DISTRIBUTIONAL SURVEYS OF FRESHWATER BIVALVES IN TEXAS: PROGRESS REPORT FOR 1993

by

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ABSTRACT

During 1993, over 2,500 unionid specimens were obtained. A total of 162 locations around the state were either directly examined or actively sampled, or were represented by specimens sent to Heart of the Hills Research Station by outside individuals or other agencies for identification. A total of 36 species (about 71% of those reported in Texas) was found during these surveys.

Living specimens or recently-dead shells (indicating mussels may still persist in the area) were found at 42% of the sites examined. However, many such sites contained few mussels and little likelihood of large, healthy populations. Only long-dead or subfossil shells were found at about 22% of the sites examined and no evidence of unionids was found at approximately 36% of sites.

Based on previously reported survey work in 1992 and present 1993 findings, unionids appear extirpated, or nearly so, from the Pedernales, Blanco, San Marcos, Llano, upper Medina, upper Guadalupe rivers, and stretches of the San Saba River. Good species abundance and diversity was found in several areas of the central Neches River, Nasworthy Reservoir, and areas of the Concho River drainage, Lake Buchanan, Lake Corpus Christi on the Nueces River drainage, and at several other locations.

Several sampling locations contained one or more year classes of juvenile mussels of several species indicating successful reproduction and recruitment in recent years. Some such sites included Lake Buchanan, B. A. Steinhagen Reservoir, and Lake Corpus Christi.

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INTRODUCTION

In January 1992, the Texas Parks and Wildlife Department (TPWD) initiated programs to study freshwater mussels or the commercial fisheries they supported. Indeed, there have been relatively few scientific studies in Texas waters to provide even baseline freshwater mussel data which these programs were designed to address.

Around the turn of the century, a major industry developed in the Mississippi Valley harvesting freshwater mussel shells to produce buttons. This fishery generally reached as far southwest as Arkansas and the Red River (Coker 1919; Coker et al. 1921), but Texas was largely spared from the massive overharvest seen elsewhere. Mussel harvest for button shells did occur in Texas (Garrett 1929), but was comparatively minor by contrast to that seen in eastern rivers. The development of plastic buttons ultimately helped cause the demise of this fishery.

Although the intense Mississippi Valley fishery provoked study by the U.S. Fish Commission (Jones 1950), such scientific attention largely overlooked Texas unionids. A number of papers that have addressed local mussels have typically focused on site-specific species composition reports (e.g., Read and Oliver 1953; Murray 1972, 1978; Littleton 1979; Metcalf 1982; Neck 1982a, 1982b, 1982c, 1986a, 1986b, 1989a, 1989b; Neck and Metcalf 1988). Shira (1913) discussed mussels associated with a pearl fishery in Caddo Lake. Two manuscripts listed species reported in Texas (Strecker 1931; Murray and Roy 1968). Studies of species distribution, abundance, changes in population structure, and associated fisheries were essentially lacking.

By late 1991, the commercial fishery in Texas for mussel shells used by the cultured pearl industry had increased to levels that could no longer be ignored. In the absence of baseline date, initial TPWD efforts first focused on a questionnaire survey of mussel-license holders (Howells 1993). Concurrently, in spring 1992, TPWD began statewide surveys of mussel populations in Texas. Results from preliminary field work in 1992 have since been reported (Howells 1994). Discussed here are findings from continuing surveys conducted in 1993.

MATERIALS AND METHODS

Various habitats were sampled at each collection site examined. Collection methods and sampling effort varied between sites depending upon personnel, equipment, time available and field conditions at the time of sampling. Minimal sampling efforts involved visual examination of shoreline and shallow-waters with hand collection. Where possible, sites were sampled by wading and snorkeling with hand collection. On several occasions, SCUBA was used to examine deeper-water situations. A brail, similar to that reported by Starrett (1971), was used at several locations when waters were too deep, fast, or cold to be otherwise sampled safely.

At some locations where mussel densities were initially estimated to exceed 1-2/m^2, quantative samples were taken by placing a grid (PVC pipe, 0.25 m^2) on the substrate and removing all bivalves and their shells found within the grid. Where mussel densities were estimated to be somewhat lower, a 6.1-m rope was stretched between two poles and all specimens located 0.6 m on either side of this transect line were enumerated. In lower-density situations, where mussels present appeared to have been clearly disturbed or numbers altered (numbers present were not representative of undisturbed populations), or where time constraints or environmental conditions restricted sampling effort, more-broadly ranging, random hand-collections were made.

Results are presented in numbers collected and percent composition of the collection. Caution should be used in considering calculated percentages from collections where few specimens were taken, where mussel abundance and species composition had been altered (e.g., after harvest by musselers), or where collection efforts focused on obtaining large numbers of particular species (for laboratory work or reference specimens). Where a species at a given locality was represented only by fragments, it was recorded as present but fragments were not used in percent-composition calculations. Densities of Asian clams, Corbicula sp(p)., were not usually quantified, except as otherwise noted. However, qualitative abundance estimates were sometimes applied: abundant (> ca. 50-100/m^2), common (ca. 1-50/m^2), or rare/uncommon (for lesser densities).

Mussels taken were identified to species whenever possible. Ill-defined taxonomic status of some "species" also precluded assigning specific identifications. Other, non-unionid bivalves were also documented. Where identifications were in doubt, R.W. Neck (Houston Museum of Natural Science), H.D. Murray (Trinity University), or J.A.M. Bergman (Boerne, Texas) were consulted. Electrophoretic analysis using horizontal starch gel techniques following Morizot and Schmidt (1990) was employed in some instances to assist in species identification.

Common and scientific names used generally follow Turgeon et al. (1988) and include species listed below:

Family: Unionidae
- Threeridge (Amblema plicata),
- Giant floater (Anodonta grandis),
- Paper pondshell (Anodonta imbecillis),
- Flat floater (Anodonta suborbiculata),
- Floater sp. (Anodonta sp.) - Collections in B.A. Steinhagen Reservoir in 1993 produced specimens of an undescribed (or at least unrecognized) floater somewhat intermediate between giant floater and flat floater. This same species has been found by P. Hartfield (U.S. Fish and Wildlife Service, Jackson, Mississippi; personal communication, pers. comm.) in Mississippi.
- Rock-pocketbook (Arcidens confragosus),
- Ouachita rock-pocketbook (Arkansia wheeleri),
- Tampico pearlymussel (Cyrtonaias tampicoensis),
- Spike (Elliptio dilatata),
- Round pearlshell (Glebula rotundata),

Texas fatmucket (Lampsilis bracteata),
Louisiana fatmucket (Lampsilis hydiana),
Sandbank pocketbook (Lampsilis satura),
Yellow sandshell (Lampsilis teres),
White heelsplitter (Lasmigona complanata),
Fragile papershell (Leptodea fragilis),
Pond mussel (Ligumia subrostrata),
Washboard (Megalonaias nervosa),
Threehorn wartyback (Obliquaria reflexa),
Bankclimber (Plectomerus dombeyanus),
Texas heelsplitter (Potamilus amphichaenus),
Salina mucket (Potamilus salinasensis),
Pink papershell (Potamilus ohiensis),
Bleufer (Potamilus purpuratus),
Southern mapleleaf (Quadrula apiculata),
Rio Grande monkeyface (Quadrula couchiana),
"Gulf mapleleaf" (Quadrula nobilis) - This species was originally described by Conrad (1854) as Unio nobilis and later by Simpson (1900) as Tritogonia verrucosa obesa; however, subsequent authors have placed it with Quadrula quadrula. Electrophoretic analysis at Heart of the Hills Research Station (HOH) successfully distinguished this species as distinct from both Q. quadrula and Q. apiculata. Examination of gill attachment morphology places it in Quadrula and not with Tritogonia. Additional electrophoretic analysis confirmed this species to be present in both the Pascagoula River, Mississippi, and Amite River, Louisiana, as well as Texas. No common name has been recognized, so the name "Gulf mapleleaf" has been applied herein.
"Mapleleaf" or Quadrula sp(p). - used when Q. apiculata and Q. quadrula could not be distinguished (pending electrophoretic analysis)
Golden orb (Quadrula aurea),
"Pimpleback" - used where confusion between Q. aurea, Q. houstonensis, Q. mortoni, or Q. pustulosa (but not Q. petrina) could not be resolved,
Southern pimpleback (Quadrula houstonensis),
Western pimpleback (Quadrula mortoni),
Wartyback (Quadrula nodulata),
Texas pimpleback (Quadrula petrina),
Pimpleback (Quadrula pustulosa),
Mapleleaf (Quadrula quadrula),
False spike (Quincuncina mitchelli),
Squawfoot (Strophitus undulatus),
Lilliput (Toxolasma parvus),
Texas lilliput (Toxolasma texasensis); including T. mearnsi-types,
Pistolgrip (Tritogonia verrrucosa),
Mexican fawnsfoot (Truncilla cognata),
Fawnsfoot (Truncilla donaciformis),
Texas fawnsfoot (Truncilla macrodon),
Deertoe (Truncilla truncata),
Tapered pondhorn (Uniomerus declivis);
Family: Corbiculidae,
Asian clam (Corbicula sp(p).); no effort was made to define species;
Family: Mactridae,
Atlantic rangia (Rangia cuneata); and

Family: Sphaeriidae,
Fingernail clams; no effort was made to define species.

Varying environmental conditions can confound attempts to accurately define how long a given specimen has been dead. A number of terms have been used herein to convey an approximation of this. While inherently inaccurate, these attempts to characterize time since death are useful in distinguishing between animals that have been dead for many decades from others that died only days or weeks before collection. Terminology used here includes:

Very-recently Dead: Soft tissue remains attached to the shell; shell is in good condition, essentially as it would be in a living specimen. Internal and external colors are not faded.

Recently Dead: No soft tissue remains attached to the shell, but shell is otherwise in good condition, essentially as it would be in a living specimen. Internally nacre is still glossy and without indication of algal staining, deposition of calcium, or internal erosive effects. Internal and external colors are not faded significantly.

Relatively-recently dead: Shell is in good condition, but internally the nacre is loosing or has lost its glossy nature; algal staining, calcium deposition, or effects of internal erosion (or some combination of these) are present on the nacre. Internal and external colors may have faded somewhat.

Long dead: Shell shows early signs of internal and external erosion, staining, calcium deposition, or some combination of these. Most or all internal coloration has faded, especially in species with colored nacres. Shell epidermis is often largely absent, or if present, clearly aged and flaking.

Very-long dead: Shell shows significant signs of erosion, staining, and calcium deposition more widely pronounced than above. Coloration is often faded to white or nearly so. Relatively little intact epidermis is left. For specimens in erosive environments, internal (e.g, lateral teeth) and external (e.g., pustules) features are often weathered and smoothed, or otherwise partially exfoliated. Shells are often brittle and crumbling.

Subfossil: Shells with little or no epidermis. Nacre is usually faded white; entire shell is often completely white, often with extensive signs of erosion, staining, and calcium deposition. Shells are often brittle and crumbling.

In the following discussion, sampling sites are generally presented north to south and east to west across the state, and upstream to downstream for each major river system.

RESULTS AND DISCUSSION

Red River Drainage

Surveys of Sanders and Pine creeks, Lamar County, were prompted by reports in late July 1993 of the collection of a federally-endangered Ouachita rock-pocketbook in Pine Creek in November 1992. This species was previously known only from the Kiamichi River in Oklahoma and the Little River drainage of Arkansas (Martinez and Jahrsdoerfer 1991). A team from HOH met with J.A.M. Bergman (OMC, Boerne, Texas) and C.M. Mather (University of Science and Arts of Oklahoma, Chickasha), who had previous experience with this species and with unionids in Texas, to survey Pine Creek and adjacent waters in Lamar County. Most specimens appeared morphologically to be mapleleaf (Q. quadrula) but several may have been southern mapleleaf (Q. apiculata) as well. Preliminary electrophoretic analyses have been limited by small sample size and have been inconclusive to date.

