Freshwater Mussels (Unionidae) of the Pimpleback-complex (*Quadrula* spp.) in Texas

by
Robert G. Howells

MANAGEMENT DATA SERIES
No. 197
2002

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

ACKNOWLEDGMENTS

Members of Texas Parks and Wildlife's Heart of the Hills Research Station provided review of this manuscript and assisted with statewide freshwater mussel surveys that helped provide the information summarized here. Dr. Kevin S. Cummings provided copies of several original species descriptions to assist with preparation of this report.

ABSTRACT

Freshwater mussels (Family Unionidae) are often morphologically plastic, with a great degree of ecophenotypic variation. Members of the pimpleback-complex (*Quadrula* spp.) are among the most variable and taxonomically perplexing of the family. This situation is particularly exacerbated in the isolated river systems that flow into the Gulf of Mexico east and west of the Mississippi River. In Texas waters, a number of forms appear distinct and taxonomically valid including: Texas pimpleback *Q. petrina*, golden orb *Q. aurea*, smooth pimpleback *Q. houstonensis*, and western pimpleback *Q. mortoni*. However, the taxonomic status of other forms in Texas remains unresolved.

Among these, pimpleback *Q. pustulosa* may be present in the Red River drainage of northern Texas, but corroborative genetic analysis to confirm identifications is lacking. The *Q. nodifera* forms, primarily of eastern Texas and Louisiana, may be phenotypes of western pimpleback, pimpleback, or taxonomically distinct, but this issue has remained unresolved for many years. In the Trinity River, members of the pimpleback-complex may resemble smooth pimpleback, western pimpleback, pimpleback, or even *Q. nodifera* forms, but again, conclusive identifications are unavailable. Finally, western pimplebacks from the Sabine and Neches rivers are morphologically distinct from those present in the San Jacinto River System and Buffalo Bayou; whether these differences are taxonomically significant has not been demonstrated.

Basic features of shell morphology and even preliminary electrophoretic analysis has proven insufficient to resolve these questions. More advanced genetic analytical techniques will be required. Accurately defining species and distributions is important in determining the conservation status of these mussels as populations and ranges decline. This manuscript summarizes information on Texas populations available to date.

INTRODUCTION

Taxonomists attempting to name and classify North American freshwater mussels (Family Unionidae) recognize many species as frustratingly polymorphic animals. Indeed, one may need to look to ichthyologists dealing with fishes like sticklebacks (Gasterosteidae) or whitefishes (Salmonidae, Coregoninae) to find similar situations where organisms appear to challenge any definition of what as species actually is. Physical variation among unionid species even within common waters of the Mississippi River Drainage Basin can be exceptionally great. Smaller, isolated river systems to the east and west of the Mississippi have provided still further cause for an increasing diversity in forms and species.

Morphological variation among quadrulid mussels of the pimpleback group (*Quadrula* spp.) presents some of the most confounding examples. Valentine and Stansbery (1971), referring to pimpleback *Q. pustulosa*, called it "one of the most bewildering species." Neck (1982) noted, "the plasticity of the shells of this group of taxa is truly maddening." Vidrine (1993) indicated "these very variable species create an enigma in species separation" and went on to state "separation of the *Q. pustulosa/mortoni/refulgens* complex defies any key in my experience."

Given the variable nature of mussels of this complex and number of unique, isolated river systems in Texas, it is not surprising that a degree of confusion and uncertainty exists regarding the taxonomic identity of some members of the pimpleback-complex in Texas. It is likewise not unexpected that a wide array of names have been attached historically to morphological forms of many pimpleback species or that the true disposition of many such names remains unresolved today.

Unfortunately, freshwater mussels are the most rapidly declining faunal group in North America (Neves 1993; Williams et al. 1993), including within Texas waters (Howells et al. 1997). Several Texas forms or species appear to have been reduced to fewer that half-a-dozen small populations. As numbers fall and ranges decrease, it becomes important to know whether a rare, endemic species is being threatened, or only an atypical localized form of a mussel that may be abundant elsewhere. Conchological shell features and soft tissue morphology are themselves not sufficient to resolve taxonomic questions with members of the pimpleback-complex. Preliminary electrophoretic analysis of genetic isozymes of Texas species also failed to provide definitive answers (discussed herein). Additionally, information provided in Freshwater Mussels of Texas (Howells et al. 1996) has become dated and new data has been developed since that book was published.

