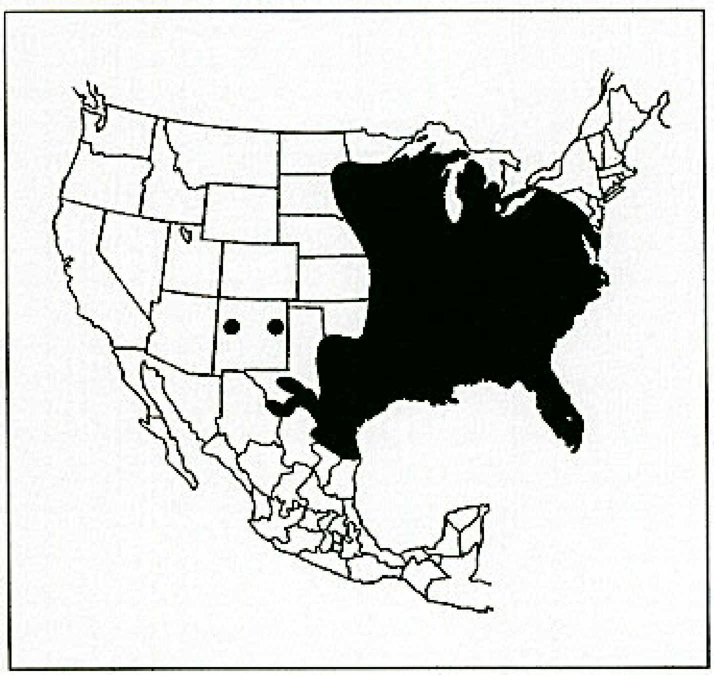


Figure 46. Historic distribution of paper pondshell *Utterbackia imbecillis*. Dots represent collections in the upper Rio Grande and Canadian River drainages, New Mexico.

Figure 47. Threeridge *Amblema plicata*: Lake Wood, Gonzales County, Texas, 17 August 1993, 95 mm shell length. Photo by R.G. Howells.

Figure 48. Round pearlshell *Glebula rotundata*: Buffalo Bayou, Harris County, Texas, 14 July 1994, 98 mm shell length. Photo by R.G. Howells.

Figure 49. Asian clam *Corbicula fluminea* – white morph: Lake Balmorhea, Reeves County, Texas, 17 August 1998, 53 mm shell length. Photo by R.G. Howells.

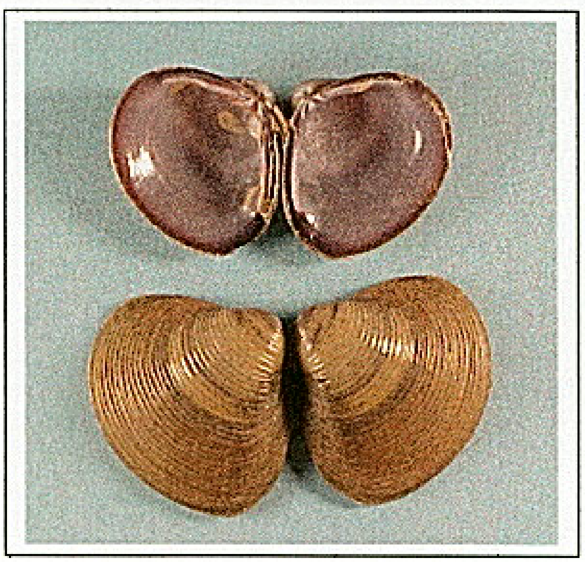


Figure 50. Asian clam *Corbicula* sp. – purple morph: San Miguel Creek, McMullen County, Texas, 27 March 1994, 27 and 32 mm shell length. Photo by R.G. Howells.

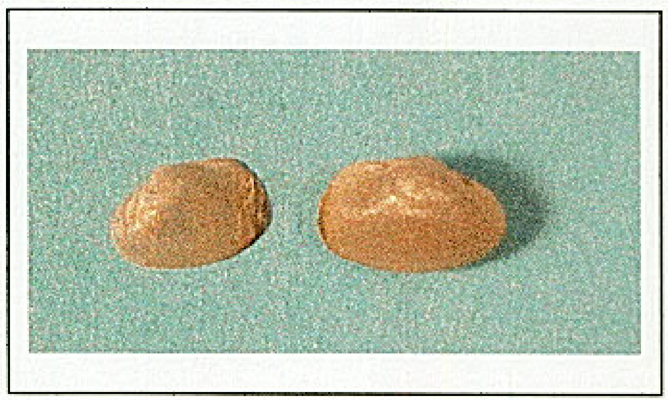


Figure 51. Fingernail clam (Sphaeriidae): Ballinger City Lake, Runnels County, Texas, August 1993, 6-7 mm shell length. Photo by R.G. Howells.

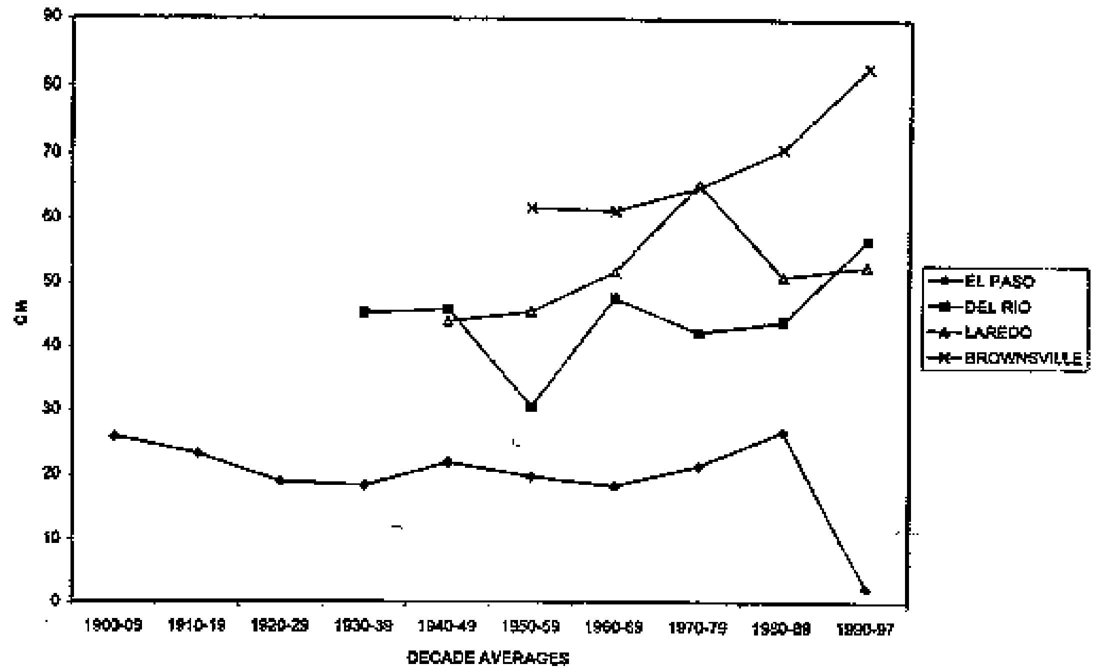


Figure 52. Mean 10-year precipitation values from selected locations on the Rio Grande, Texas. Data was obtained from the Texas Office of State Climatologist, College Station, Texas. Values were created by averaging all available data for each site for each decade or partial decade.