Pat Mayse Reservoir (Sanders Creek Drainage), cove at the western-most U.S. Corps of Engineers campground on the north shore or the reservoir, Lamar County, 8 August 1993:
The shoreline of this cove was briefly examined during early staging for a subsequent examination of Sanders and Pine Creeks. Asian clam (Corbicula spp.) was common. Shoreline substrate was sandy mud.

Pat Mayse Reservoir; non-quantitative samples

Species	*N* live	*N* shell	Percent
Paper pondshell	0	1.0	33.3
Mapleleaf (sp.)	0	1.0	33.3
Lilliput	0	1.0	33.3

Sanders Creek, rip-rap area immediately downstream of Pat Mayse Reservoir dam, Lamar County, 8 August 1993:
This area contained extremely abundant Asian clams; several shell fragments of fragile papershell were also found. Areas of Sanders Creek downstream of this area were examined by J.A.M. Bergman and C.M. Mather on the same day. They reported finding mapleleafs, pimpleback (Q. pustulosa), wartybacks, fragile papershell, and threehorn wartyback. They also found a single, very recently-dead shell of Ouachita rock-pocketbook (only the second specimen to be found in Texas and the first for Sanders Creek). They indicated threehorn wartyback was the dominant species in the area.

Crook Lake (Pine Creek drainage), east shore, Lamar County, 8 August 1993:
Examination of this area by wading and snorkeling produced several unionids. Shells from Asian clam were moderately common along the shoreline. The substrate was primarily soft mud over hard clay. Commercial musselers interviewed by J.A.M. Bergman and C.M. Mather during an earlier survey of the area indicated they occasionally harvested mapleleafs from this reservoir.

Crook Lake; non-quantitative samples			
Species	*N* live	*N* shell	Percent
Giant floater	1	1.0	20.0
fragile papershell	1	0.0	10.0
Mapleleaf (sp.)	7	0.0	70.0

Pine Creek tributary, the first tributary from the south downstream of Crook Lake dam, Lamar County, 8 August 1993:
This small stream was examined by wading for several hundred meters upstream of the Crook Lake Road bridge. Only a single tapered pondhorn was found. No other unionids or Asian clams were present. The substrate was mud, sand, and gravel with scattered rocks; this stream may be intermittent during drought periods.

Pine Creek, County Road 2648 bridge (third crossing upstream of State Highway 906 bridge), Lamar County, 9 August 1993:
Both up- and downstream from this crossing was sampled by wading. Substrate was primarily hard clay with some areas of sand and gravel. This site was extensively used as a dump near the bridge for residential garbage, household appliances, and even dead animals. Mussel shells were present, but few were found alive. Asian clams were present. Species collected included:

Pine Creek, County Road 2648; non-quantitative samples			
Species	*N* live	*N* shell	Percent
Giant floater	0	0.5	4.1
Paper pondshell	0	fragments	present
Yellow sandshell	0	0.5	4.1
Fragile papershell	1	1.0	8.3
Mapleleaf (spp.)	1	16.5	75.0
Bleufer	0	2.0	8.3

Pine Creek, first and second crossings upstream of State Highway 906 (unnamed), Lamar County, 9 August 1993:
The second crossing upstream of State Highway 906 was located by the HOH team but was not sampled. Steep banks limited access, no good mussel habitat was apparent from the abandoned bridge upstream of the site, and no mussels or their shells were observed. The first crossing upstream of State Highway 906 had been examined by J.A.M. Bergman and C.M. Mather earlier; they reported similar conditions there.

Pine Creek, State Highway 906, Lamar County, 9 August 1993:
This location was the collection site of the first Ouachita rock-pocketbook specimen in November 1992. The HOH team examined areas upstream of this crossing by wading and snorkeling; J.A.M. Bergman and C.M. Mather examined downstream areas by wading and SCUBA at deeper sites. Substrate was primarily hard clay with soft mud or mud and fine gravel above; some areas contained sand or silt, and others were bars of gravel or clay balls. Stream depths upstream of the road crossing were rarely more than 1 m in depth. Asian clams were not found at this site. Unionids taken by the HOH team included:

Pine Creek, State Highway 906; non-quantitative samples			
Species	*N* live	*N* shell	Percent
Giant floater	0	fragments	present
Paper pondshell	0	fragments	present
Yellow sandshell	10	8.0	30.0
Fragile papershell	10	2.0	20.0
White heelsplitter	6	16.0	36.7
Threehorn wartyback	2	0.5	5.0
Pink papershell	0	2.0	3.3
Bleufer	0	1.0	1.7
Mapleleafs (spp.)	2	0.0	3.3

Among bleufer, mapleleafs, yellow sandshell, fragile papershell, and white heelsplitter, many additional specimens were located but not retained. J.A.M. Bergman and C.M. Mather reported similar species composition and abundance downstream of State Highway 906. No additional Ouachita rock-pocketbook specimens were found.

Big Cypress Bayou Drainage

Caddo Lake, Harrison and Marion Counties, fall 1993:
Musselers visiting this site sent two washboard specimens to HOH for examination. Both specimens were very badly eroded. The musselers reported many unionids in this area with eroded shells; some to the point where the living animal had been exposed at holes in the shell.

Sulphur River Drainage

North Sulphur River, State Highway 50, Hunt County, and State Highway 24, Delta and Lamar counties, 22-23 June 1993.
This sanctuary was sampled by wading but no unionids were found. Both the banks and substrate were hard clay with little evidence of good mussel habitat.

South Sulphur River, State Highway 50, Hunt County, 22-23 June 1993.
This sanctuary was sampled by wading. The substrate was mud and gravel with depths of about 0.5 m. Species collected included:

South Sulphur River, State Highway 50; non-quantitative samples			
Species	*N* live	*N* shell	Percent
Yellow sandshell	0	3.0	54.5
Fragile papershell	0	fragments	present
Bleufer	0	1.0	18.2
Tapered pondhorn	0	1.5	27.3

South Sulphur River, State Highway 154, Hopkins County, 22-23 June 1993.
This sanctuary was sampled by wading. The substrate was primarily hard mud and rock rubble; water depths averaged about 0.3 m. Asian clams were present. Species collected included:

South Sulphur River, State Highway 154; non-quantitative samples

Species	*N* live	*N* shell	Percent
Yellow sandshell	0	9.5	22.6
Fragile papershell	0	23.5	56.0
Southern mapleleaf	0	6.0	14.3
Bleufer	0	2.0	4.8
Tapered pondhorn	0	1.0	2.4

South Sulphur River, State Highway 11, Hunt and Hopkins counties, 22-23 June 1993.
This sanctuary was sampled by wading. The substrate was primarily soft mud and heavy rock rubble; depths averaged about 1 m. Only a few unidentifiable unionid shell fragments were found at this site.

Middle Sulphur River, State Highway 11, northwest of Commerce, Hunt County, 22-23 June 1993.
This site was sampled by wading. The substrate consisted of silt and gravel; water depths averaged about 0.2 m.

Middle Sulphur River, State Highway 11; non-quantitative samples

Species	*N* live	*N* shell	Percent
Tapered pondhorn	13	12	100.0

Sulphur River, State Highway 37, upstream of the confluence of the North and South Sulphur River branches, Franklin County, 22-23 June 1993.
This sanctuary was sampled by wading. The substrate consisted of silt and hard, flat mud; water depths averaged 1-1.3 m. Only a single dead yellow sandshell was found; however, the shell was recently dead and in very good condition.

White Oak Creek, State Highway 37, Franklin County, 22-23 June 1993.
This sanctuary was sampled by wading. The substrate was primarily mud and gravel; water depths averaged less than 1 m. Six fragments from a very-recently dead bleufer valve were the only unionids encountered.

Sabine River Drainage

Sabine River, State Highway 19 downstream of Lake Tawakoni, 9 August 1993.
This sanctuary area (dam at Lake Tawakoni to State Highway 19) was examined by wading and snorkeling only from about 50 m downstream of the highway bridge to about 300 m upstream. The substrate was primarily mud or mud and gravel; depths averaged about 1.5 m. The following species were collected:

Sabine River, State Highway 19; non-quantitative samples

Species	*N* live	*N* shell	Percent
Giant floater	0	fragments	present
Yellow sandshell	0	3.0	20.7
Fragile papershell	2	0.0	13.8
Southern mapleleaf	3	1.5	31.0

Bleufer	0	2.0	13.8
Pistolgrip	0	0.5	3.4
Deertoe	0	1.0	6.9
Unidentified unionid	0	1.5	10.3

The unidentified valves were long dead and badly eroded; they were likely either ill-shaped yellow sandshells or possibly pond mussel. The pistolgrip valve was also very long dead.

Sabine River, Longview, Gregg County, September 1993.
Five valves collected by the Texas Natural Resources Conservation Commission (previously the Texas Water Commission) were sent to HOH for identification. All were those of yellow sandshell.

Neches River Drainage

Attoyac Bayou, Angelina River drainage, from Sam Rayburn Reservoir several km upstream, San Augustine County, 5 May 1993.
This area was examined by boat, but was not sampled. Heavy rains and subsequent flooding of adjacent bottom lands prior to arrival of the HOH survey crew made it necessary to use a depth finder to locate the bayou itself. Water levels were considered too high to allow divers to enter and extensive snags precluded brail sampling.

Sam Rayburn Reservoir, park immediately east of dam, Jasper County, 16 February 1993.
Wading the shoreline in this area produced only a single, old Asian clam valve. However, recent, dramatic increases in water level here likely placed most bivalves and their shells in far deeper water.

Sam Rayburn Reservoir, boat ramp east of dam, Jasper County, 16 February 1993.
Wading the shoreline in this area produced no bivalves or their shells (see note above).

Angelina River, Sam Rayburn Reservoir dam downstream to Bevilport, Jasper County, 4 June 1993.
High water levels and flood conditions precluded diving during this survey, but brail hauls were made in the Sam Rayburn Reservoir spillway channel, the old river channel upstream of the spillway channel, and for several km downstream of the spillway channel. No unionids were taken in any samples although local residents had reported beds of large mussels (presumably washboards) here during the construction of Sam Rayburn Reservoir. Additional brail samples were taken at and for several km upstream of Bevilport, but no unionids were taken. The only mussel obtained was a single western pimpleback found by wading on a sand bar adjacent to the first major tributary upstream of Bevilport. However, in late December 1993, personnel from the TPWD fisheries management office in Jasper reported low water levels associated with a drawdown of B.A. Steinhagen Reservoir downstream exposed a number of large mussels. Surveys conducted during highwater conditions may not accurately reflect mussel populations present in this area.

Jasper State Fish Hatchery canal, Jasper, 16 February 1993.
Wade sampling here failed to located either unionids or Asian clams. The canal bottom and sides were heavily vegetated (undesirable mussel habitat).

Creek adjacent to Jasper State Fish Hatchery Canal, Jasper, 16 February 1993.
Wade sampling this creek failed to locate either unionids or Asian clams. Much of the substrate was deep, shifting sand (undesirable mussel habitat).

B. A. Steinhagen Reservoir, Tyler and Jasper Counties; 16 February, 3 March, 4 May, and 29 December 1993.
This reservoir was briefly sampled by shoreline wading in February and March, more intensively sampled by wading and snorkeling in May, and exposed bottom areas were reexamined in December following a 2-m drawdown.

February and March samples, which were taken in the vicinity of boat ramps immediately north and south of State Highway 190 on the west side of the reservoir, yielded specimens of yellow sandshell, Louisiana fatmucket, Texas lilliput, and Asian clams, all of which were relatively abundant. Additionally, two shells from Texas heelsplitter were also found.