This manuscript was prepared to update current knowledge about this group in Texas and to assist others planning genetic analysis of the pimpleback-complex utilizing DNA studies. This paper itself is not intended to resolve species identification questions regarding all the forms and species of pimplebacks locally. Rather it is intended to update, correct, and summarize information from Texas to assist others in the field.

MATERIALS AND METHODS

Species descriptions and discussions presented by Simpson (1914), Strecker (1931), Vidrine (1993) and Howells et al. (1996, 1997) were reviewed and species terminology given in Williams et al. (1993) and Turgeon et al. (1998) was considered. Specimens obtained during freshwater mussel surveys conducted by Texas Parks and Wildlife's (TPW) Heart of the Hills Research Station (HOH) from 1992 through 2001 provided tissue samples and were used to expand available descriptions of local pimpleback species. Both published literature sources and HOH survey results were used to develop the distribution maps presented in this report.

In late 1993 and early 1994, horizontal gel electrophoresis was employed at HOH to examine isozymes of several pimpleback species. Methods generally followed those of Aebersold et al. (1987) and Shaklee and Keenan (1986). Buffers used included tris-citrate pH 7.0 and TEB (tris-citrate, EDTA, and boric acid) pH 8.0 in both gels and wells. Gels were run at 26-30 volts and 28-30 milliamps for 24 hours. Gels were run and banding patterns scored by a technician who, in the absence of previously established allele designations, recorded diagrammatic images of the patterns (Table 1).

Primary river systems in Texas are presented in Fig. 1. Probable historic ranges of pimpleback-complex species in Texas are given in Figs. 2-3 and known current distribution is shown in Fig. 4. Shell measurements (length, height, width, and lateral tooth length) are presented in Table 2 and proportional percentages of these measurements given in Table 3.

The term "flanged" is used in regard to descriptions of lateral teeth. The ventral surface of some right lateral teeth is relatively straight. However, in some cases, the ventral side of the tooth develops a shelf-like structure called a flange herein. Note that some sources consider this to be a second lateral tooth, but it is quite different from the left lateral teeth that are nearly always double.

The original description is presented for each taxon, as well as a subsequent description by Simpson (1914) and a current redescription (expanded from Howells et al. 1996). English versions of descriptions that were initially published in Latin are my own translations.

RESULTS AND DISCUSSION

Pimpleback species present in Texas waters have been discussed by Simpson (1914), Strecker (1931), Howells et al. (1996, 1997), and others. However, all struggled with species identification problems.

Species at issue in Texas waters include (Plates 1-9):

1) Texas pimpleback *Quadrula petrina* (Figs. 5-10, 44).
2) Golden orb *Q. aurea* (Figs. 11-16, 42).
3) Smooth pimpleback *Q. houstonensis* (Figs. 17-22, 43, 45).
4) Western pimpleback *Q. mortoni* (Figs. 23-32, 47, 49):

given as *Q. p. mortoni* by Williams et al. (1993) and Turgeon et al. (1998).

5) Pimpleback *Q. pustulosa* (Figs. 37-41, 46):
given as *Q. p. pustulosa* by Williams et al. (1993) and Turgeon et al. (1998).

Primary areas of confusion include:

1) Distinction between pimpleback and western pimpleback populations in East Texas, including the Red River (Figs. 35-36).
2) Status of the pimpleback described as "*Quadrula nodifera*" (placed by some under pimpleback, but included with western pimpleback by others)(Figs. 23-25, 27). Note that the *Q. nodifera* form has no common name.
3) Identification of pimplebacks from the Trinity River Drainage (Figs. 33-34, 48) that may show morphological similarities to pimpleback, western pimpleback, smooth pimpleback, and *Q. nodifera.*
4) Genetic comparisons of several populations assumed to be western pimplebacks, but which differ morphologically.

Species Accounts

TEXAS PIMPLEBACK *Quadrula petrina* (Gould 1855) (Figs. 4-10, 44).

Type Locality: Llanos [Llano] River, Texas. Taylor (1967) later determined this site to have been near U.S. 87 southeast of Mason, Mason County, Texas.

Systematics: Also includes *U. bolli* Call 1881 (Strecker 1931). This species is usually readily distinguishable from other quadrulids and readily identifiable, except in deformed, worn, or badly weathered shells. Specimens from the Colorado River drainage given by Howells et al. (1996) as golden orb are actually this species.