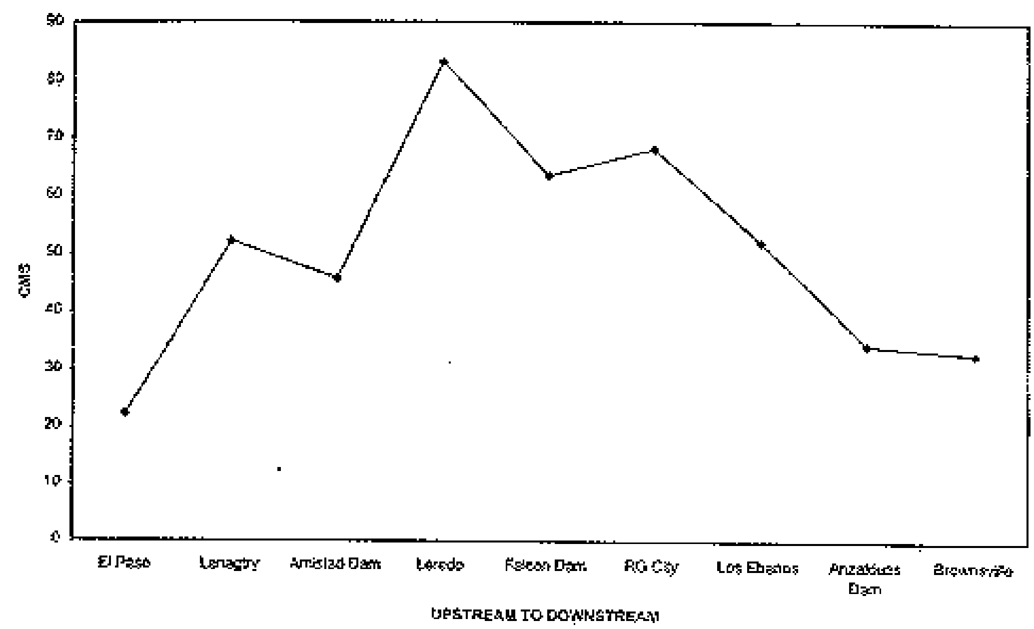


Figure 53. Mean flow rate (cubic meters/second, CMS) at selected locations on the Rio Grande, Texas, calculated from data presented in U.S. Geological Survey reports for water years 1968 (USGS 1968), 1975 (USGS 1975), 1986 (Buckner et al. 1986), 1996 (Gandara et al. 1996), 1999 (Gandara et al. 1999), and 2000 (Gandara et al. 2001). Values for Amistad, Falcon, and Anzaludas dams were actually taken in the Rio Grande downstream of those structures.

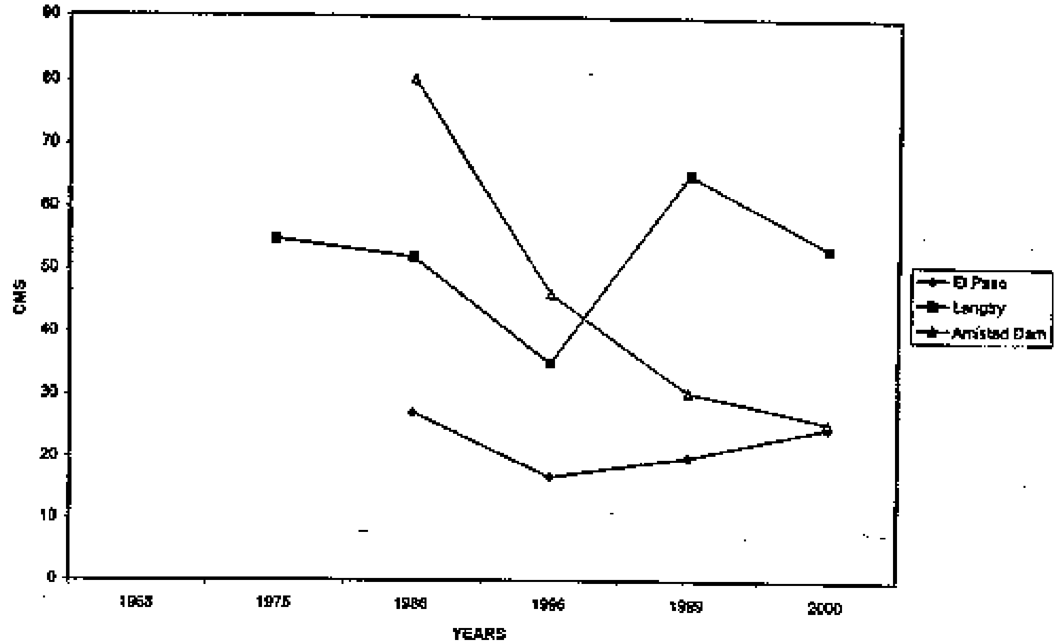


Figure 54. Mean flow rates (cubic meters/second, CMS) at selected sites on the upper Rio Grande, Texas, calculated from data presented in U.S. Geological Survey reports for water years 1975 (USGS 1975), 1986 (Buckner et al. 1986), 1996 (Gandara et al. 1996), 1999 (Gandara et al. 1999), and 2000 (Gandara et al. 2001). Values for Amistad Dam were actually taken in the Rio Grande downstream of that structure.