Transect (N = 4, random, deeper waters of 1.5-2.0 m) and grid samples (N = 6, random, along shoreline vegetation beds, < 1.0 m deep) at the cove at the boat ramp NW of the State Highway 190 bridge on 4 May 1993 were taken. Substrate was sandy mud along the shoreline and soft, deep mud in deeper waters. Water hyacinth and hydrilla were abundant. Sampling produced the following species:

B. A. Steinhagen Reservoir; cove NW State Highway 190; transect and grid samples

Sample type	Species	N live	N/m^2
transect	Giant floater	2	<0.1
grid	Louisiana fatmucket	3	2.00
	Yellow sandshell	1	0.70
	Asian clam	2	1.40

Additional non-quantitative efforts throughout this NW cove in May produced:

B. A. Steinhagen Reservoir; cove NW State Highway 190; non-quantitative samples

Species	N live	N shell	Percent
Giant floater	44	9.0	37.1
Paper pondshell	1	0.0	0.9
Flat floater	2	2.0	3.4
Rock-pocketbook	0	1.0	0.9
Louisiana fatmucket	31	1.0	27.6
Yellow sandshell	12	1.0	11.2
Southern mapleleaf	1	1.0	1.7
Texas lilliput	4	3.5	6.9

Bleufer	2	0.0	1.7
Western pimpleback	1	0.0	0.9
Asian clam	6	3.0	7.8

The boat ramp area on the SW side of State Highway 190 was sampled in May quantitatively by grid (N = 4). The substrate was sandy mud and hydrilla and pondweed were abundant. Species collected included:

B.A. Steinhagen Reservoir; cove SW State Highway 190; grid samples

Sample type	Species	N live	N/m^2
grid	Giant floater	2	0.5
	Southern mapleleaf	1	0.3
	Fragile papershell	1	0.3
	Western pimpleback	1	0.3

Additional non-quantitative efforts along this shoreline in May produced:

B. A. Steinhagen Reservoir; cove SW State Highway 190; non-quantitative samples

Species	N live	N shell	Percent
Giant floater	6	0.0	13.3
Rock-pocketbook	0	1.0	2.2
Louisiana fatmucket	11	2.0	28.9
Yellow sandshell	10	9.0	42.2
Fragile papershell	1	0.0	2.2
Bankclimber	1	0.0	2.2
Texas heelsplitter	0	1.0	2.2
Southern mapleleaf	2	0.0	4.4
Western pimpleback	1	0.0	2.2

Non-quantative sampling in May at the state park boat ramp immediately NE of State Highway 190 found sandy mud substrates and the following species:

B. A. Steinhagen Reservoir; cove NE State Highway 190; non-quantitative samples

Species	N live	N shell	Percent
Giant floater	4	0.0	20.5
Louisiana fatmucket	5	0.0	25.6
Yellow sandshell	5	1.0	30.8
Bleufer	1	0.5	7.7
Texas lilliput	0	1.0	5.1
Asian clam	2	0.0	10.3

Brief non-quantitative examination of heavily-timbered areas adjacent to boat ramps in the Wolf Creek Park area of the northwestern shore of B.A. Steinhagen Reservoir in February produced shells from yellow sandshell (3), fragile papershell (1), and Asian clams (many). Two, old and weathered Atlantic rangia valves were also found here. This species is known from the lower Neches River and its shells are also extensively used as fill material; the origin of these specimens is unknown. The

Wolf Creek Park area was again reexamined in December 1993 during a drawdown, but massive growths of hydrilla and other aquatic plants blanketed the area obscuring any mussels present.

B. A. Steinhagen Reservoir was reexamined in December 1993 during the drawdown to kill excessive growths of water hyacinth and hydrilla. A team was sent from HOH to collect living specimens for use in a variety of research efforts. All of the above areas were examined as were additional sites southeast of State Highway 190 not previously surveyed. Except for a small number of giant floaters, yellow sandshells, Louisiana fatmuckets, and a single Texas lilliput whose shells were retained, only living specimens were collected including:

B. A. Steinhagen Reservoir; non-quantitative samples

Species	*N* live	Percent
Threeridge	19	4.5
Giant floater	29	6.9
Paper pondshell	1	0.2
Flat floater	1	0.2
Floater sp.	3	0.7
Rock-pocketbook	2	0.5
Louisiana fatmucket	33	7.8
Yellow sandshell	55	13.1
Fragile papershell	11	2.6
Washboard	3	0.7
Threehorn wartyback	76	18.1
Bankclimber	41	9.7
Bleufer	61	14.5
Texas heelsplitter	1	0.2
Southern mapleleaf	11	2.6
Western pimpleback	54	12.8
"Gulf mapleleaf"	19	4.5
Pistolgrip	1	0.2

This collection indicated species like giant floater, yellow sandshell, and Louisiana fatmucket were abundant as earlier sampling had suggested or were not abundant (flat floater, rock-pocketbook, paper pondshell) as in previous samples. However, a number of species were taken during the drawdown sampling that had not been found in earlier surveys (washboard, threeridge, threehorn wartyback, pistolgrip, "Gulf mapleleaf") or had been much less abundant (western pimpleback, bankclimber). Additionally, all but a few of these species included juvenile as well as adult specimens indicating successful reproduction had occurred in the reservoir in recent years.

Wolf Creek, NW tributary of B. A. Steinhagen Reservoir, State Highway 92, 16 February and 29 December 1993.
When examined in February, water levels were too high and fast to permit access during winter weather. When reexamined by wading in December, the substrate was sandy but no mussels were found.

Rush-Camp Creek, SW tributary of B. A. Steinhagen Reservoir, State Highway 92, 29 December 1993.
Wade sampling of this stream several hundred m up- and downstream from the highway bridge found sandy bottoms with no mussels present. The survey crew reported a strong smell of sewage in the area.

Stream at State Highway 96 about 2 km south of Jasper, Jasper County, 16 February 1993.
Wade sampling of this stream found deep, shifting sand bottoms and no mussels present. Bridge and other construction work on-going in the area at the time were apparently causing major erosion problems. Local sandy soils eroded rapidly after even minor disturbances which removed critically important vegetative cover. If mussel populations had been present in this stream, they were so heavily covered with deep, shifting sands so that even shells could not be located.

Neches River, from immediately downstream of B. A. Steinhagen Reservoir dam to about 5 km downstream, 3 May 1993.
This mussel sanctuary was sampled successfully by brail. Flood conditions during the survey resulted in water levels over 2-m higher than normal and flows too fast to allow safe diving; most brail samples were taken at 6-8 m deep. Substrates were typically thought to be gravel and mud, based on brail responses when towed. Very large numbers of active and abandoned trot lines in this area snagged brail hauls and precluded efforts to accurately quantify catch. Specimens collected in seven brail hauls included:

Neches River downstream of B. A. Steinhagen Reservoir; brail samples

Species	*N* live	*N* shell	Percent
Threeridge	3	0.0	2.9
Rock-pocketbook	1	0.0	1.0
Sandbank pocketbook	1	0.0	1.0
Fragile papershell	1	0.0	1.0
Southern mapleleaf	2	0.0	1.9
Threehorn wartyback	6	0.0	5.7
Western pimpleback	78	0.0	74.6
Wartyback	6	0.0	5.7
"Gulf mapleleaf"	2	0.0	1.9
Unidentified mapleleaf	2	0.0	1.9
Bleufer	0	1.5	1.4
Fawnsfoot	1	0.0	1.0

All specimens were alive when taken except bleufer which was represented by one shell and one valve found snagged on a brail hook. Western pimpleback may have also included specimens of pimpleback (Quadrula pustulosa cf. nodifera). However, these and two unidentified mapleleafs could not be identified further based on shell morphology alone; these may be extremely rugose "Gulf mapleleafs", hybrids, or some other species. Further, attempts to return specimens alive to HOH were confounded by extremely high mortality among brail-caught specimens which precluded obtaining tissue for electrophoretic examination. Among 78 western pimplebacks taken alive by brail and held in water in

oxygenated, fish-hauling tanks, then transported to HOH where they were placed in flow-through raceways, only 13 remained alive after 30 days. Other mussels taken by hand in B. A. Steinhagen Reservoir (over 100) during this same survey reached HOH and remained alive in raceways with virtually no mortality.

Trinity River Drainage

Fort Richardson Lake, Jacksboro, Jack County, 1 December 1993:
This lime-stone quarry lake had steep, rocky sides and bottoms; good mussel habitat was lacking. No bivalves were found.

Trinity River, West Fork, State Highway 148, Jack County, 1 December 1993:
This fork of the Trinity River had a mud and silt bottom with drainage from adjacent grazing lands; however, when examined it contained only standing pools without flowing water and appeared to be intermittent. Only a single, long-dead pair of valves from tapered pondhorn was found. No Asian clams were present.

Trinity River, Elm Creek Fork downstream of Lake Ray Roberts at Highway 2153, Denton County, 8 September 1993;
Several unionid valves were found in beach collections during survey work by fishery management biologists. These included: threeridge (subfossil), pistolgrip (subfossil), giant floater (long dead), pink papershell (long dead), southern mapleleaf (relatively-recently dead), yellow sandshell (recently dead), lilliput (long dead), and bleufer (long dead); several recently dead Asian clam valves were found as well. This represents a second collection of pink papershell which was first taken by TPWD at Eagle Mountain Reservoir in 1992, but was otherwise unreported from the Trinity River drainage.

Lake Arlington, Tarrant County, 23 June 1993:
Sampling by brail (seven 100-m tows at localities around the reservoir) and wading (two areas on the south and southwest shores) produced no unionids or their shells. Asian clams were present

Eagle Mountain Reservoir, Tarrant and Wise counties, 24 June 1993:
This reservoir was sampled by brail and several sites were examined by wading. Brail samples included:

Eagle Mountain Reservoir; brail hauls

Location	*N* tows	Distance	Species	*N* live	*N* shell
Southeast corner	4	75 m	Threeridge	1	1
			"Pimpleback"	2	0
Southcentral island	2	50 m	Threeridge	3	0
			"Pimpleback"	1	0
Eastcentral embayment	1	100 m	Threeridge	1	0
			Giant floater	0	1
Southcentral point	1	100 m	None	0	0
Southcentral	3	100 m	Threeridge	3	1

One living threeridge, several threeridge fragments, and one dead pimpleback were taken by hand during wade sampling of shoreline areas. Pimplebacks here are unusual; they are tentatively being considered southern pimplebacks, but could represent western pimplebacks or pimplebacks. Positive identification will need to await electrophoretic analysis.

Cedar Creek Reservoir,

Sampling included 18 brail hauls (50-100 m) covering 16,470 m^2 of substrate, six 0.25-m^2 grid samples taken by SCUBA diver, and four areas examined by wading. During TPWD efforts on this reservoir, a commercial mussel diver, G. A. Atherington (Malakoff, Texas), voluntarily assisted in collection of grid samples and with two additional, random hand collections in deeper waters. Depths sampled reached from the shore line to a maximum of 6.1 m. Total species and numbers collected by all methods included:

Cedar Creek Reservoir; total of all collection methods

Species	*N* live	*N* shell	Percent
Threeridge	0	1.0	0.5
Giant floater	0	1.0	0.5
Louisiana fatmucket	0	0.5	0.5
Yellow sandshell	2	0.5	1.4
Southern mapleleaf	206	1.0	97.2

A questionnaire survey of mussel license holders (Howells 1993) found Cedar Creek Reservoir to be the most heavily musseled reservoir in the state. Nutrient input associated in part with extensive residential development in the area in conjunction with a previous die-off of extensive macrophyte beds appears to have produced a nutrient-rich plankton community which in turn supports good mussel survival and growth. Grid samples taken to estimate mussel abundance at favored harvest sites ranged from 6 to 30.7/m^2, with most over 20/m^2. Two randomly-collected samples taken by diver (all mussels that could be located within a 5-min period contained 55 and 62 southern mapleleafs. Among these southern mapleleafs, nearly 7% were above legal minimum size (70 mm) and about 74% are within 20 mm of legal size.

Navarro Mills Reservoir, Hill and Navarro counties, fall 1993:

Musselers sent two Louisiana fatmuckets and one fragile papershell taken here to HOH for examination.