Distribution: Endemic to the Colorado and Brazos River drainages, Texas (Fig 3).

Original Description: *Unio petrinus* Gould 1855 (translated from Latin).

"Solid, ovate-quadrate, subequilateral, anterior shape rounded, posterior widely truncate, scarcely arched beneath, adorned with small oblique folds behind nearly to the dorsal margin; umbos moderate, flattened; epidermis weakly yellowish-green; cardinal teeth robust, pyramid-shaped, lateral teeth short; nacre white."

Shell Description Given by Simpson (1914):

"Shell subelliptical, subquadrate or subrhomboid, somewhat inflated, slightly inequilateral, solid; beaks moderately full and high, turned over a lunule, their sculpturing consisting of irregular corrugations, which are almost nodulous on the posterior ridge; posterior ridge widely rounded, sometimes feebly biangulate below; anterior end rounded; base line curved; posterior end obliquely or squarely truncate; umbonal region corrugated; posterior slope faintly corrugated; epidermis rather smooth , somewhat shining, sometimes dirty straw-color, usually yellowish-green with irregular bands of clouds of green; pseudocardinals stumpy, triangular, two in the left valve and three in the right; beak cavities deep, compressed; muscle scars deep, smooth; nacre silvery, iridescent and thinner behind."

Current Redescription:

Size – Larger than most pimpleback species in Texas; usually 60-90 mm sl; to at least 103 mm sl.

Shape – Subquadrate, subrhomboidal, to nearly round; slightly to moderately inflated. Gravel bar morphs are atypically elongate and rectangular.

Proportions (means and ranges) – Shell height 78.7% sl (73-87) and shell width 51.4% sl (48 -56); gravel bar morphs shell height 66.3% sl (64-68) and shell width 39.0% sl (38-41).

Thickness – Thick; solid.

Beaks – Full and high.

Beak sculpture – 2-4 rows of nodules with the anterior nodules often absent and the posterior nodules elongate.

Posterior ridge – Broadly rounded with little or no indication of a sulcus.

Disk sculpture – Disk usually smooth or very rarely with vague, mid-disk pustules; posterior slope usually with a series of parallel ridges.

Beak cavity – Deep.

Pseudocardinal teeth – Two left teeth, massive, often (but not always) heavily grooved, anterior left pseudocardinal tooth usually triangular and leaning forward in juveniles, but becoming square and chisel-like in larger specimens (this tooth is rarely triangular in *Q. aurea* or *Q. houstonensis*), anterior and posterior left pseudocardinal teeth often rather widely separated; one right, massive, triangular, heavily grooved, usually with an anterior or posterior denticle, or both.

Lateral teeth – Heavy, straight to slightly curved, 29-41% sl, right lateral tooth not flanged posteriorly.

Interdentum - Short, but wide.

Muscle scars - Anterior adductor muscle scars deeply impressed; posterior adductor muscle scars deeply impressed on the anterior edge, but often shallow posteriorly.

Soft Tissues: White to off white, similar to other typical pimpleback type quadrulids.

Shell Coloration: Externally yellowish-brown, greenish-brown, yellowish-green, to gray-green or dark brown; occasionally with irregular green blotches in vague rays; darker in older specimens. Internally white; iridescent posteriorly.

Habitat: Occurs on mud, sand, gravel, and cobble, including gravel-filled cracks in bedrock bottoms; in medium-sized streams and rivers, not known from impoundments; usually in shallow waters, not taken by HOH at depths over 2 m; usually in slow to moderate flows. Appears to avoid extremely soft substrates, shifting sands, and scoured bottoms.

Biology: Females have been found with marsupial eggs in July, glochidia in June and August, and both in July. The smallest female found to be gravid was 45 mm sl. Glochidia were described by Howells et al. (1996). No other information on reproductive biology is apparently available.

Conservation Status: This species is no longer known to survive anywhere in the San Antonio or Guadalupe River System. Colorado Drainage Basin populations have apparently been reduced to only four sites in recent years (Fig. 4). A population in the lower Concho River, Concho County, was devastated by dewatering in 1999 and 2000; no living specimens have been found there since. A second population in a nearby tributary of the Colorado River, Runnels County, was not examined in 1999 and 2000, but likely experienced some degree of dewatering at that time with a subsequent damaging flood that extensively modified the area in late 2000; when reexamined by J.A.M. Bergmann in 2001 (pers. comm.) no living or

recently dead specimens were found. A population in the Colorado River upstream of Lake Buchanan, San Saba County, was only discovered in 1999 when the river became completely dry and all specimens were apparently lost. The remaining population in the upper San Saba River, Menard County, reportedly (S. Martin, San Angelo, Texas; pers. comm.) survived drought conditions in 1999 and 2000 (this location did not become dry), but the area was heavily impacted by a severe flooding in late 2000 and the status of mussels at this site is currently undetermined.