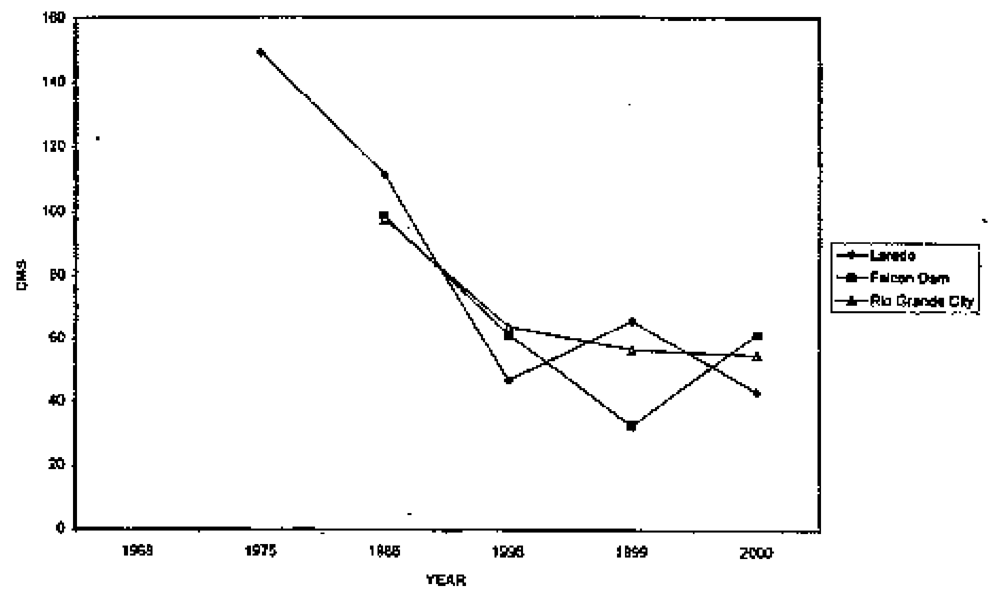


Figure 55. Mean flow rates (cubic meters/second, CMS) at selected sites on the central Rio Grande, Texas, calculated from data presented in U.S. Geological Survey reports for water years 1975 (USGS 1975), 1986 (Buckner et al. 1986), 1996 (Gandara et al. 1996), 1999 (Gandara et al. 1999), and 2000 (Gandara et al. 2001). Values for Falcon Dam were actually taken in the Rio Grande downstream of that structure.

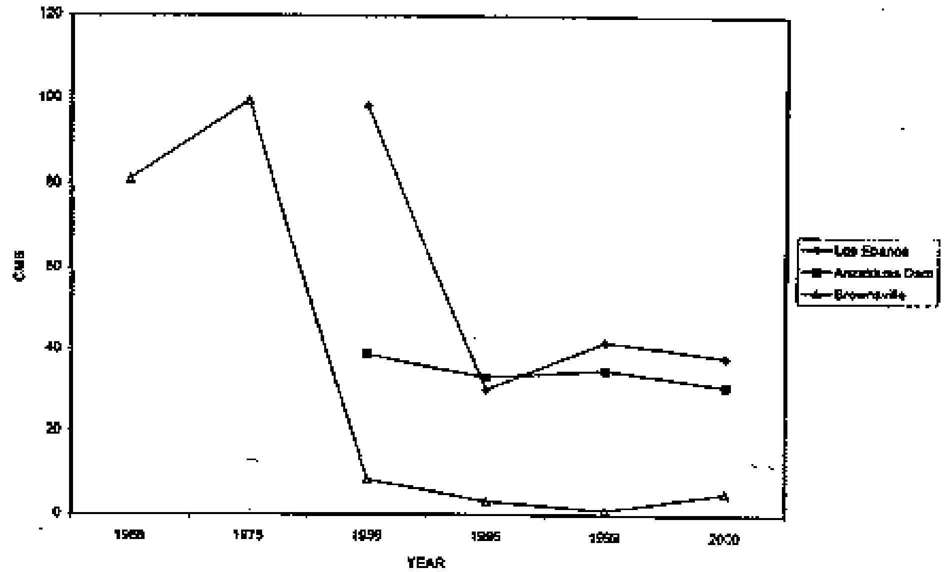


Figure 56 Mean flow rates (cubic meters/second, CMS) at selected sites on the central Rio Grande, Texas, calculated from data presented in U.S. Geological Survey reports for water years 1968 (USGS 1968), 1975 (USGS 1975), 1986 (Buckner et al. 1986), 1996 (Gandara et al. 1996), 1999 (Gandara et al. 1999), and 2000 (Gandara et al. 2001).

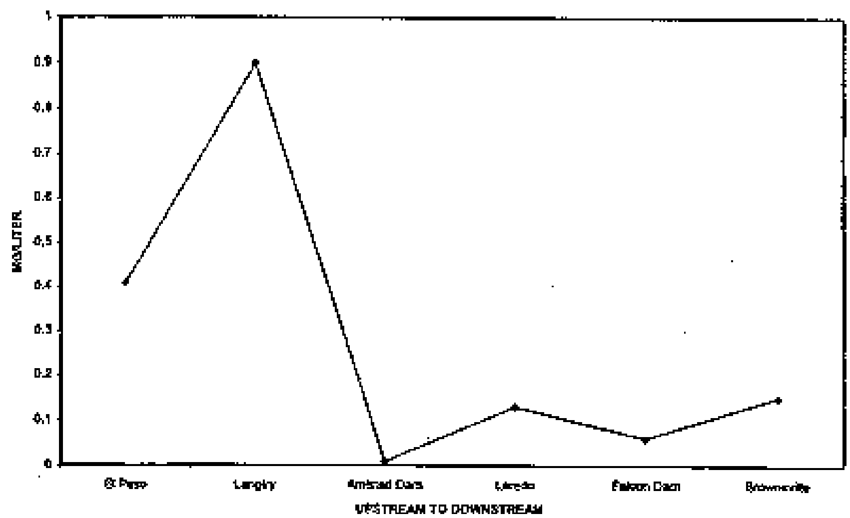


Figure 57. Mean total phosphorus levels (mg/L) at selected sites on the Rio Grande, Texas, calculated from data presented in U.S. Geological Survey reports for water years 1968 (USGS 1968), 1975 (USGS 1975), 1986 (Buckner et al. 1986), 1996 (Gandara et al. 1996), 1999 (Gandara et al. 1999), and 2000 (Gandara et al. 2001). Values for Amistad and Falcon dams were actually taken in the Rio Grande downstream of those structures.