Trinity River, Lake Livingston dam to U.S. Highway 59, San Jacinto and Polk counties, 13 July 1993:

This mussel sanctuary was sampled by brail hauls (six 100-m tows and several aborted attempts) made at a variety of sites from downstream of the dam to about 2 km downstream, including both the main river channel and secondary channel; additional areas further down stream were examined by wading. River substrates were typically sand and sandy mud with a gravel bar about 1 km downstream from the dam and scattered rocks and boulders throughout the area. No unionids were taken in brail hauls between the dam and downstream gravel bar; Asian clams were present.

Gravel bar at the first bend in the river downstream of Lake Livingston dam:
Brailing here produced no living mussels; however, several living and recently dead southern mapleleafs were found adjacent to the bar and a wide variety of species were represented by subfossil valves at this location. Asian clams were present. Species present included:

Trinity River downstream of Lake Livingston; non-quantitative samples

Species	*N* live	*N* shell	Percent
Threeridge	0	1.0	2.1
Yellow sandshell	0	0.5	2.1
Fragile papershell	0	fragment	present
Washboard	0	2.0	4.2
Bankclimber	0	13.5	29.2
Bleufer	0	1.0	2.1
Southern mapleleaf	4	20.5	52.1
"Pimpleback"	0	2.5	6.3
Pistolgrip	0	0.5	2.1

Tributary stream, SW side of river downstream of a gravel bar:
Sampling by wading and snorkeling produced no unionids or Asian clams.

Rocky outcropping about 500 m downstream of a gravel bar and tributary:
Sampling by wading and snorkeling produced no unionids or Asian clams in the sandy patches between rocks and boulders.

Long King Creek, Trinity River sanctuary tributary at County Road 2989; Polk County, 12 July 1993:
River level fluctuations in the Trinity River apparently severely impact this tributary causing extensive erosion of sandy banks. Deep-shifting sand had filled the creek bed and smothered mussel habitat. Only a few cm of water flowed over many areas and during bright, summer days, water temperatures may reach lethal levels. Only a few recently-dead valves of Asian clams were found.

Trinity River, about 100 m downstream of U.S. Highway 59; San Jacinto County, 12 July 1993:
Steep sandy river banks in this area were collapsing into the river and covering the bottom. Examination of the shore line produced only shells from Asian clams and fingernail clams.

Trinity River tributary about 1 km downstream of U.S. Highway 59, San Jacinto County, 12 July 1993:
This tributary was similar to the previous two sites with collapsing sandy banks. Examination of the shore line produced a variety of subfossil unionid shells but no living specimens. Asian clams were present. Species included:

Trinity River tributary 1 km downstream of U.S Highway 59; non-quantitative samples

Species	*N* live	*N* shell	Percent
Threeridge	0	6.0	36.4

Louisiana fatmucket	0	1.0	6.1
Yellow sandshell	0	0.5	3.0
Washboard	0	1.0	6.1
Southern Mapleleaf	0	1.0	6.1
"Pimpleback"	0	6.0	36.4
Mapleleaf sp.	0	0.5	3.0
Bankclimber	0	0.5	3.0
Bleufer	0	fragments	present

Mussel Shoal Creek, upper reach at County Road 1127, San Jacinto County, 12 July 1993:

The upper reach of Mussel Shoal Creek at this location was largely comprised of soft mud and detritus bottom with large amounts of leaves, sticks, and branches from the encroaching forest. There was no flow at the time of sampling resulting in stagnant conditions. A single dead Texas lilliput was found. Other areas on this creek could not be reached by road.

Mussel Shoal Creek, tributary east of Shepard, San Jacinto County, 12 July 1993:

Most areas of this tributary were surrounded by dense woodland. Sampling by wading and snorkeling indicated substrate was typically hard clay with patches of mud and silt. Asian clams were present and a number of unionids were found:

Mussel Shoal Creek tributary east of Shepard; non-quantitative samples

Species	*N* live	*N* shell	Percent
Louisiana fatmucket	14	3.5	48.6
Yellow sandshell	0	1.0	2.7
Bleufer	1	0.0	2.7
Southern mapleleaf	2	0.5	8.1
Texas lilliput	4	7.5	32.4
Tapered pondhorn	2	0.0	5.4

San Jacinto River Drainage

Lake Stubblefield, Walker County, fall 1993:

Musselers sent two southern mapleleafs taken here to HOH for examination.

Lake Conroe, Montgomery County, fall 1993:

Two specimens of giant floater taken from this reservoir by a musseler were sent to HOH for identification. Additionally, a local resident reported giant floaters, southern mapleleafs, and Asian clams present. However, this reservoir has not been surveyed by TPWD to date.

Brazos River Drainage

Lake Mexia, Limestone County, fall 1993:

Musselers sent two southern mapleleafs and two pond mussels taken here to HOH for examination.

Lake Limestone, Limestone County, fall 1993:
Musselers sent one southern mapleleaf and one yellow sandshell taken here to HOH for examination.

Little Brazos River, U.S. Highway 79, Robertson County, 9 August 1993:
This location had been examined on several occasions in 1992 and was found to contain a large, diverse mussel fauna (Howells 1994). However, during a brief visit in 1993 to collect several large washboard specimens for display purposes, massive mortalities were observed to have occurred. Although species composition and abundance was essentially the same as previously reported, all but a few bivalves were represented only by dead shells. Only a few threeridges, southern mapleleafs, and Asian clams were found alive. All others at this location appeared to have perished during the nine months since the site was last examined. Personnel sampling the stream in 1993 found a "sticky" feeling to the skin upon exiting the river, and noticed an ethereal, pesticide smell in the air around the creek the following morning. No cause for the die-off was confirmed. Mussel populations up- and downstream of this location were not examined in 1993.

Lake Proctor, Comanche County, 29 September 1993:
A brief examination of this reservoir during a low-water period produced a single live giant floater and many shells of this species found in the soft mud as water levels receded.

Leon River, downstream of Lake Proctor dam, Comanche County, 12-13 October 1993:
This stretch of the Leon River was sampled by wading and snorkeling. The following specimens were found:

Leon River downstream of Lake Proctor; non-quantitative samples

Species	*N* live	*N* shell	Percent
Threeridge (long dead)	0	0.5	20.0
Fragile papershell (recent)	0	2.0	80.0

Leon River, U.S. Highway 377/67, Comanche County, 12-13 October 1993:
This stretch of the Leon River was sampled by wading and snorkeling. The following specimens (all relatively-recently dead) were found:

Leon River at U.S. Highway 377/67; non-quantitative samples

Species	*N* live	*N* shell	Percent
Giant floater	0	1.0	16.7
Yellow sandshell	0	2.0	33.3
Fragile papershell	0	2.0	33.3
Pistolgrip	0	1.0	16.7

Leon River, County Road 1476, Comanche County, 12-13 October 1993:
This stretch of the Leon River was sampled by wading and snorkeling. A single pair of valves from a recently-dead fragile papershell was found.

Leon River, County Road 1702, Comanche County, 12-13 October 1993:
This stretch of the Leon River was sampled by wading and snorkeling. No unionids or their shells were found.

Leon River, at U.S. Highway 281, Hamilton County, 12-13 October 1993:
This stretch of the Leon River was sampled by wading and snorkeling. The following specimens (condition of dead shell noted) were found:

Leon River at U.S. Highway 281; non-quantitative samples			
Species	*N* live	*N* shell	Percent
Threeridge (long dead)	1	4.5	30.0
Yellow sandshell (long dead)	0	0.5	5.0
Fragile papershell (recent)	0	2.0	10.0
Bleufer (relatively long dead)	0	1.5	10.0
Southern pimpleback* (long dead)	1	3.0	20.0
Pistolgrip (one recent; others long dead)	0	4.5	25.0

* The pimpleback specimens taken here were problematic in appearing somewhat intermediate between southern pimpleback and golden orb. Initial electrophoretic analysis indicates closer association with smooth pimpleback.

Leon River, at Alternate Highway 281 (bypass route east of U.S. Highway 281), Hamilton County, 12-13 October 1993:
This stretch of the Leon River was sampled by wading and snorkeling; however, most of the river in this area was too deep to be successfully sampled without diving gear or brail. A single, recently-dead fragile papershell was found.

Leon River, at State Highway 22, Hamilton County, 12-13 October 1993:
This site was examined but not sampled due to excessively deep-water conditions (> 5 m). Diving gear or brail will be required to assess the presence or absence of unionids here.

Leon River, at State Highway 36 north of Gatesville, 12-13 October 1993:
This stretch of the Leon River was sampled by wading and snorkeling. The following specimens (condition of dead shell noted) were found:

Leon River at State Highway 36; non-quantitative samples			
Species	*N* live	*N* shell	Percent
Threeridge (long dead)	0	0.5	4.0
Fragile papershell (recent)	0	4.0	32.0
Bleufer (one very recent, predator kill; others long dead)	0	4.0	32.0
Southern mapleleaf (long dead)	0	3.0	24.0
Pistolgrip (long dead)	0	1.0	8.0

Leon River, unmarked county road (second crossing upstream of Farm Road 2412), Coryell County, 12-13 October 1993:

This stretch of the Leon River was sampled by wading and snorkeling. The bottom at this site was extremely soft mud and no unionids or their shells were found.

Leon River, State Highway 2412 west of Gatesville, 12-13 October 1993:
This stretch of the Leon River was sampled by wading and snorkeling. The following specimens (all long dead) were found:

Leon River at State Highway 2412; non-quantitative samples			
Species	*N* live	*N* shell	Percent
Yellow sandshell	0	2.0	50.0
Pistolgrip	0	1.0	25.0
Bleufer	0	1.0	25.0

Leon River, State Highway 36 south of Gatesville, 12-13 October 1993:
This stretch of the Leon River was sampled by wading and snorkeling. Only a single, relatively-recent valve from a juvenile washboard was found.

Leon River, County Road 1828 off State Highway 36 south of Gatesville, 12-13 October 1993:
This stretch of the Leon River was sampled by wading and snorkeling. The following specimens (all long dead) were found:

Leon River at County Road 1828; non-quantitative samples			
Species	*N* live	*N* shell	Percent
Fragile papershell	0	0.5	33.3
Threeridge	0	0.5	33.3
Pistolgrip	0	0.5	33.3

Bosque River, U.S. Highway 67, Stephenville, Erath County, 1 December 1993:
This site was briefly examined, but not sampled. No acceptable mussel habitat was apparent.

Colorado River Drainage

Colorado River, State Highway 2133 at Ballinger, Runnels County, 5 August 1993:
Sampling, including wading and snorkeling, indicated primarily bedrock and cobble bottom but with areas of sand and mud where mussels were present. Water depths were typically less than 1 m.

Colorado River at State Highway 2133; non-quantitative samples			
Species	*N* live	*N* shell	Percent
Tampico pearlymussel	5	many	-
Fragile papershell	3	several	-
Southern mapleleaf	0	many	-
Texas pimpleback	0	1.5	-
Bleufer	0	1.0	-
Tapered pondhorn	0	1.0	-

Because low water levels for several weeks prior to examination of this site exposed mussels making them easily observable from the highway bridge and adjacent river banks, musselers had been actively harvesting mussels here. This was evidenced by numerous human footprints and a large number of opened shells in the area. No efforts were made to accurately count shells and valves because of obvious human disturbance. Asian clams were present.

Colorado River, State Highway 83 at Ballinger, Runnels County, 5 August 1993:
Wading and snorkeling this site found solid bedrock bottom with a thin covering of silt and mud; depths averaged 3.5 m. Little good mussel habitat was evident. A shell from a single fragile papershell was the only unionid found; Asian clams were present.

Elm Creek upstream of Elm Creek Lake, third low-water crossing upstream of Elm Creek Lake, Runnels County, 5 August 1993:
This area (about 100 m up- and downstream) consisted of bedrock, cobble, and gravel with extensive growths of macrophytes and filamentous algae. Relatively little good mussel habitat was apparent in the immediate area. Asian clams were very abundant. Several shells and fragments of Tampico pearlymussel, Texas fatmucket, and southern mapleleaf were found, but no living unionids were located.