Note: Most pimpleback mussels in Texas do not grow to large enough sizes to be legally taken by commercial, shell musselers. However, Texas pimpleback is an exception and is occasionally taken by musselers harvesting southern mapleleafs *Q. apiculata* within its range.

GOLDEN ORB *Quadrula aurea* (Lea 1859) (Figs. 11-16, 42)

Type Locality: Texas.

Systematics: Not generally problematic except for some possible confusion with smooth pimpleback.

Distribution: Currently, and probably historically restricted to the Nueces-Frio and Guadalupe -San Antonio River drainages (Figure 2). Reports by Howells et al. (1996) from the North Concho River and San Saba River in the Colorado River drainage basin were misidentified Texas pimplebacks. Strecker (1931) reported the species from the Bosque, North Bosque, and Leon rivers of the Brazos River drainage. However, more recent collections in these areas have produced only smooth pimplebacks (including subfossil specimens and material from archeological sites). It seems likely that the specimens referenced by Strecker were misidentified smooth pimplebacks; Figures 21-22 show examples of this species that could be mistaken for golden orb.

Original Description: *Unio aureus* Lea, I. 1859 (translated from Latin).

"Shell smooth, rather triangular, compressed, slightly flat to the side, nearly inequilateral; valves relatively thick, thick anteriorly; beaks slightly elevated, pointed at the tip; epidermis golden, striated, obscure rays; cardinal teeth thick, erect, furrowed [or striated], double in both valves; lateral teeth short and oblique; nacre white and iridescent."

Shell Description Given by Simpson (1914):

"Shell subrhomboid, subcompressed to convex, inequilateral, subsolid; beaks slightly elevated, rather compressed, their sculpture a few coarse, irregular ridges; posterior ridge rounded; anterior end rounded; base straight or lightly curved; posterior end obliquely, rarely squarely, truncate; surface nearly smooth; there are occasional faint plications on the dorsal slope and a few feeble nodules on the disk; epidermis yellowish-tawny or brownish, rarely greenish or having slight greenish markings, scarcel shining; pseudocardinals radial, somewhat split up; lateral of the right valve single or somewhat double; beak cavities moderately deep, compressed; muscle scars not deep; nacre whitish, often purple-tinted, iridescent behind."

Current Rediscription:

Size – To about 82 mm, but usually much less.

Shape – Subrectangular, subquadrate, rectangular, oval, to nearly round, but always longer than high. Sometimes slightly round-pointed posterio-ventrally.

Proportions (means and ranges) – Shell height 77.6 % sl (69-86) and shell width 47.2% sl (42-57).

Thickness – Only moderately thick; subsolid.

Beaks – Elevated, but not high; narrower and more pointed than other pimpleback species; nearly facing (less turned forward than other pimpleback species).

Beak sculpture – Usually absent or with obscure ridges that are angled posteriorly.

Posterior ridge – Broad, low; sulcus usually obscure.

Disk sculpture – Usually smooth and unsculptured; but very rarely with vague pustules in the central disk. Rarely with small pustules or rows of pustules on the posterior slope.

Beak cavity – Moderately deep.

Pseudocardinal teeth – Only moderately heavy, less massive than other local quadrulids; two left, posterior tooth usually smaller and triangular, anterior tooth larger and quadrate (chisel-shaped, even in small individuals), both often grooved; one right, triangular, slightly to moderately grooved, often with an anterior or posterior denticle, or both.

Lateral teeth: Two left and one right; straight to slightly curved; 34-43% sl, right lateral tooth is often flanged posteriorly.

Interdentum - Short and often somewhat depressed.

Muscle scars - Anterior adductor muscle scars well impressed; posterior adductor muscle scars moderately well impressed anteriorly, but only slightly impressed posteriorly.

Soft Tissues: White or off-white; typical of the genus.