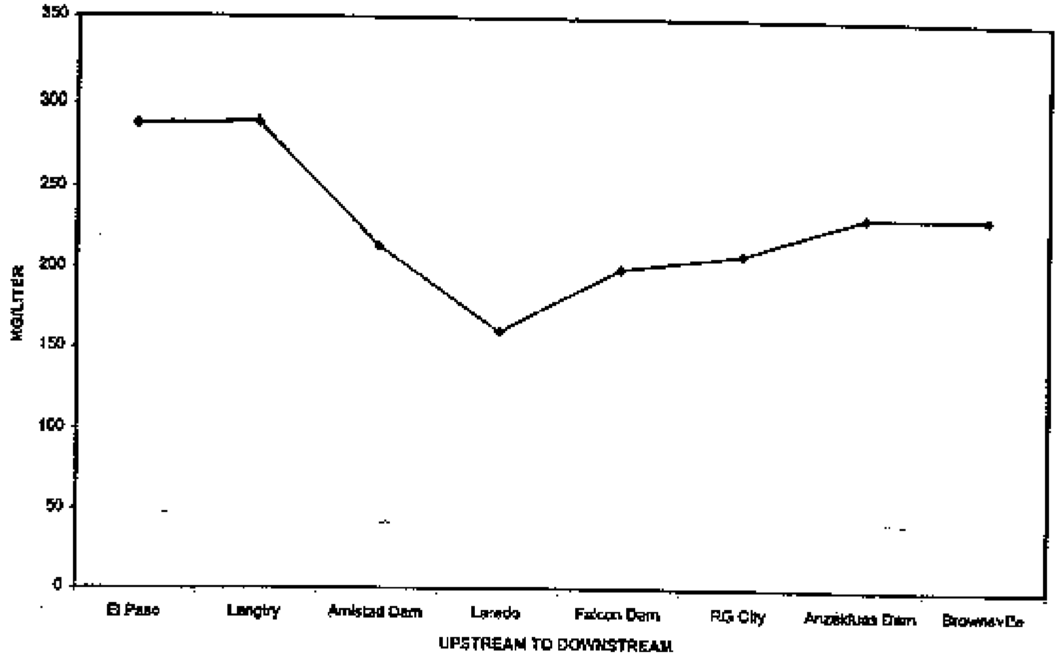


Figure 58. Mean sulfate levels (mg/L) at selected sites on the Rio Grande, Texas, calculated from data presented in U.S. Geological Survey reports for water years 1968 (USGS 1968), 1975 (USGS 1975), 1986 (Buckner et al. 1986), 1996 (Gandara et al. 1996), 1999 (Gandara et al. 1999), and 2000 (Gandara et al. 2001). Values for Amistad, Falcon, and Anzalduas dams were actually taken in the Rio Grande downstream of those structure: RG City = Rio Grande City.

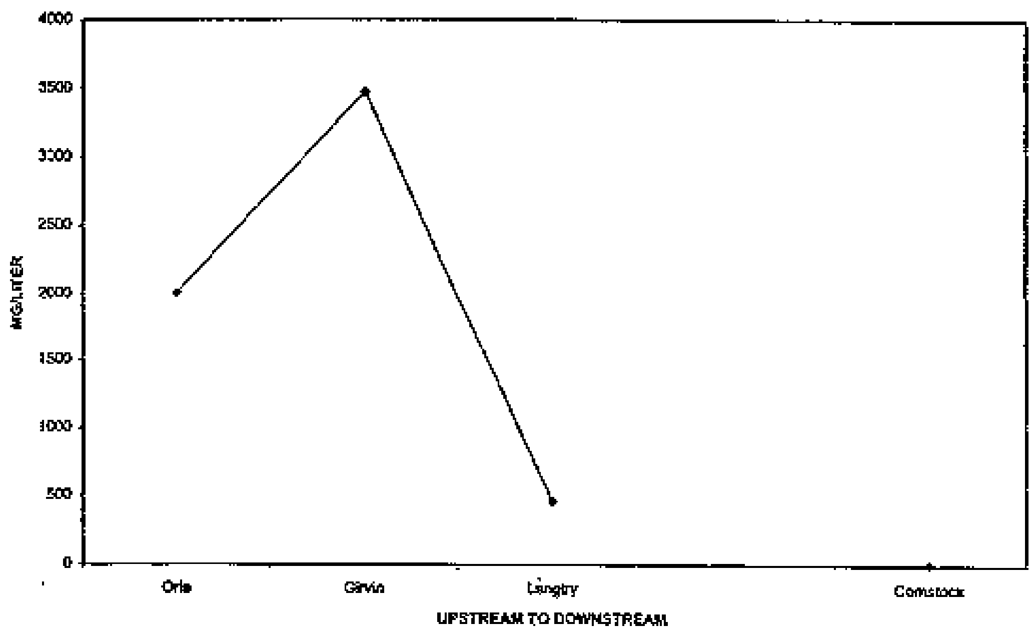


Figure 59. Mean sulfate levels (mg/L) at Orla, Girvin, and near Langtry on the Pecos River (1968, 1975, 1986, 1996, 1999, 2000) and near Comstock on the Devils River (1986, 1996), Texas, calculated from data presented in U.S. Geological Survey reports for water years 1968 (USGS 1968), 1975 (USGS 1975), 1986 (Buckner et al.1986), 1996 (Gandara et al. 1996), 1999 (Gandara et al. 1999), and 2000 (Gandara et al. 2001).

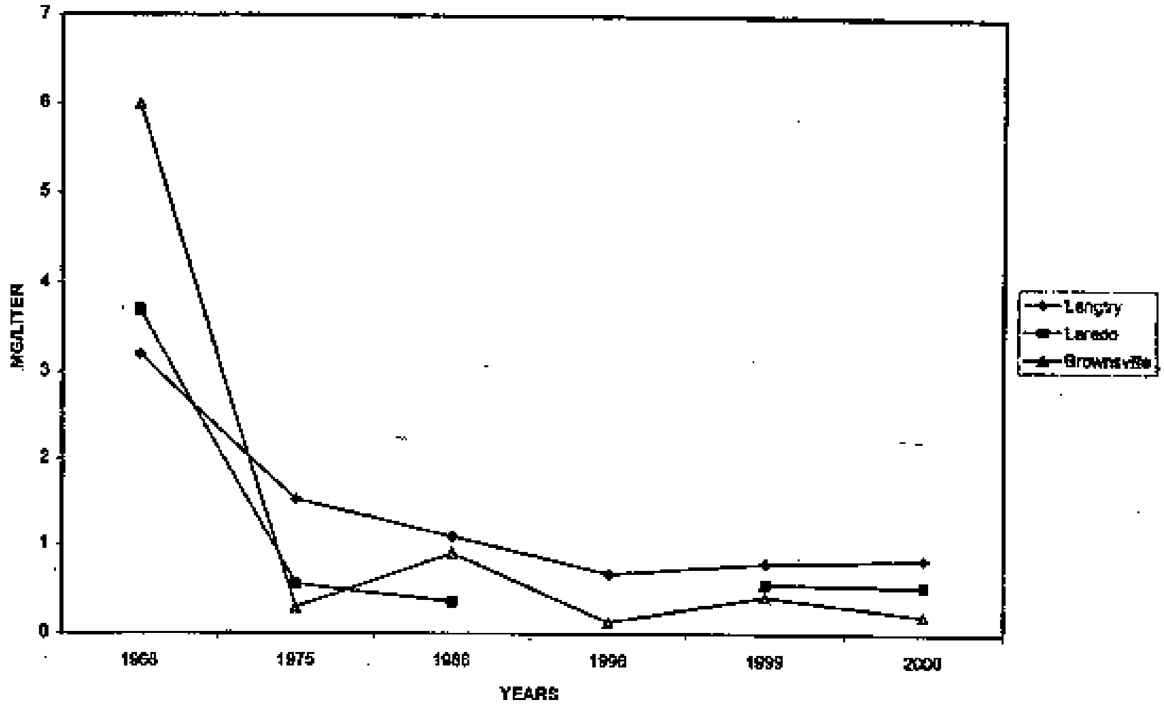


Figure 60. Mean nitrate levels (mg/L) near Langtry and at Laredo and Brownsville, Rio Grande, Texas, calculated from data presented in U.S. Geological Survey reports for water years 1968 (USGS 1968), 1975 (USGS 1975), 1986 (Buckner et al. 1986), 1996 (Gandara et al. 1996), 1999 (Gandara et al. 1999), and 2000 (Gandara et al. 2001).