Elm Creek upstream of Elm Creek Lake, second low-water crossing upstream of Elm Creek Lake, Runnels County, 5 August 1993:
Wading and snorkeling at this site found varied bottom types: bedrock, cobble, gravel, sand, and mud, with areas of bedrock slabs along one bank. Water depths were typically less than 1 m. Asian clams and fingernail clam shells were present. Although both living unionids and their shells were retained, only living specimens were enumerated.

Elm Creek, second crossing upstream of Elm Creek Lake; non-quantitative samples

Species	*N* live	*N* shell	Percent (live)
Paper pondshell	0	1.5	0.0
Tampico pearlymussel	20	abundant	57.1
Texas fatmucket	10	abundant	28.6
Southern mapleleaf	4	many	11.4
Texas pimpleback	1	none	2.9

This was the only location where Texas fatmuckets, endemic to Central Texas, were found alive during 1992 and 1993 surveys. Living specimens were found here between cracks in bedrock slabs where they often crawled as far in as their shell size would allow; none were taken in other substrate types. Additionally, this was one of only three locations where Texas pimpleback, also endemic to Central Texas, was found alive in 1992 and 1993. Both species appear to have declined dramatically in recent decades.

Elm Creek upstream of Elm Creek Lake, first low-water crossing upstream of Elm Creek Lake, Runnels County, 5 August 1993:
First crossing upstream of Elm Creek Lake, county road crossing:

This area was wide and deep (impoundment influence by the dam at Elm Creek Lake downstream) with rock rubble along the low-water crossing and soft muddy banks. The site was used as a dumping site for trash. The area received only a brief shoreline examination. Tampico pearlymussel, southern mapleleaf, and Asian clam shells and fragments were present.

Elm Creek Lake, Ballinger City Park, Ballinger, Runnels County, 5 August 1993:
This small impoundment located just upstream of the confluence of Elm Creek with the Colorado River was sampled by wading and snorkeling. Deep layers of sand and gravel mixed with mud had been deposited along the dam; mud and sand bars lined banks upstream of the dam. Apparently the same floods which deposited substrate materials immediately behind the dam also deposited numerous unionids and Asian clams here as well. Although some shells were taken, collections focused on living specimens. Asian clams were abundant and fingernail clams (living and shells) were present:

Elm Creek Lake; non-quantitative samples

Species	*N* live	*N* shell	Percent (live)
Paper pondshell	1	0.0	1.4
Tampico pearlymussel	57	abundant	82.6
Southern mapleleaf	11	many	15.9
Squawfoot	0	0.5 (very old)	0.0

Elm Creek downstream of Elm Creek Lake dam, Ballinger City Park, Runnels County, 5 August 1993:
Wading and hand collection here indicated primarily bedrock bottom with some cobble and gravel; however, some sand and mud areas were present behind a small island located in mid-stream. Numerous shells from Tampico pearlymussel, fragile papershell, southern mapleleaf, and Asian clam were present in the area. Several living individuals of each of the above species were found. Many shells showed evidence of having been opened by anglers or musselers. Because large numbers of mussels were present in shallow water immediately upstream of the dam, shell found both up- and downstream this dam were likely generated by anglers seeking mussels for bait. Pearlers would not likely have left such large numbers of Tampico pearlymussels at a shallow, easily-harvested site.

North Concho River, mussel sanctuary between Sterling, Sterling County, and Water Valley, Tom Green County, private Ranch, mid-way between Sterling and Water Valley, 5 July 1993:
No living unionids were found. However, relatively recent fragments of paper pondshell and fragile papershell were located, suggesting both species may persist somewhere upstream. Shells of fingernail clams were relatively abundant in mud banks, but no living individuals were taken. Subfossil shells of threeridge, golden orb, pistolgrip, and Texas lilliput were common in a deposit within a mud and gravel bank above present stream level; several fragments which may have been false spike were also found in this deposit. This section of river was shallow with limited flow. The land owner reported it often dried up completely during hot summers; however, he also indicated permanent water did occur

further upstream at Sterling (possibly the source of recent shell fragments found here). This area once supported populations of large, long-lived, slow-growing unionids, but droughts and scouring during floods have apparently extirpated all but a few thin-shelled, fast-growing, short-lived species which are tolerant of environmental disruption.

North Concho River, mussel sanctuary at Water Valley Park, County Road 2034, Water Valley, Tom Green County, 5 August 1993:
The lower end of the North Concho River sanctuary at this point appeared to contain excellent mussel habitat, but no living bivalves or shells from unionids were found. Recently-dead shells of Asian clam were present in some areas. The substrate was typically mud and fine gravel with water depths of 1-2 m; downstream of the sanctuary the river narrowed and flowed through gravel riffles. Woodlands bordered the river with ranch lands beyond. Local residents indicated this area had been completely dry during a drought several years earlier. Several oil drilling and pumping wells are located upstream and local ranch lands are likely sprayed with herbicides or pesticides occasionally, but no particular sources of pollution were noted. This location could be used as a reintroduction site, but the potential of future drying during droughts remains a possibility.

Middle Concho River, State Highway 67 to Twin Buttes Reservoir, 11 May and 5 July 1993:
A brief examination of the river just downstream of State Highway 67 in May by snorkeling produced no specimens; however, river levels were very high and effective sampling was not possible. The bottom was mud and appeared to be good mussel habitat. This site and others down to Twin Buttes Reservoir was sampled by brail in July. A single bleufer was taken in six 100-m brail hauls.

Dove Creek, County Road 2325 upstream of Twin Buttes Reservoir, Tom Green County, 11 May 1993:
Depths averaged 1.0-1.5 m over cobble and mud bottoms. Asian clam was abundant but no unionids were found. This site had been examined following a report of Texas fatmucket being found here several years earlier.

Spring Creek, small park impoundment and creek downstream of County Road 2325 upstream of Twin Buttes Reservoir, Tom Green County, 11 May 1993:
The impoundment had depths to about 2 m and a substrate of cobble with mud and gravel along the shoreline. Relatively-recently dead shells from Texas fatmucket (8 pair of valves) and paper pondshell (6) were found; Asian clams were abundant. The creek immediately downstream of the impoundment was mostly boulders and cobble and shallow waters. A single pair of valves from a Texas lilliput was taken; Asian clams were present. No living unionids were found at either location.

Twin Buttes Reservoir, Tom Green County, 5 July 1993:
Attempts to brail the canal between the two main reservoir pools and the flats adjacent to the canal in the north pool were unsuccessful. High

winds prevented efforts to keep the brail on the bottom and collection attempts were ineffective. Additionally, local biologists reported this area had been dry two years earlier, suggesting mussel concentrations likely occurred in much deeper waters.

Concho River, 3-4 km upstream of Kickapoo Creek, impoundment on Dodson Ranch, Concho County, 22 June 1993:
Wading and snorkeling the area immediately upstream of the dam found a heavy cobble bottom covered with leaves and sticks from terrestrial vegetation. Depths reached over 2 m. No bivalves were found.

Concho River, 3-4 km upstream of Kickapoo Creek, downstream of the dam on Dodson Ranch, Concho County, 22 June 1993:
Wading and snorkeling found mostly bedrock and cobble bottom with depths less than 1 m. The only living bivalves were Asian clams. A gravel bar downstream of the dam produced valves of paper pondshell (4 valves), fragile papershell (2), and southern mapleleaf (10); Asian clam valves were abundant.

Concho River, 3-4 km upstream of Kickapoo Creek, about 200 m downstream of Dodson Ranch impoundment, Concho County, 22 June 1993:
This stretch of river bottom consisted of solid, deeply-grooved bedrock with mud and slit accumulations in the grooves. Depths were less than 0.5 m. Asian clams (living and shells) and fingernail clam shells (none alive) were extremely abundant in these deposits. No unionids were found.

Concho River, 1 km upstream of Kickapoo Creek, Dodson Ranch, 22 June 1993:
The substrate was cobble, gravel, gravel and mud, and mud along the river banks with depths to about 1.5 m. Areas of bedrock and boulders were present at some locations. Asian clams were present. Unionids were found here in a gravel bar downstream of a mid-river island.

Concho River, 1 km upstream of Kickapoo Creek; non-quantitative samples

Species	*N* live	*N* shell	Percent
Fragile papershell	4	5.0	28.1
Southern mapleleaf	9	8.0	53.1
Texas pimpleback	1	0.0	3.1
Bleufer	1	4.0	15.6

Concho River, sanctuary 2 km upstream of Paint Rock, Concho County, 22 June 1993:
This site was sampled by wading with several additional 0.25-m^2 grid samples. The location was approximately in the center of this sanctuary and had long stretches of bedrock riffles upstream with little or no good mussel habitat. However, downstream of the last major bedrock shelf, mud and silt accumulated on the north side of the river and provided good mussel habitat; central and southern river areas were bedrock and heavy cobble. Asian clams were extremely abundant; indeed, a major portion of the substrate in which unionids were living consisted of living Asian clams and their shells. Unionids taken in random collections included:

Concho River, 2 km upstream of Paint Rock; non-quantitative samples			
Species	*N* live	*N* shell	Percent
Paper pondshell	0	1.0	1.3
Fragile papershell	9	11.0	25.8
Southern mapleleaf	28	14.0	54.2
Texas pimpleback	12	0.0	15.5
Bleufer	1	1.5	3.2

Through 1992 and 1993 survey work, Texas pimpleback was found alive at only three locations (12 at this site, one specimen upstream of this sanctuary, and one in Elm Creek, Runnels County). This species which is endemic to central Texas appears to be declining dramatically in many areas of its range. The presence of reproductively-active adults (determined during subsequent examination of these specimens) within a designated sanctuary is encouraging.

Grid samples included one taken in a high-density area and one in a low-density area of Asian clams. Sample sites were excavated down to depths of about 20 cm. Only Asian clams, fragile papershells, and their shells were taken in these samples with the following results:

Concho River, 2 km upstream of Paint Rock; 0.25-m^2 grid samples			
Species	*N* live	*N* shell	N/m^2
	High-density sample		
Asian clam	365	197.0	2,248
Fragile papershell	0	4.0	16
	Low-density sample		
Asian clam	45	3.5	194

Concho River, about 200 m upstream of Paint Rock dam (just downstream of the sanctuary discussed above), Concho County, 22 June 1993:
Snorkeling here found mud over bedrock bottoms to depths of 2-3 m. No bivalves were found. Areas immediately downstream of Paint Rock dam were largely fast water over bedrock and concrete slabs leading into gravel bars in reaches further downstream; because of apparent lack of good mussel habitat, this area was not sampled.

Colorado River, State Highway 503, downstream of O. H. Ivie Reservoir, 22 June 1993:
Wading and snorkeling at this site found bottom primarily of mud and mud and gravel with water depths 1.0-2.5 m. Two living fragile papershells were found and Asian clams were present. This appeared to be a potentially good mussel habitat site but apparently few were present. Construction of the O.H. Ivie Reservoir dam upstream may have made negatively impacted unionids downstream prior to completion. The mud and gravel present during our examination may actually be relatively recent material from the O.H. Ivie site. Fragile papershell tolerates disturbed areas and may have either survived the construction period or

be reinvading the area. Regardless, this location could apparently support mussels and could represent a reintroduction site for TPWD efforts.

Brady Lake, McCulloch County, 21 July 1993:
Efforts to sample this reservoir were thwarted by recent, dramatic increases in water level which placed mussels at depths too great to easily examine. Areas which could be waded or snorkeled were covered with terrestrial shrubs or heavy rock and bolder outcroppings. Examination of one small cove produced a pair of valves from paper pondshell and several Asian clams.

Brady Creek, Brady City State Park, Brady, McCulloch County, 21 July 1993:
This creek had very slow flow rates when examined with deep, soft mud bottoms, large amounts of trees and branches from surrounding woodlands, and signs of general anoxic conditions. Two living paper pondshells were taken and several of their valves were found on the creek bank where they had apparently been left by predators. Asian clams were present in small numbers.