Shell Coloration: Externally yellow-brown, greenish-brown, tan (frequently with an orange tint), to dark brown and nearly black; rarely with obscure green rays. Nacre white; iridescent posteriorly. None of the numerous specimens examined by the author have had purple-tinted nacre as suggested by Simpson (1914).

Habitat: Usually found on sand or gravel; occasionally cobble; does not appear to tolerate soft mud and silt, shifting sand, or scoured bottoms. Usually in rivers; occasionally in smaller streams. Does not appear to tolerate impoundment except in a single reservoir in the lower Nueces River Drainage where it occurred on wind-swept points with sand and gravel bottoms (where wave action may simulate riverine conditions). Found from shallows to depths of about 3 m.

Biology: Females with marsupial eggs have been found from May thorough August (Howells 2000a). Glochidia have not been described and hosts remain unknown.

Conservation Status: Current status is extremely precarious though not legally protected under either state or federal regulations. It has been found alive at only five sites in the past decade and the present survival of most of those is now questionable (Fig. 4). Populations present in the Guadalupe River downstream for two dams in Gonzales County in 1995 and 1996 were subjected to major floods since last examined and current status is unknown. Living specimens were found in the lower San Marcos River in 1999 and 2000, but numbers are extremely small. Flooding revealed a small population in the upper Guadalupe River, Kerr County, in 1997; however, the city of Kerrville dewatered the area in 1998 to construct a foot-bridge in a local park and all specimens may have been eliminated at that time (none have been found since). A recently dead shell was collected in the Frio River, McMullen County, upstream of Choke Canyon Reservoir in 1994, but no living specimens have been found since. A population present in Lake Corpus Christi on the lower Nueces River, Live Oak County, was subjected to a major drought-related drawdown in mid-1996; no living or recently dead specimens have been found there since (through 2000). Collectively, it seems

likely there are at least limited numbers surviving at two sites in the lower Guadalupe River, one in the lower San Marcos River, and survivors may persist in Lake Corpus Christi or the Nueces River immediately upstream. Unfortunately, except for the San Marcos River location and Lake Corpus Christi, none of the other sites has been examined in about five years.

SMOOTH PIMPLEBACK *Quadrula houstonensis* (Lea 1859) (Figs. 17-22, 43, 45)

Type Locality: Houston and Reutersville, Brazos River Drainage, Texas.

Systematics: Historical confusion between this species and golden orb, western pimpleback, and pimpleback has been problematic. This species name may have been used historically as a catch-all for atypical pimpleback quadrulids (Howells et al. 1996).

Distribution: Endemic to the Colorado and Brazos Drainages of Central Texas (Fig. 2). Reported from the Trinity and San Jacinto rivers, Texas (Strecker 1931). The identity of populations from the Trinity River is uncertain and those from the San Jacinto River are more properly associated with western pimpleback.

Original Description: *Unio houstonensis* Lea, I. 1859 (translated from Latin).

"Shell smooth; nearly round, rather inflated, equilateral, slightly flat to the side; valves rather thick, thick anteriorly; beak elevated, small wavy ridges at the tip; epidermis smooth, greenish-yellow, either rayless or with obscure rays; cardinal teeth large, erect, crenulated; lateral teeth short nearly straight; nacre silvery and iridescent."

Note: Lea (1859) immediately followed his description of *Unio houstonensis* with a description of *U. rutersvillensis*; however, this was soon combined under *U. houstonensis* in subsequent publications, although Lea had originally considered them distinct.

Original description: *Unio rutersvillensis* Lea 1859 (translated from Latin).

"Shell smooth, transversely elliptical, rather inflated, slightly inequilateral; obtusely angled posteriorly; valves rather thin, slightly thick anteriorly; beak elevated, regular and fine wavy ridges at the tip; epidermis either dusky brown or dusky yellow and slightly rayed; cardinal teeth small, compressed, pointed, crenulated, double in both valves; lateral teeth long, lamellar, rather [or nearly] curved; nacre bluish-white and slightly iridescent."

Shell Description Given by Simpson (1914):

"Shell rhomboid or subquadrate, inflated, solid, nearly or quite equilateral; beaks full and high, turned forward over a lunule; posterior ridge well developed, narrowly rounded or subangular, ending at or near the base in a blunt point; anterior end rounded, sometimes slightly slopingly truncate above; baseline curved or nearly straight; posterior end nearly or quite squarely truncated; surface usually free from pustules, rarely having a few feeble ones; epidermis yellowish-green in young shells, sometimes faintly rayed, becoming ashy brown or lurid brown when old; pseudocardinals strong, often split up; left valve with two laterals; right valve with a single or somewhat double one; beak cavities deep; muscle scars large, impressed; nacre silvery white."