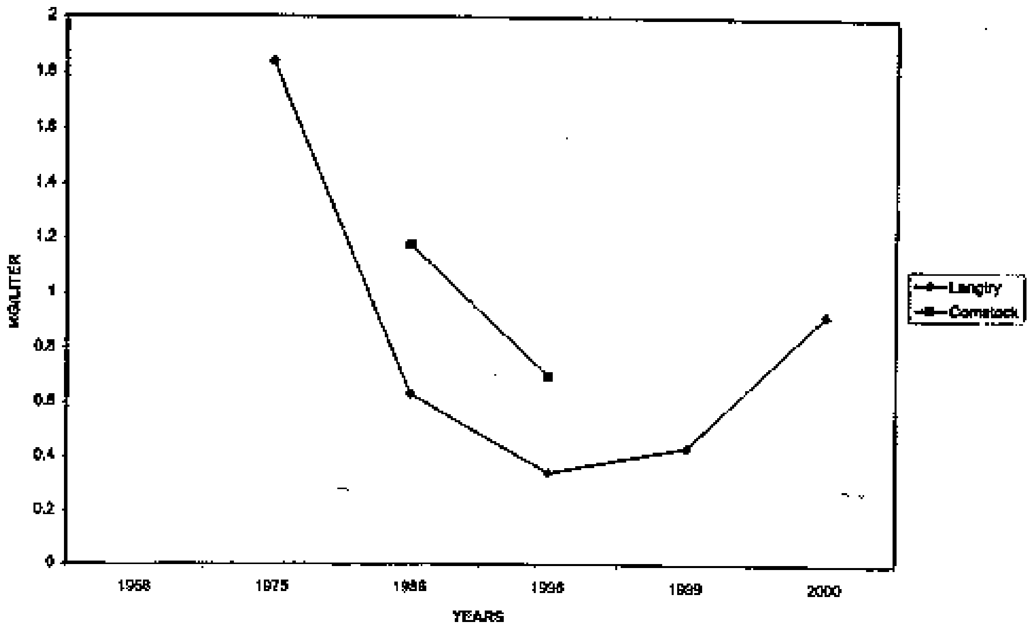


Figure 61. Mean nitrate levels (mg/L) in the Pecos River near Langtry and the Devils River near Comstock, Texas, calculated from data presented in U.S. Geological Survey reports for water years 1975 (USGS 1975), 1986 (Buckner et al. 1986), 1996 (Gandara et al. 1996), 1999 (Gandara et al. 1999), and 2000 (Gandara et al. 2001).

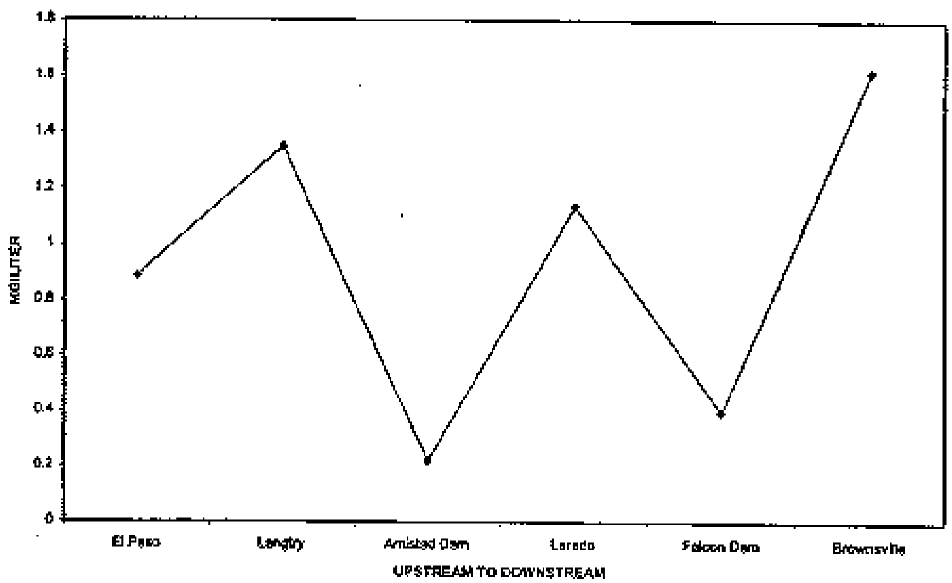


Figure 62. Mean nitrate levels (mg/L) at selected sites on the Rio Grande, Texas, calculated from data presented in U.S. Geological Survey reports for water years 1968 (USGS 1968), 1975 (USGS 1975), 1986 (Buckner et al. 1986), 1996 (Gandara et al. 1996), 1999 (Gandara et al. 1999), and 2000 (Gandara et al. 2001). Values for Amistad, Falcon, and Anzalduas dams were actually taken in the Rio Grande downstream of those structure: RG City = Río Grande City.

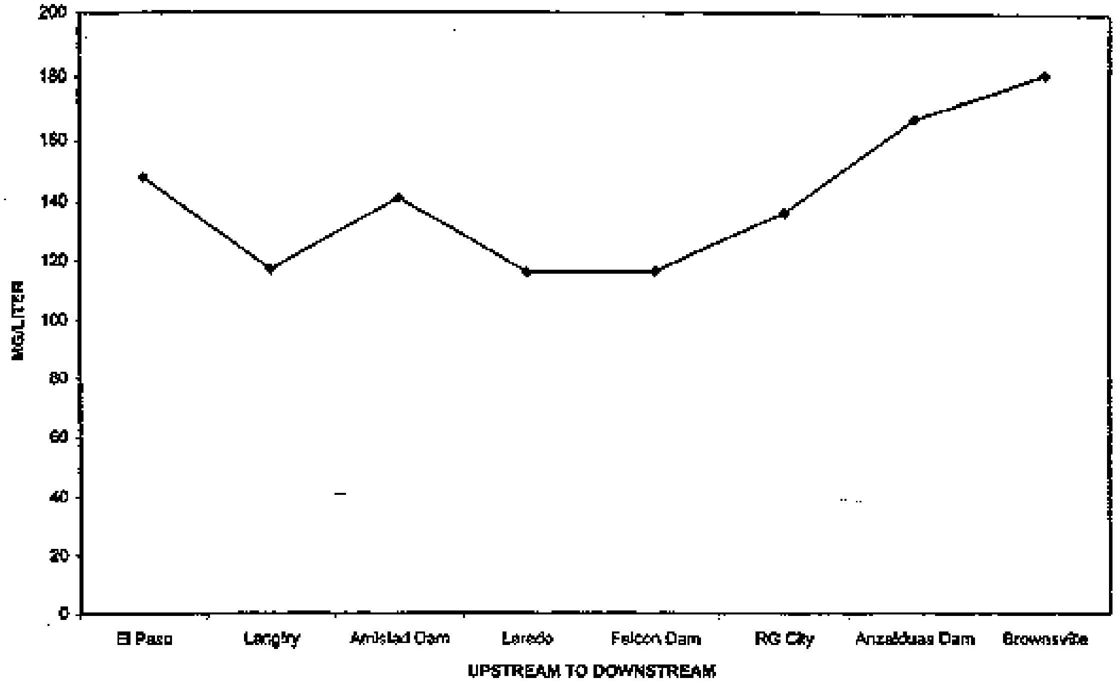


Figure 63. Mean chloride levels (mg/L) at selected sites on the Rio Grande, Texas, calculated from data presented in U.S. Geological Survey reports for water years 1968 (USGS 1968), 1975 (USGS 1975), 1986 (Buckner et al. 1986), 1996 (Gandara et al. 1996), 1999 (Gandara et al. 1999), and 2000 (Gandara et al. 2001). Values for Amistad, Falcon, and Anzalduas dams were actually taken in the Rio Grande downstream of those structures: RG City = Rio Grande City.