San Saba River, County Road 1311, Menard County, 18 May 1993:
The upper limit of this mussel sanctuary, which was previously examined in 1992 (Howells 1994), was visited only briefly on a single occasion in 1993. Conditions and species composition was essentially the same as reported in 1992; however, substantially less shell was apparent.

San Saba River, State Highway 87, McCulloch County, 21 July 1993:
The lower reaches of this mussel sanctuary were comprised almost completely of solid bedrock substrate with some sand and silt accumulation between rock slabs. Only Asian clam was found alive. Subfossil shells and fragments of threeridge, Tampico pearlymussel, fragile papershell, an unidentified pimpleback, and false spike were found. Although the area from State Highway 87 upstream to at least 2 km appeared a undesirable mussel habitat, local musselers have indicated pockets of mussels do continue to occur in this area. Indeed, recovery of pieces of yellow cowlily (Nuphar) which requires a rich, soft, highly-organic substrate were found drifting with the current here, suggesting more acceptable mussel habitat likely does occur upstream within the sanctuary.

Lake Brownwood, Brown County, fall 1993:
Musselers who visited this reservoir sent one yellow sandshell and three Texas lilliput specimens to HOH for identification. They reported species composition here similar to Nasworthy Reservoir, Tom Green County (Howells 1994).

Langes Mill Creek, Gillespie County, 21 July 1993:
This small, spring stream was examined but no bivalves were present. Substrates of bedrock and cobble in addition to propinquity of the stream to its spring source indicated undesirable mussel habitat.

Lake Buchanan, from Garrett Island in the upper reaches to the dam, Llano and Burnet Counties, visited several times August through December 1993: This reservoir was examined in 1992 shortly after water levels had increased about 10 m over previous recent levels. This dramatic increase in water level placed unionids at depths that could not be sampled at the time. However, during the interim, unionids had sufficient time to crawl into shallow waters where they were exposed in late summer and fall 1993 as reservoir levels again started to fall.

Coves on the SW and SE sides of the lake: A number of unionid species were collected here and Asian clams were abundant. All species were represented by juveniles, in some cases very small juveniles, indicating despite low water levels in previous years, successful reproduction had occurred. Indeed, except for two bleufers and a giant floater which were large, old adults, all specimens collected were older juveniles or young adults. In general, only living specimens were collected including:

Lake Buchanan, SW and SE lake coves; non-quantitative samples

Species	*N* live	*N* shell	Percent
Threeridge	2	0.0	1.0
Giant floater	1	0.0	0.5
Tampico pearlymussel	201	0.0	95.7
Southern mapleleaf	3	0.0	1.4
Bleufer	3	0.0	1.4

Garrett Island, upper lake: Similar collections were taken on and in the vicinity of Garrett Island. Species composition and size distribution were similar to that observed in the lower lake, except that fragile papershell was only taken here:

Lake Buchanan, Garrett Island; non-quantitative samples

Species	*N* live	*N* shell	Percent
Threeridge	9	0.0	11.1
Giant floater	1	0.0	1.2
Tampico pearlymussel	53	0.0	65.4
Fragile papershell	2	0.0	2.5
Southern mapleleaf	8	0.0	9.9
Bleufer	8	0.0	9.9

These sites were visited several times throughout the fall in efforts to obtain juveniles for related research projects. Species composition and size distribution remained essentially unchanged throughout this period. Opened Tampico pearlymussel shells at many sites were evidence that musselers had been harvesting this species for pearls despite most specimens being below legal minimum harvest size.

Pedernales River, unnamed road crossing south of Fredericksburg, Gillespie County, 20 August 1993:
This site contained bedrock and heavy cobble. No good mussel habitat was evident and no unionids were found. Several Asian clam valves were present.

Pedernales River, Jung Road crossing, Gillespie County, 12 October 1993:
Only bedrock, cobble, and deep-shifting sand was present and Asian clams were the only bivalves present.

Pedernales River, State Highway 1623 crossing north of Stonewall, Gillespie County, 12 October 1993:
This location contained deep-shifting sands, cobble, and heavy gravel; no good mussel habitat was evident. Asian clams were the only bivalves observed. A local resident had reported mussels present here just prior to this survey; however, his observations were likely either based on misidentification of Asian clams or based on unionids that inhabited this area years earlier, but which are no longer present.

Pedernales River, LBJ State Park, up- and downstream of the impoundment dam, Gillespie County, 12 October 1993:
The substrate both up- and downstream of this impoundment was solid bedrock without good mussel habitat. Only a few Asian clam valves were collected.

Pedernales River, Johnson City Lake, Blanco County, 3 June 1993:
This impoundment had a substrate of mud and cobble in shallower waters and silt over leaves and sticks in deeper waters. Wading and snorkeling this area produced only abundant Asian clams; no unionids were found.

Pedernales River, Pedernales Falls State Park, Blanco County, 3 June 1993:
The river in this area was sampled by wading and snorkeling (1) upstream of the main waterfalls, (2) downstream of the main waterfalls, (3) between the main waterfalls and the swimming area downstream, and (4) within the swimming area. No living or recently-dead unionids were found; Asian clams were present throughout this area. Several long-dead shell fragments from Texas fatmucket were taken. Much of this area is now bedrock, cobble, and deep-shifting sands without good mussel habitat. Decades earlier, a number of unionid species occupied this area (H.D. Murray, Trinity University; pers. comm.). A visitor to the park reported finding a living yellow sandshell in a small muddy pocket within the swimming area in late September 1993 (identified by examining a labelled shell collection). Even if this report is valid and mussels may not have been totally extirpated from this area, certainly very few remain.

Onion Creek, Austin, Travis County, 3 June 1993:
Collections made from McKinney Falls State Park downstream to the State Highway 24 crossing failed to produce living unionids. Upper reaches of the stream within the state park were largely bedrock and cobble, often with extensive growths of filamentous algae indicating high nutrient input to the system. A single valve from a Texas lilliput was the only unionid remains found; Asian clams were abundant. Lower reaches downstream of State Highway 24 contained mud and gravel (acceptable habitat) but totally lacked living bivalves. Presumably years of association with the city of Austin and a local military base have had numerous negative environmental impacts on the system. Mussels appear extirpated here. Historical reports of speckled pocketbook (Lampsilis

streckeri), now a federally-endangered species, from this stream are believed by some to be misidentified Texas fatmuckets. However, this issue is now academic.

Colorado River, downstream of Austin at Farm to Market Road 973 upstream of the confluence of Onion Creek, Travis County, 3 June 1993:
This area was sampled by wading and snorkeling. The substrate was gravel, cobble, and deep-shifting sand. Flow rates were swift and the hard or unstable bottom did not provide good mussel habitat. However, shells of Tampico pearlymussel and bleufer were common in the area, suggesting populations may occur elsewhere upstream. Asian clams were present.

Beuscher State Park Lake, Bastrop, Bastrop County, 24 May 1993:
Examination of the shoreline of this small, state park lake produced only a single valve of Texas lilliput and fragments of another unidentified unionid. No significant unionid populations appear to occur here.

Giddings State School Lake, Giddings, Lee County, 24 May and 1 October 1993:
Wading this small, farm-impoundment with a mud and fine-gravel substrate in May produced:

Giddings State School Lake; non-quantitative samples

Species	*N* live	*N* shell	Percent
Pond mussel	1	0.0	1.9
Texas lilliput	26	22.0	88.9
Tapered pondhorn	4	1.0	9.3

A second, more-intense collection effort at this pond in October produced:

Giddings State School Lake; non-quantitative samples

Species	*N* live	*N* shell	Percent
Giant floater	5	10.0	6.2
Paper pondshell	5	5.0	4.2
Pond mussel	0	78.0	32.5
Texas lilliput	59	40.0	41.3
Tapered pondhorn	13	25.0	15.8

The October samples were biased toward pond mussel and tapered pondhorn which were taken to provide tissue for electrophoretic analysis and shell for reference collections. Texas lilliput was unquestionably the numerically most-numerous taxon. Both giant floater and paper pondshell had been overlooked on the first visit. Among these pond mussels, three valves may have been male; otherwise, all were females.

Winedale Pond (Cummings Creek drainage), Fayette County, 10 April 1993:
In 1992, a single Texas lilliput was collected here; however, when reexamined in 1993 during very low water conditions, only a few shell fragments of this species could be located.

Guadalupe River Drainage

Guadalupe River, downstream of Ingram Lake dam, Kerr County, Texas, 28 October 1993:
Three valves of long-dead Texas lilliputs were found here. Bottom is primarily bedrock and heavy cobble without good mussel habitat and subject to heavy scouring during floods.

Guadalupe River, Lemos Street crossing, Kerrville, Kerr County, 16 May 1993:
Upstream of this crossing the substrate is heavy cobble with a shallow covering of silt; downstream of stretches of bedrock and rubble are replaced by heavy cobble. No good mussel habitat is present and severe scouring occurs during flooding. A single, long-dead valve of Tampico pearlymussel was found on a gravel bar and Asian clams were abundant.

Block Creek, State Highway 473 north of Comfort, Kendall County, 27 January 1993:
The substrate at this site is bedrock with a shallow covering of silt. No bivalves were found.

Guadalupe River, Comfort, Kendall County, 12 January 1993:
The river in this area is largely gravel, cobble, and bedrock with little good mussel habitat. Three subfossil valves from threeridges were found. Asian clam was present.

Guadalupe River, railroad bridge downstream from Comfort, Kendall County, 27 January 1993:
The river bottom in this area is bedrock and cobble. Subfossil fragments of threeridges were present as were Asian clams.

Guadalupe River, State Highway 311 crossing, Comal County, 12 October 1993:
The river bottom at this site was bedrock and cobble. No bivalves were found.

Guadalupe River, first low-water crossing upstream of Canyon Reservoir, Comal County, 12 October 1993:
At this location, the river cuts several feet into solid bedrock and appears more like a canal than a natural river. No acceptable mussel habitat was and no bivalves were found.

Guadalupe River, about 1.5 km downstream from Canyon Reservoir dam, Comal County, 26 October 1993:
This section of river contains rock, cobble, and gravel with little good mussel habitat. A subfossil valve from a pistolgrip and several from threeridges were found. Asian clams were present.

Guadalupe River, State Highway 123 crossing, Seguin, Guadalupe County, 26 May 1993:
Although this section of river bottom (upper portions of a mussel sanctuary) consists of mud and gravel, sampling was not possible during the survey of this area. Dam operation upstream had almost completely blocked off flow; only a minor trickle down one bank continued. Such

occasional flow obstructions not only leave local unionids exposed to the air and predators, but to the impact of severe scouring when flow is abruptly resumed.

Guadalupe River, about 2 km upstream of State Highway 80 downstream of Seguin, Guadalupe County, 26 May 1993:
Five 200-m brail hauls in this sanctuary area failed to collect any unionids. Substrates were largely sand and gravel with occasional gravel bars. Water management practices described above have contributed to extensive erosion of sand banks which in turn have covered the river bottom here. Examination of gravel bars produced subfossil and long-dead shells of threeridges, Tampico pearlymussels, fatmuckets (Texas, Louisiana, or both), yellow sandshell, washboards, southern mapleleafs, golden orbs, false spike, and pistolgrips. Among these, only single specimens of threeridge, washboard, and golden orb were relatively-recently dead. Many specimens were highly polished from sand blasting associated with erosion of sand banks following sudden, high-volume water releases upstream.

Guadalupe River, about 2 km downstream of State Highway 80 downstream of Seguin, Gonzales County, 26 May 1993:
Two 200-m brail hauls in this area produced no unionids. River banks and bottom were similar to the above site. Examination of shell remains on gravel bars produced similar species composition. A large deposit of threeridge and washboard shells located on one eroding island provided indication of unionid populations that occurred here in the recent past.

Lake Gonzales, Gonzales County, 26 May 1993:
Water retention upstream resulted in low lake levels at the time of survey. A bed of mussels, predominately threeridges, located on a mud-bottom area here in 1992 was reexamined by brail, 0.25-m^2 grid, and random-hand collection. Three 200-m brail hauls over this bed failed to take any unionids; however, grid and hand collection demonstrated the bed to still be present.