Current Redescription:

Size – Adults are often 45-65 mm sl.

Shape – Subquadrate, subrhomboidal, quadrate, to nearly round; inflated (much more

inflated than golden orb).

Proportions (means and ranges) – Shell height 88.9% sl (88-92) and shell width 60.2% sl (58 -70).

Thickness – Moderately thick to thick; solid.

Beaks – Full, elevated well above the hinge, usually turned forward over a lunule.

Beak sculpture – 2-3 nodular ridges, angled posteriorly.

Posterior ridge – Broadly rounded, sometimes with a second or third secondary ridge; sulcus (if present at all) usually little more than a flattened area anterior to the posterior ridge.

Disk sculpture – Current specimens from the Colorado and Brazos drainages are usually smooth, or very rarely with a few small pustules. R.W. Neck indicated some museum specimens from older collections are more heavily sculptured (Howells et al. 1996), but it is unclear if these represented Trinity River material (that do have pustules) or were from the Colorado-Brazos (where pustules are nearly always lacking).

Beak cavity – Deep.

Pseudocardinal teeth – Relatively strong and massive; two left, posterior tooth smaller and lightly grooved, anterior left pseudocardinal tooth usually square, chisel-like, and much larger; one right, triangular, grooved, often with denticles anteriorly, posteriorly, or both.

Lateral teeth – Straight to slightly curved, 31-43% sl; heavy, right lateral tooth flanged posteriorly.

Interdentum - Short, thick anterior-dorsally.

Muscle scars - Anterior adductor muscle scar deeply impressed; posterior adductor muscle scar moderately impressed anteriorly, but only slightly impressed posteriorly.

Soft Tissues: White or off white; similar to other typical quadrulids.

Shell Coloration: Externally tan to light brown, dark brown, chestnut, to black; occasionally with light-dark growth-rest bands; not rayed. Nacre white; iridescent posteriorly.

Habitat: Typically in mud, sand, or gravel in small- to moderate-sized rivers; tolerates impoundment at some locations, but not others; from slow to moderate flow rates.

Biology: Spawning and brooding periods, glochidia, and fish hosts are largely unknown (Howells 2000a).

Conservation Status: This species has seen dramatic reductions in distribution and abundance (Fig. 4). Some such reductions reflect terrestrial land management and modification that has increased runoff resulting in riverbed scouring and loss of acceptable habitat. Interestingly, specimens recovered from an archeological site within the Brazos River drainage, Milam County, Texas, found this species to have been much more abundant at deeper, older levels of excavation than at upper, more-recent elevations, even prior to European contact and subsequent environment damage (Howells 2000b). These data may represent a shift in species taken due to changing preferences among the Indians over time or perhaps over harvest of local populations, but could also suggest a natural decline that began long ago. Within the Colorado River Drainage, a single specimen from one reservoir and 13 from another in the central drainage and three from the lower Colorado River are the only records of living specimens in over a decade. In the Brazos River Drainage, scattered groups or individuals have been found alive in the Brazos from the Waco area to the mouth of the Navasota River and in the Little Brazos River, Leon River, and elsewhere.

WESTERN PIMPLEBACK *Quadrula mortoni* (Conrad 1836) (Figs. 23-32, 47-49)

Type Locality: Bayou Teche, Louisiana.

Systematics: This pimpleback apparently includes *U. sphaecia* Lea 1865, *U. turgidus* Lea 1838, and possibly *U. nodiferus* Conrad 1841 (Vidrine 1993; Howells et al. 1996). The *Q. nodifera* type was originally described from Jackson, Louisiana, apparently from Thompson Creek (Vidrine 1993). The association between western pimpleback, *Q. nodifera*, and *Q. pustulosa* var. cf *nodifera* was discussed by Vidrine (1993), but remains uncertain. The American Fisheries Society (Williams et al. 1993; Turgeon et al. 1998) places *mortoni* as a subspecies of *Q. pustulosa*, but Vidrine (1993) and Howells et al. (1996) elevated *mortoni* to species status.