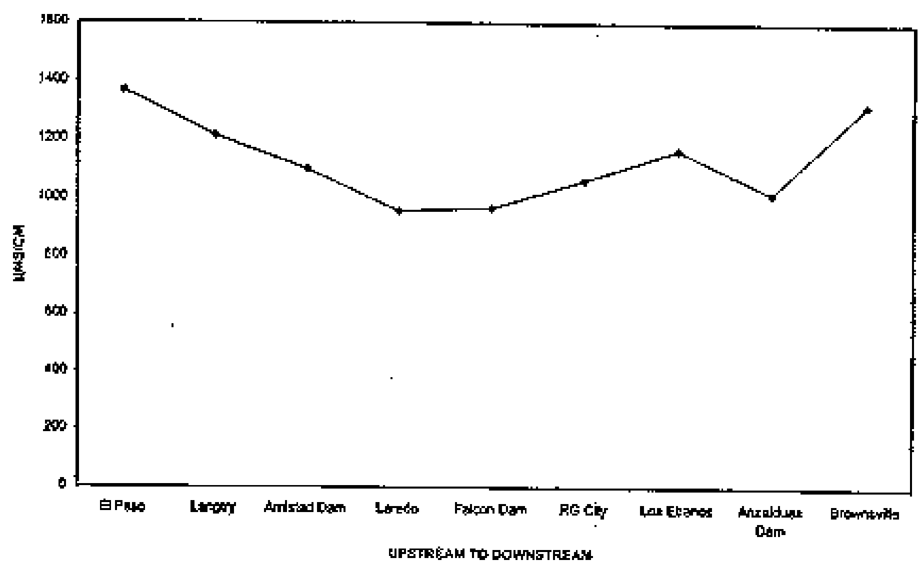


Figure 64. Mean conductivity levels (µS/cm) at selected sites on the Rio Grande, Texas, calculated from data presented in U.S. Geological Survey reports for water years 1968 (USGS 1968), 1975 (USGS 1975), 1986 (Buckner et al. 1986), 1996 (Gandara et al. 1996), 1999 (Gandara et al. 1999), and 2000 (Gandara et al. 2001). Values for Amistad, Falcon, and Anzalduas dams were actually taken in the Rio Grande downstream of those structures: RG City = Rio Grande City.

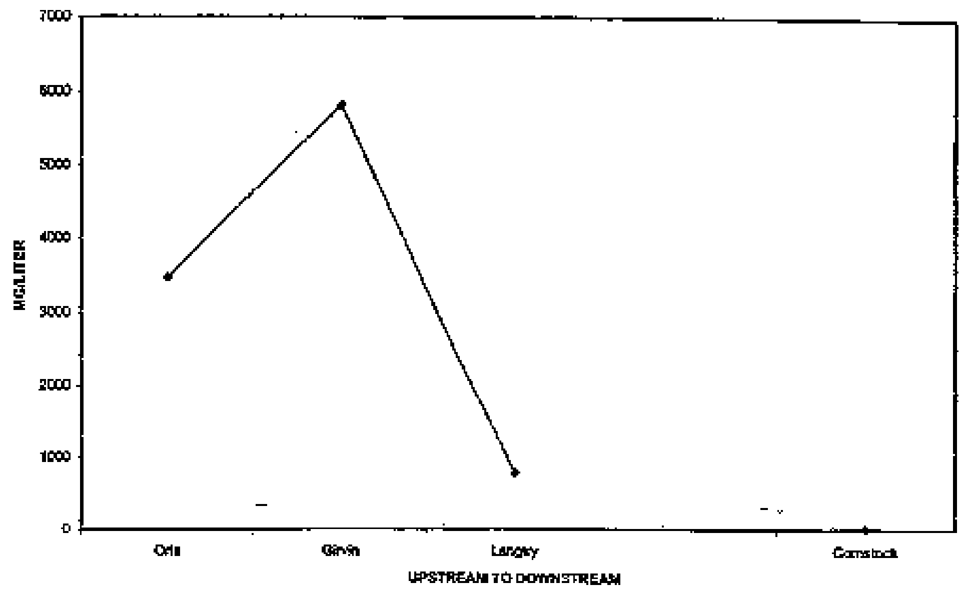


Figure 65. Mean chloride levels (mg/L) at Orla, Girvin, and near Langtry on the Pecos River (1968, 1975, 1986, 1996, 1999, 2000) and near Comstock on the Devils River (1986, 1996), Texas, calculated from data presented in U.S. Geological Survey reports for water years 1968 (USGS 1968), 1975 (USGS 1975), 1986 (Buckner et al. 1986), 1996 (Gandara et al. 1996), 1999 (Gandara et al. 1999), and 2000 (Gandara et al. 2001).

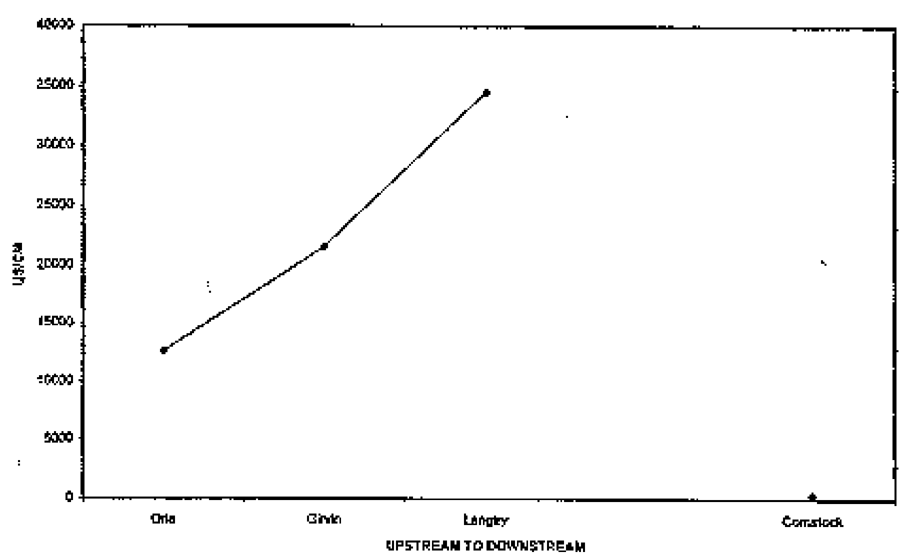


Figure 66. Mean conductivity levels (μS/cm) at Orla, Girvin, and near Langtry on the Pecos River (1968, 1975, 1986, 1996, 1999, 2000) and near Comstock on the Devils River (1986, 1996, 2000), Texas, calculated from data presented in U.S. Geological Survey reports for water years 1968 (USGS 1968), 1975 (USGS 1975), 1986 (Buckner et al. 1986), 1996 (Gandara et al. 1996), 1999 (Gandara et al. 1999), and 2000 (Gandara et al. 2001).