Lake Gonzales; mean of four 0.25-m^2 grid samples

Species	N/m^2	Percent
Threeridge	8.00	26.0
Giant floater	2.70	8.8
Tampico pearlymussel	1.32	4.3
Asian clam	18.7	60.9

Lake Gonzales; non-quantitative samples

Species	*N* live	*N* shell	Percent
Threeridge	42	1.0	87.8
Giant floater	1	1.0	4.1
Southern mapleleaf	4	0.0	8.2

Failure to collect unionids by brail despite their presence here likely related to the extremely shallow waters (0.75 m) and slow flow rate which necessitated using the boat engine to pull the brail (rather than drifting with the current). Presumably engine noise and prop wash

frightened mussels into closing before the brail hooks arrived. Brail use in still, shallow waters is apparently unproductive.

Guadalupe River, downstream of Lake Wood dam, Gonzales County, 17 August 1993:
Sampling here included hand collection (Asian clams not included) and use of 0.25-m^2 grid samples. Most areas were less than 1.0 m in depth and had gravel and cobble bottoms.

Guadalupe River downstream of Lake Wood; mean of three 0.25-m^2 grid samples

Species	N/m^2	Percent
Threeridge	8.00	74.4
Washboard	2.67	24.8
Asian clam	0.08	0.7

Guadalupe River downstream of Lake Wood; non-quantitative samples

Species	*N* live	*N* shell	Percent
Threeridge	14	0.0	73.7
Tampico pearlymussel	1	0.0	5.3
Washboard	3	0.0	15.8
Pistolgrip	0	1.0	5.3

Guadalupe River, State Highway 183 crossing downstream of Lake Wood, Gonzales County, 18 August 1993:
Wading and hand collection produced the following species (Asian clams not included):

Guadalupe River at State Highway 183; non-quantitative samples

Species	*N* live	*N* shell	Percent
Threeridge	7	5.5	36.2
Washboard	16	5.0	60.9
Yellow sandshell	1	0.0	2.9

Guadalupe River, lower reaches, Calhoun County, October 1993:
Attempts to sample unionids during fish surveys of this area were thwarted by steep banks and deep waters. Sampling with brail or SCUBA will be necessary in the future.

Green Lake, Calhoun County, 7 July 1993:
This area was examined to determine access prior to formal sampling in the future. Strecker (1931) reported uniquely large, pale round pearlshells inhabiting this lake which may represent the southwestern-most range limit for it. However, this site seems not to have been examined since. The only bivalve shells found during examination of a boat ramp downstream were marine and estuarine species.

Blanco River, several km of river upstream of Blanco State Park, Blanco County, 12 October:
This area was briefly examined, but not sampled. Substrate here was largely bedrock and without good mussel habitat.

Blanco River and impoundments, Blanco State Park, Blanco County, 12 October 1993:
Areas within and downstream of three impoundments were examined by wading and snorkeling. Except for limited bank areas of mud, bottoms were exclusively bedrock. Within the impoundments, Chara covered most or all of the bottom. Good mussel habitat was not present and only Asian clam was found.

Blanco River, midway between Valley Ford and Wimberly, just slightly NE of Hays County line, Hayes County, 4 July 1993:
The river in this area is primarily bedrock, cobble, and gravel without good mussel habitat and only Asian clams were found. However, a pair of valves from a gravelbar morph of Texas pimpleback was found here. This specimen had been dead for an extended period prior to collection.

Blanco River, 0.5-1.0 km upstream of the confluence with the San Marcos River, 17 August 1993:
Examination of this section of river found extensive gravel and cobble bars with evidence of extensive scouring during floods. No unionids were found; Asian clams were present.

San Marcos River, upstream of U.S. Highway 35, Hays County, 27 January 1993:
The river at this site has areas with mud, sand, gravel, and cobble bottoms at depths to about 4 m with current velocities from very slow to swift; heavy vegetation is present in some areas. Only Asian clams were present.

San Marcos River, first low-water crossing downstream of the Blanco River, Hays County, 8 June 1993:
Bedrock and cobble bottoms with relative swift currents were present at this site. No unionids were found; Asian clams were present.

San Marcos River, Sculls Crossing, Guadalupe and Caldwell counties, 8 June 1993:
Bedrock and cobble bottoms with relative swift currents were present at this site. No unionids were found; Asian clams were present.

San Marcos River, State Road 1979 crossing, Guadalupe and Caldwell counties, 8 June 1993:
Bedrock and cobble bottoms with relative swift currents were present at this site. No unionids were found; Asian clams were present.

San Marcos River, State Road 1977 crossing, Guadalupe and Caldwell counties, 8 June 1993:
A dam about 0.5 km downstream creates a small impoundment at this site. Private land blocked access and this location was not sampled. The impounded nature of this area suggests mussels may be able to survive here during floods that scour other areas in this system. Conversely, it may act as a catch basin for mud and silt making the bottom inhospitable to unionids.

San Marcos River, State Highway 20 crossing at Fentress, Guadalupe and Caldwell counties, 8 June 1993:
The substrate at this site was mostly gravel with fairly swift currents. A backwater area with a mud and sand bottom behind a gravel bar was sampled by snorkeling. This backwater area contained abundant Asian clams. A single, long-dead unionid valve was found on the adjacent bar; it was badly eroded but may have been that of Tampico pearlymussel.

San Marcos River, low-water crossing at Prairie Lea, Guadalupe and Caldwell counties, 8 June 1993:
This area was dominated by bedrock and extensive gravel bars. Private land blocked access and prevented sampling; however, good mussel habitat was not in evidence.

San Marcos River, first low-water crossing downstream of Prairie Lea, Guadalupe and Caldwell counties, 8 June 1993:
The substrate at this site contained extensive gravel beds and rather swift current. Subfossil fragments of threeridges were found along one bank; Asian clams were present. A local angler interviewed at this site indicated the area once held abundant mussel populations, but reported it had been many years since living specimens had been seen.

San Marcos River, U.S. Highway 90 W of Luling, Guadalupe and Caldwell counties, 8 June 1993:
This broad, deep (about 5 m) area sampled by snorkeling had mud and sand or mud and gravel bottoms with a gravel bar downstream. Although it appeared to hold reasonably good mussel habitat, no unionids were found; Asian clams were present. A local angler interviewed during the survey indicated the highway bridge had been constructed only about two years earlier, and extensive environmental modification had occurred at that time. He further reported that location occasionally scoured badly during floods. The angler also reported periodic dumping of oil field contaminants into the river upstream of this location.

San Marcos River, Luling City Park downstream of an old cotton gin dam, Luling, Guadalupe and Caldwell counties, 8 June 1993:
Much of the area downstream of this dam has swift current and bedrock bottom. A backwater area with a gravel and mud bottom on the east side of the river was examined by wading and snorkeling. Subfossil fragments of an unidentified quadrulid were found as were a small number of Asian clams. Downstream of this area, river banks become steep and sandy; the river narrows and runs rapidly over a gravel and cobble bottom with little evidence of good mussel habitat.

San Marcos River, from U.S. Highway 90A downstream to confluence with the Guadalupe River, Gonzales County, 17 August 1993:
This area was characterized by collapsing sand and mud banks. Shallow areas were waded and snorkeled, and deeper areas were sampled by brail. No living bivalves were found. Several unidentifiable, subfossil unionid fragments were located.

San Antonio River, San Antonio Riverwalk, Bexar County, 6 January 1993:
Annual draining of the riverwalk area for cleaning and archeological surveys permitted access to exposed substrates. Bottom was mud, sand, silt, or gravel, depending upon location, with evidence of black, organic material suggesting probable anoxic periods during warm summer months. Apparently long-dead valves of one Texas lilliput, and fragments of Tampico pearlymussel and Texas pimpleback were found. Asian clams were abundant. Archaeologists who examine this area annually did not report finding unionids or their shells.

San Antonio River, Espada Dam, SW of San Antonio, Medina County, 6 January 1993:
Both the river and riverine impoundments in this area had bedrock and cobble bottoms without good mussel habitat. No unionids were found; Asian clams were present.

Elmendorf Lake, San Antonio, Bexar County, 10 November 1993:
This small, city impoundment had been drained prior to examination. No bivalves were found.

Millers Pond Park Lake, San Antonio, Bexar County, 10 November 1993:
Surveys of the shoreline at this small, city impoundment produced no bivalves.

Southside Lions Park Lake, San Antonio, Bexar County, 10 November 1993:
Only a single pair of valves of paper pondshell were found when this small, city impoundment was examined.

Boerne City Park Lake on Cibilo Creek, Kendall County, 29 May 1993:
The bottom of this small impoundment was primarily mud and gravel. Only Asian clams were found.

Cibolo Creek, about 0.25 km downstream of Boerne City Park Lake, Kendall County, 29 May 1993:
The bottom of this small stream was gravel and rock with some sand. Only Asian clams were found.

Cibolo Creek, Boerne City Natural Area, Kendall County, 29 May 1993:
This stretch of stream consists of a sand, gravel, and rock bottom flowing among baldcypress trees which line the bank. Only Asian clams were found.

Cibolo Creek, three low-water crossing between U.S. Highway 281 and Garden Ridge, Bexar and Comal counties, 8 May 1993:
These areas were dry when examined and have only intermittent flow. No bivalves were found.

Cibolo Creek, State Highway 78, Bexar and Comal counties, 8 May 1993:
This area had a mud and gravel bottom with very limited flow. A single living paper pondshell was the only bivalve found.

Cibolo Creek, low-water crossing about 2.5 km S of Schertz, 8 May and 25 September 1993:
The substrate at this site included areas of mud, sand, gravel, and cobble with slow to swift currents. Wading and snorkeling in May produced the following unionids:

Cibolo Creek, about 2.5 km S of Schertz; non-quantitative samples			
Species	*N* live	*N* shell	Percent
Giant floater	0	1.0	8.3
Tampico pearlymussel	1	0.0	8.3
Pond mussel	0	1.0	8.3
Southern mapleleaf	4	0.0	33.3
Tapered pondhorn	1	3.5	41.7

Asian clams were abundant. A second examination of this site in September found only recently dead shells. Among these, were many giant floaters and tapered pondhorns, and three paper pondshells; Asian clams were again abundant. This area appears to experience scouring during floods. Additionally, a small pond (water-filled borrow pit) adjacent to the stream many be a source of some unionid introductions during periods of high water.

Cibolo Creek, crossing at U.S. Highway 35, Bexar and Comal counties, 8 May 1993:
This site was dry when examined. No bivalves were found.

Cibolo Creek, about 1 km up- and downstream from U.S. Highway 10, Bexar and Comal counties, 8 May 1993:
This location appeared to have good mussel habitat with mud and clay bottoms and occasional gravel, slow current, and limited growths of aquatic macrophytes. Asian clams were abundant and the following unionids were taken:

Cibolo Creek, about 2.5 km south of Schertz; non-quantitative samples			
Species	*N* live	*N* shell	Percent
Tampico pearlymussel	1	1.0	66.7
Southern mapleleaf	0	1.0	33.3

Reasons for the limited numbers and diversity of unionids here may reflect tendency to develop anoxic areas during warm summer temperatures or impact from a major interstate highway.

Cibolo Creek, about 3 km downstream from State Highway 97, Stockdale, Wilson County, 8 may 1993:
This area had sand, gravel, cobble, and rock bottoms with moderate flow rates, but also had sand and silt mixed in with these substrates. Shells were abundant, but only Asian clams were found alive. Shells included some specimens that were relatively-recently dead to others that were nearly subfossil. Unionids represented here included: threeridge, Tampico pearlymussel, yellow sandshell, washboard, southern mapleleaf, golden orb, and at least one, and possibly both fatmucket species (too weathered for accurate identification).

Cibolo Creek, low-water crossing at State Road 2538, New Berlin, Wilson County, 8 May 1993:
Gravel bottom dominated this area. Shells, mostly fragments, were present with species composition similar to the above site; however, none was alive.