Distribution: Generally west of the Mississippi River into southern Arkansas, across Louisiana, and the Big Cypress, Neches-Angelina, and Sabine drainages of Texas. Specimens from the San Jacinto River and Buffalo Bayou, Texas, have been considered western pimpleback, but differ from the typical Neches and Sabine forms. Status in the Trinity River, Texas, is unclear, but specimens from the lower reaches resemble western pimpleback; those from the central and upper regions are particularly confusing and may be associated with smooth pimpleback, or even pimpleback and *Q. nodifera* types. Records from the Colorado and Brazos drainages, Texas, are almost certainly smooth pimpleback. Reports by Simpson (1914) from Oklahoma and southwestern Tennessee are questionable.

Original Description: *Unio mortoni* Conrad 1836.

"Shell suborbicular, not thick, ventricose; disk flattened, or slightly furrowed from the beaks to base, covered with irregular tubercles; anterior margin subtruncated; posterior margin straight, direct; ligament margin subarcuate, oblique, forming an angle with the posterior margin; umbo with an oblique furrow, prominent; beaks rather retuse, decorticated; umbonal slope angular, slightly arcuate; posterior slope flattened; epidermis yellowish brown, with fine crowded wrinkles; within white; anterior margin not thickened; cardinal teeth compressed, very prominent, oblique."

Shell Description Given by Simpson (1914):

"Shell subquadrate, inflated, subsolid, sometimes solid when old, inequilateral; beaks high and full, turned forward over a lunule; posterior ridge well developed, angled or narrowly rounded, rarely somewhat double below, ending at the base of the shell in a blunt point; anterior end rounded, sometimes slightly, obliquely truncate above; baseline straight or slightly curved; outline of dorsal slope curbed or raised in the middle to an angle; surface varying from almost smooth to densely pustulosa, pustules generally covering the whole shell; epidermis ashy-brown or lurid brown, having a greenish tint and sometimes a broad, broken, green ray when young; pseudocardinals triangular, not greatly split up; lateral of the right valve scarcely double; beak cavities deep, compressed; muscle scars impressed; nacre whitish with a purplish tint, purple and iridescent behind."

Current Redescription:

Size – Usually 40-60 mm sl; to at least 71 mm sl for typical Sabine and Neches Drainage specimens, but to over 80 mm sl in Lake Houston (San Jacinto River), Texas.

Shape – Subquadrate, subrectangular, to nearly round; some specimens round-pointed posterio-ventrally (appearing almost triangular); inflated.

Proportions (means and ranges) – Shell height 88.9% sl (88-92) and shell width 60.2% sl (58

-70), but range in shell height is greater in the San Jacinto-Buffalo Bayou populations (82-100% sl).

Thickness – Thick; solid.

Beaks – High, full, turned forward.

Beak sculpture – Usually vague to lacking, rarely showing a few angular ridges.

Posterior ridge – Variable, well developed to obscure; usually with sulcus vague to lacking.

Disk sculpture – Extremely variable; completely unsculptured, slightly pustuled, to heavily sculptured; pustules may be small pimples or larger round, drop-shaped, or horizontal pustules; some populations may also have a series of parallel ridges running posteriorly from the posterior slope.

Beak cavity – Deep.

Pseudocardinal teeth – Massive; two left, posterior tooth triangular, lightly grooved, and much smaller, anterior tooth large and quadrate (chisel-like); one right, triangular, more-heavily grooved; usually with both anterior and posterior denticles.

Lateral teeth – Heavy, straight to slightly curved, 31-50% sl, right lateral tooth flanged posteriorly.

Interdentum - Very short and wide.

Anterior adductor muscle scar very deeply impressed; posterior adductor muscle scar relatively deeply impressed anteriorly, but only slightly impressed posteriorly.

Soft Tissues: White to off white; similar to other typical pimpleback quadrulids.

Shell Coloration: Externally tan to dark brown or black, occasionally with light-dark growth -rest bands; typically unrayed, except occasionally in juveniles that may display a single, broad green ray at the beak. In the Neches and Sabine drainages, quadrate to round forms are often tan to reddish-brown, but those that are round-pointed posteriorly are more frequently dark, umber brown to black (*nodifera* forms). Nacre white; iridescent posteriorly. Two specimens from the Neches River had purple markings around the interior margin of the shell similar to those in purple pimpleback *Quadrula refulgens* that occurs east of the Mississippi River.

Habitat: Occurs in mud, sand, and gravel in streams, river, lakes, and reservoirs (tolerates impoundment well in some reservoirs); found from shallow waters to depths over 7 m and in lotic conditions to rapid flow rates.