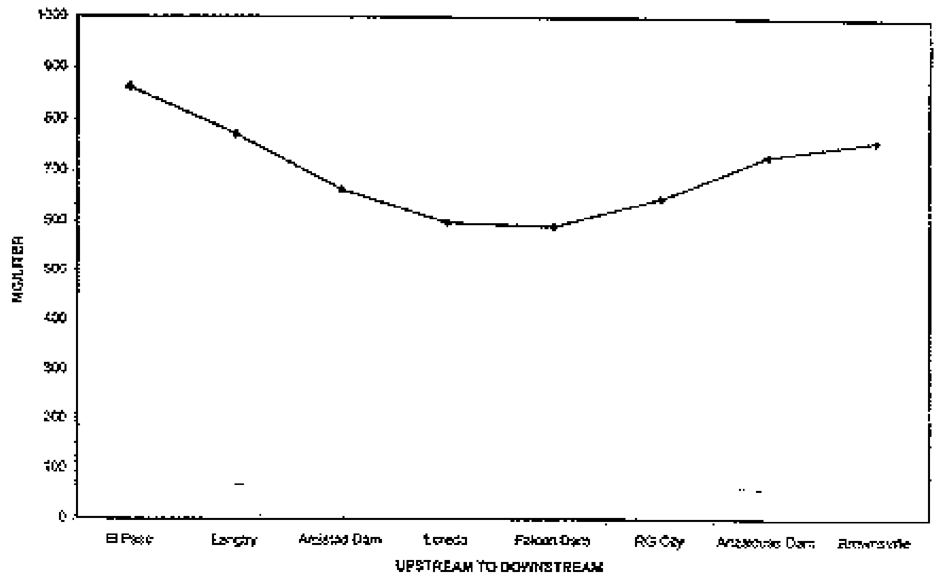


Figure 67. Mean total dissolved solids (mg/L) at selected sites on the Rio Grande, Texas, calculated from data presented in U.S. Geological Survey reports for water years 1968 (USGS 1968), 1975 (USGS 1975), 1986 (Buckner et al. 1986), 1996 (Gandara et al. 1996), 1999 (Gandara et al. 1999), and 2000 (Gandara et al. 2001). Values for Amistad, Falcon, and Anzalduas dams were actually taken in the Rio Grande downstream of those structures: RG City = Rio Grande City.

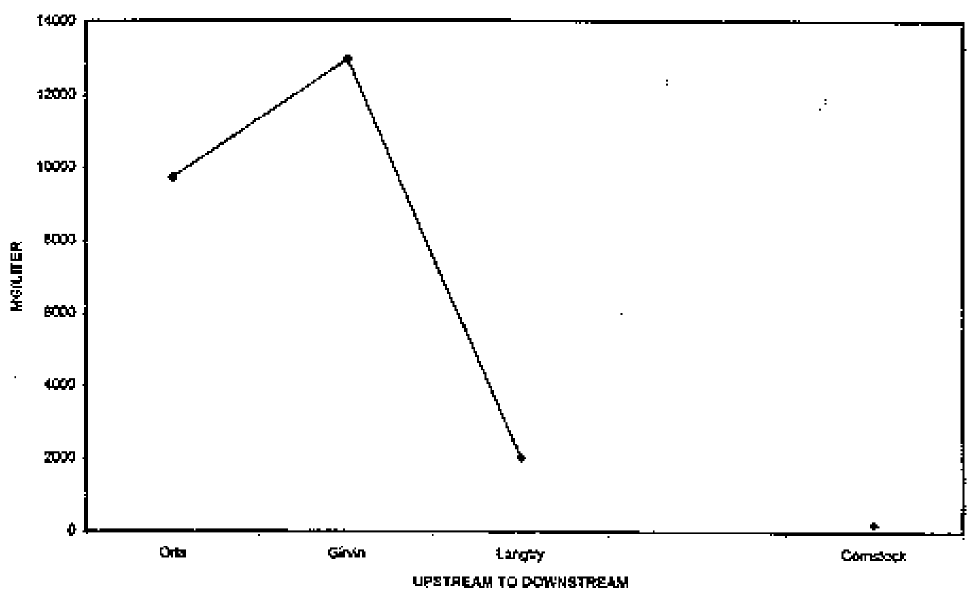


Figure 68. Mean total dissolved solids (mg/L) at Orla, Girvin, and near Langtry on the Pecos River (1975, 1986, 1996, 1999, 2000) and near Comstock on the Devils River (1986, 1996), Texas, calculated from data presented in U.S. Geological Survey reports for water years 1975 (USGS 1975), 1986 (Buckner et al. 1986), 1996 (Gandara et al. 1996), 1999 (Gandara et al. 1999), and 2000 (Gandara et al. 2001).

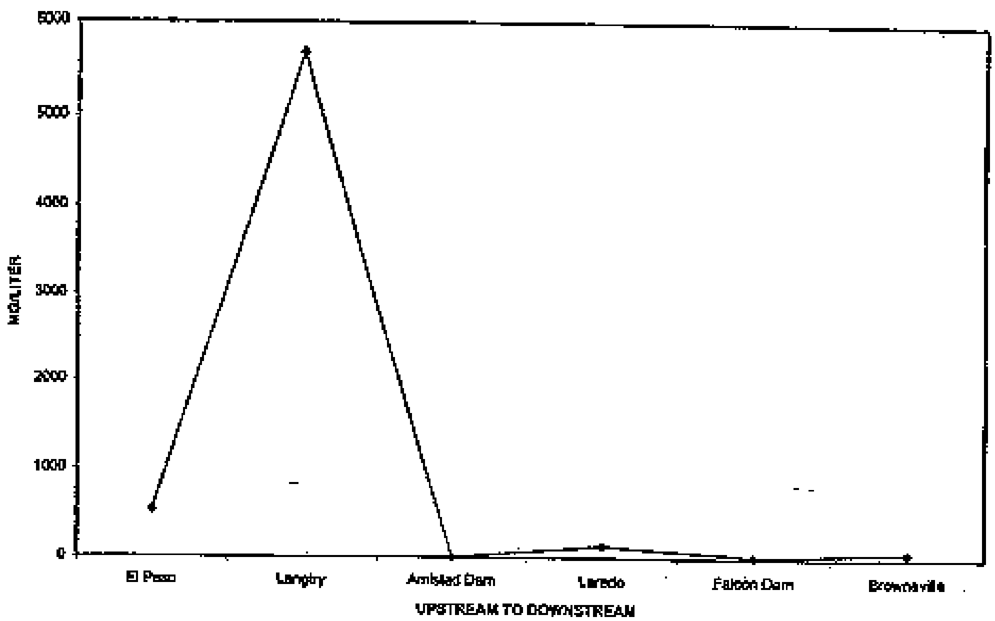


Figure 69. Mean suspended sediment levels (mg/L) at selected sites on the Rio Grande, Texas, calculated from data presented in U.S. Geological Survey reports for water years 1986 (Buckner et al. 1986), 1996 (Gandara et al. 1996), 1999 (Gandara et al. 1999), and 2000 (Gandara et al. 2001). Values for Amistad and Falcon dams were actually taken in the Rio Grande downstream of those structures.