Cibolo Creek, State Highway 775, La Vernia, Wilson County, 8 May 1993:
This location had gravel bottoms and swift currents with numerous shells; however, only Asian clams were alive. Representative unionids included:

Cibolo Creek at State Highway 775; non-quantitative samples

Species	*N* live	*N* shell	Percent
Threeridge	0.0	6.0	37.5
Giant floater	0.0	fragments	present
Tampico pearlymussel	0.0	3.0	18.8
Louisiana fatmucket	0.0	3.0	18.8
Yellow sandshell	0.0	0.5	6.3
Southern mapleleaf	0.0	1.5	12.5
Golden orb	0.0	0.5	6.3

Cibolo Creek, State Highway 887 just upstream of Panna Maria, Karnes County, 8 May 1993:
This area contained sandy bottoms and banks. Only shells were found at this site including:

Cibolo Creek at State Highway 887; non-quantitative samples

Species	*N* live	*N* shell	Percent
Threeridge	0.0	8.5	24.3
Paper pondshell	0.0	4.5	12.9
Tampico pearlymussel	0.0	4.0	11.4
Fatmucket (one or both species)	0.0	3.0	8.6
Yellow sandshell	0.0	1.0	2.9
Washboard	0.0	4.0	11.4
Southern mapleleaf	0.0	1.0	2.9
Golden orb	0.0	2.0	5.7
Tapered pondhorn	0.0	4.5	12.9
Texas lilliput	0.0	2.5	7.1
Sphaeriidae	0.0	several	present
Asian clam	0.0	several	present

Salitrillo Creek, crossing at State Highway 1604, Bexar County, 25 September 1993:
This small stream contained very deep and soft silt (> 2 m) with less than 1 m of water above. Only Asian clams were present, including some extremely large individuals.

Nueces River Drainage

Frio River, about 2 km downstream of Concan, Uvalde County, 23 May 1993:
This area consisted of solid bedrock bottoms with heavy boulders and

cobble. It experienced major scouring flooding in 1992. No bivalves were found. Local residents reported not finding bivalves in the river for many years.

Utopia City Park Lake, upper Sabinal River drainage, Utopia, Uvalde County, 23 May 1993:
Soft mud bottoms and heavy macrophyte growths on this small lake precluded good mussel habitat. Only two Asian clam valves were found. The river downstream of the dam at this site was bedrock and cobble, and no bivalves were found.

Nueces River, between U.S. Highway 59 and State Highway 72, cove on W side of the river, Live Oak County, 5 October 1993:
This location had mud bottom with some macrophytes. Earlier spraying to control water hyacinths was evidenced by a large number of dead and moribund plants. The area was sampled by wading and hand collection; Asian clams were abundant.

Nueces River cove between U.S. Highway 59 and State Highway 72; non-quantitative samples

Species	*N* live	*N* shell	Percent
Giant floater	5	1.0	42.9
Tampico pearlymussel	0	4.0	28.6
Yellow sandshell	1	1.0	14.3
Bleufer	1	0.0	7.1
Southern mapleleafs	0	1.0	7.1

Nueces River, between U.S. Highway 59 and State Highway 72, river island about 200 m downstream of cove, Live Oak County, 5 October 1993:
The downstream end of this island was sampled by wading and snorkeling with hand collection on the side adjacent to the main river channel. Asian clams were present, but less abundant than at the previous site.

Nueces River island downstream of cove between U.S. Highway 59 and State Highway 72; non-quantitative samples

Species	*N* live	*N* shell	Percent
Giant floater	3	0.0	9.4
Tampico pearlymussel	18	2.0	62.5
Yellow sandshell	2	4.0	18.8
Bleufer	0	2.0	6.3
Texas lilliput	0	1.0	3.1

Nueces River, between U.S. Highway 59 and State Highway 72, main river channel adjacent to and immediately downstream of an island about 200 m downstream of cove, Live Oak County, 5 October 1993:
Two 100-m brail hauls in this channel at about 6 m deep failed to collect any bivalves. However, pressure on the brail line indicated a bottom of very soft silt where most unionids would not be expected.

Lake Corpus Christi, cove at the KOA Camp Grounds, E shore of the reservoir, Live Oak County, 5 October 1993:
This area was sampled by wading and hand collection. Substrates

consisted of cobble near the cove mouth, but changed progressively to gravel, sand, mud, and finally silt toward the back of the cove. Dropping water levels left many unionids in very shallow waters. Asian clams were very abundant.

Lake Corpus Christi, cove at KOA Camp Grounds; non-quantitative samples			
Species	*N* live	*N* shell	Percent
Giant floater	8	4.0	14.1
Tampico pearlymussel	1	3.5	5.9
Yellow sandshell	14	7.5	25.9
Bleufer	27	8.0	29.4
Southern mapleleaf	3	3.0	7.1
Texas lilliput	1	13.5	17.6

A subsequent collection at another cove closer to the dam in November 1993 found these same species. However, Tampico pearlymussel was much more abundant at that location and several living paper pondshells and valves of golden orb were also collected. Species composition reported Murray (1978) in this reservoir during an earlier low-water period was similar to the present study, except bleufer was not found in the earlier survey. Because it is a large, easily-identifiable species not likely to be over looked, bleufer appears to be not only a recent introduction into this system but to be surviving and reproducing very well.

Lake Corpus Christi, upper reservoir flats, Live Oak County, 5 October 1993: This area was sampled by wading and hand collection in shallow waters (< 1 m). The bottom was mud and sand with emergent vegetation remains. Asian clams were present.

Lake Corpus Christi, upper reservoir flats; non-quantitative samples			
Species	*N* live	*N* shell	Percent
Giant floater	5	1.0	17.6
Tampico pearlymussel	1	0.0	2.9
Yellow sandshell	15	0.0	44.1
Southern mapleleaf	1	2.0	8.8
Bleufer	9	0.0	26.5

Rio Grande Drainage

Pecos River, at Grand Falls, Crane and Pecos counties, September 1993. Subfossil fragments of seven Tampico pearlymussels were found and sent to HOH for identification.

Rio Grande, Big Bend, Brewster County, 8-12 February 1993: No bivalves were taken during wading and hand-collection in this area. However, high water at the time of sampling could have placed unionids in deeper waters where they could not be sampled at the time.

SPECIES SUMMARY

Over 2,500 unionid specimens were obtained during 1993 field surveys. This included a total of 36 species (about 71% of the species reported in Texas). Species of sport and commercial importance (including Tampico pearlymussel, threeridge, and southern mapleleaf) were common or even abundant at some locations. Commercially-important washboards were not found in abundance anywhere in 1993; however, lack of diving gear precluded sampling many deep-water areas where this species might occur.

Rare or absent from both 1992 (Howells 1994) and 1993 surveys were most endemic species from the Rio Grande drainage and Central Texas. In the Rio Grande, no Rio Grande monkeyface, Mexican fawnsfoot, or false spike were found. Texas hornshell and Salina mucket were represented only by one shell of each species found in early 1992 near Big Bend (Howells 1994). In Central Texas, no specimens of Texas fawnsfoot were found, false spike was represented only by subfossil fragments, and golden orb was collected only as shells. Texas pimpleback was found alive at three locations (two of which produced only a single animal). Texas fatmucket was found alive at only a single site.

Flat floater was found in B.A. Steinhagen Reservoir in the Neches River drainage. This species was not found by Strecker (1931) earlier in the century, but has been expanding its range into Texas (advantaged by reservoir construction). Bleufer has also been introduced into the Nueces River drainage where it was not previously known to occur.

RIVER SYSTEM SUMMARY

Tributaries of the Red River in Lamar County, Texas, were found to contain a diverse array of unionids including Ouachita rock-pocketbook, a federally-endangered species not previously known outside Oklahoma and Arkansas. Caddo Lake on the Big Cypress River drainage was not sampled by TPWD, but specimens and comments submitted to HOH by musselers indicated unionid populations still remain there.

North, Middle, and South branches of the Sulphur River, White Oak Creek, and mainstream Sulphur River upstream of White Oak Creek were found to support few significant unionid populations. Many areas are channelized and lack good mussel habitat. Reports by musselers of major commercial harvest in the system (Howells 1993) must reflect areas further downstream not surveyed to date. Present mussel sanctuaries in this system largely protect only a limited number of species like fragile papershell and tapered pondhorn which tolerate environmental alteration.

The Sabine River has been only briefly surveyed in the lower reaches of the sanctuary downstream of Lake Tawakoni. Unionids were present at the site examined and likely also occur both up- and downstream as well.

The central reaches of the Neches River contained the most diverse assemblage of unionid species located in TPWD surveys to date. B.A.

Steinhagen Reservoir held 19 species and the Neches River immediately downstream of produced 11 species (22 total species collected). Another 12 or more species likely occur in this area but have not been taken in sampling to date. Few bivalves were found in the Angelina River and Sam Rayburn Reservoir; however, recent water level increases and flooding at the time of sampling confounded efficient survey efforts.

Some reservoirs on the upper Trinity River contain populations of commercially-important mussels. Most noteworthy was Cedar Creek Reservoir which supports a high-density population of southern mapleleafs. In the lower Trinity River downstream of Lake Livingston dam (a mussel sanctuary), most mussel populations appear to have been lost due to habitat modification associated in part to water management practices in the area. Historically-important Mussel Shoal Creek (Strecker 1931) still supports mussels in its upper reaches, but lack of access precluded examination of the central and lower portions of this stream.

Thus far the San Jacinto River has not been formally surveyed. However, specimens sent to HOH by musselers and telephone conversations with local residents indicate mussels are still present in Lake Conroe and Lake Stubblefield.

Several reservoirs in the central Brazos River basin support mussel populations. The Little Brazos River, which held a significant unionid assemblage in 1992 (Howells 1994), was found to have experienced major losses in 1993 due possibly to pollution. Upper reaches of the Little Brazos River will be surveyed in 1994 to determine how far upstream these losses occurred. Most of the Leon River was examined in 1993, but few living mussels were found. Shells found in the Leon River indicate a diverse mussel fauna once existed there but dramatic declines have occurred in recent years. Much of the Brazos River system remains to be surveyed.

The Colorado River basin has contrasting areas of significant mussel populations and other regions where unionids appear to have been extirpated. The upper Colorado River mainstream, the Concho River and associated reservoirs, and some small, local tributaries support a variety of mussel species as do reservoirs in the central Highland Lakes area (e.g., Lake Buchanan, Inks Lake, etc.). Stretches of the San Saba River, and apparently all of the Llano and Pedernales rivers seem to have completely lost their unionid faunas.

Similarly, mussels have been largely lost from the Guadalupe River upstream of Seguin. Divers in Canyon Reservoir report an occasional mussel (unverified and unsurveyed by TPWD to date) and several paper pondshells and one Texas lilliput (environmental-alteration tolerant species) were found in Ingram Lake, Kerr County; otherwise, only subfossil shell remains in this area. Lake Gonzales, Lake Wood, and the Guadalupe River downstream of Lake Wood still support populations of commercially-important species. Mussels also appear to have been extirpated from the Blanco and San Marcos rivers, the upper San Antonio River, and most of the Medina River.

Lake Corpus Christi and the Nueces River upstream of the lake support a

number of mussel species. However, commercially-important washboards and threeridges were not taken in sampling and southern mapleleaf is represented by limited numbers of rather small individuals. Pearl-producing Tampico pearlymussels and bleufers are rather abundant. Bleufer is apparently a recent introduction to this system.

Sites examined on the Rio Grande in 1992 and 1993 from Big Bend to Brownsville failed to produce living unionids. A few relatively-recent shells were found, but in general, the outlook for unionids in this system is not promising.

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Figure 1. Texas locations examined for the presence of freshwater mussels (Family: Unionidae) by Texas Parks and Wildlife Department Inland Fisheries staff in 1993 (dots) and where mussels were collected by other parties and sent to TPWD for examination (triangles).