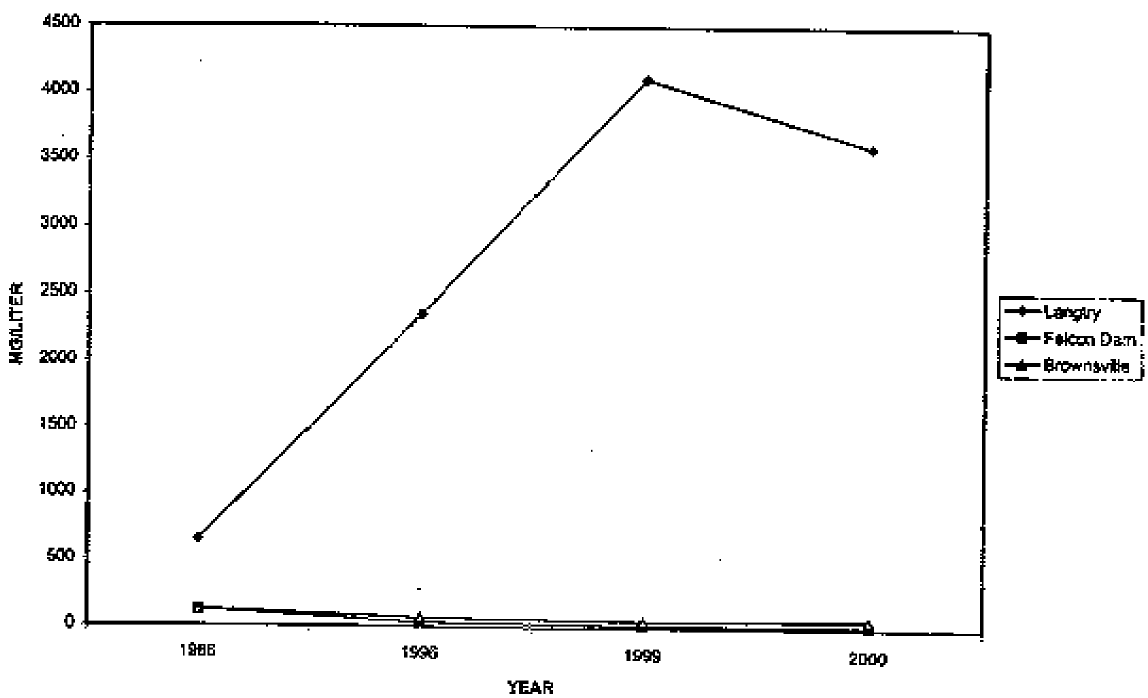


Figure 70. Mean suspended sediment levels (mg/L) in the Rio Grande near Langtry, Laredo, and Brownsville, Texas, calculated from data presented in U.S. Geological Survey reports for water years 1986 (Buckner et al. 1986), 1996 (Gandara et al. 1996), 1999 (Gandara et al. 1999), and 2000 (Gandara et al. 2001).

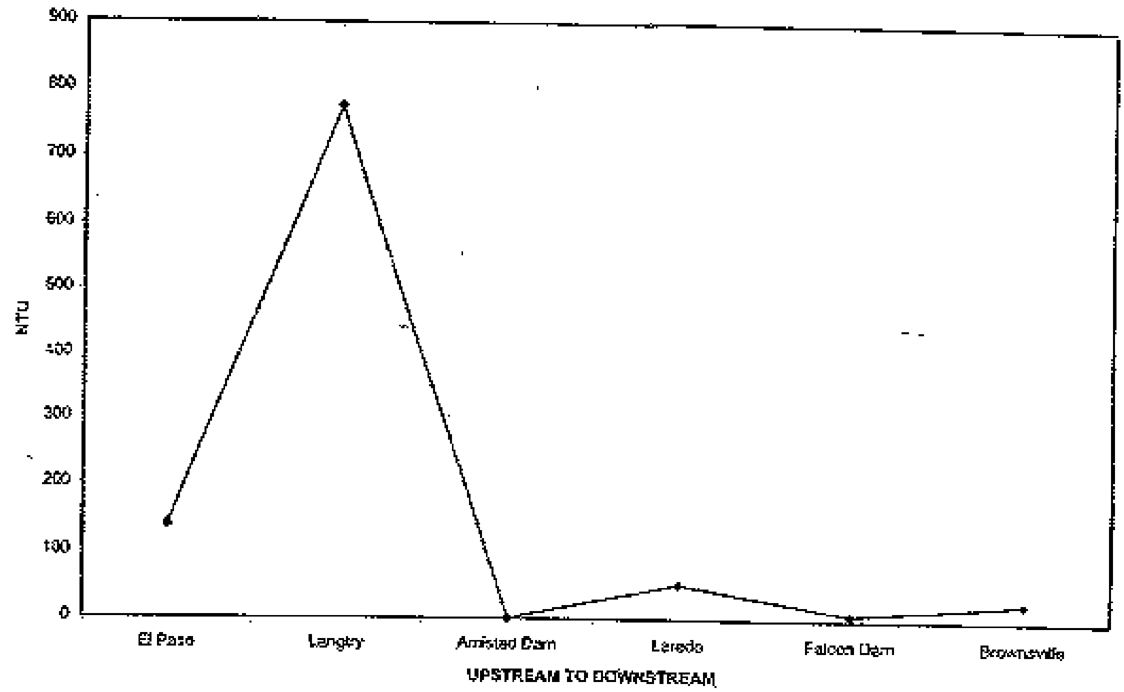


Figure 71. Mean turbidity levels (nephelometric turbidity units, NTU) at selected sites on the Rio Grande, Texas, calculated from data presented in U.S. Geological Survey reports for water years 1975 (USGS 1975), 1986 (Buckner et al. 1986), 1996 (Gandara et al. 1996), 1999 (Gandara et al. 1999), and 2000 (Gandara et al. 2001). Values for Amistad and Falcon dams were actually taken in the Rio Grande downstream of those structures.