Biology: In Texas, eggs were found in marsupia in June and July, and glochidia were present in May and July; reproductive biology appears otherwise unreported. Howells et al. (1996) provided a description of the glochidia. Hosts are unreported.

Conservation Status: This species remains more abundant than any other pimpleback species in Texas waters, and probably in Louisiana as well. Substantial populations are present in the Central Neches River drainage and it persists in Village Creek off the lower Neches River, Hardin County, Texas. In the Sabine River, it has probably been reduced or eliminated downstream of Toledo Bend Reservoir; it is still present in the river upstream of Toledo Bend, but in limited numbers. It remains in Big Cypress Bayou as well (assuming the *Q. nodifera* types here are western pimpleback), but also in limited numbers in most areas. In the San Jacinto System, few living specimens remain in either the east or west branches of the river; a substantial population in Lake Houston was devastated in 1999 and 2000 by drought-related dewatering. A small number of specimens were found in Buffalo Bayou in 1994, but urban development at the primary collection site has likely all but eliminated the species from the area. Status in Louisiana is less well defined at present.

Comments on "nodifera" forms: Surveys by HOH found this form occurs in the Neches and Sabine rivers, and possibly in the Trinity River and Big Cypress Bayou, Texas; Vidrine (1993) discussed its range in Louisiana. It was combined with *Q. mortoni* in data from the Neches and Sabine rivers in HOH reports. No pimplebacks of any kind were found by HOH in the Sulphur River in northeastern Texas. Mather and Bergmann (1994), Shafer et al. (1992), and Vidrine (1993) considered pimplebacks they documented from Big Cypress Bayou to be *Q. pustulosa*. Specimens from Big Cypress Bayou had shell height proportions somewhat less (mean 81.7% sl and range 79-84) than in typical *Q. mortoni* from the Neches and Sabine basins; shell width and lateral tooth length were similar. Whether "*nodifera*" forms are only variants of *Q. pustulosa* or *Q. mortoni*, or are taxonomically distinct, remains unresolved. Previous descriptions include:

Original description: *Unio nodiferus* Conrad 1841.

> "Obtusely subovate, ventricose, moderately thick; surface with a few nodules about the middle of the valves, and smaller ones near the ligament margin; a slight, not very wide, furrow extends from the beak to the base; posterior margin approaching a regular curve; beaks eroded; within white; cardinal teeth robust, prominent, direct, and profoundly sulcated in old shells; epidermis chestnut-brown."

Description presented by Simpson (1914).

> "Shell subquadrate or subrhomboid, inflated, moderately solid, somewhat inequilateral; beaks full and high; anterior end rounded, usually a little narrowed; base line curved in front, straight behind; posterior end rounded from the beaks to the lower end of the posterior ridge; posterior ridge moderately developed, subangular, ending in front of the extreme posterior end of the shell; surface smooth or having a few scattered nodules; epidermis dull, dirty or grayish-brown; pseudocardinals triangular, much split up into radial denticles; lateral of the right valve double or single; beak cavities rather deep; muscle scars small, impressed; nacre white or lurid, often blotched."

"TRINITY RIVER" PIMPLEBACKS *Quadrula* sp(p). (Figs. 33-34, 48)

Original Description: See comments below.
Type Locality: See comments below.
Systematics: Pimplebacks from this river have been called pimpleback, western pimpleback, and smooth pimpleback (Strecker 1931; Neck 1990) and they remain problematic. Preliminary electrophoretic work at HOH revealed little. Two specimens from Eagle Mountain Reservoir, Tarrant County, in the Upper Trinity River Drainage had fast alleles at one locus that were distinct from all other pimplebacks examined. At another electrophoretic locus, the Eagle Mountain material appeared more like western pimpleback from the Neches River than smooth pimpleback from the Brazos River. Clearly, DNA analysis will be needed to clarify whether pimplebacks from the Trinity River Drainage are western pimpleback, smooth pimpleback, something distinct from either, or a combination or intergradation between these and possibly even true pimpleback.
Distribution: Trinity River drainage, Texas.
Shell Description: Typical of many pimpleback species, individual specimens from populations

from the upper and central Trinity River Drainage easily fit descriptions of western pimpleback, smooth pimpleback, and pimpleback, as well as possibly *Q. nodifera*. Specimens from the lower river reaches downstream of Lake Livingston sometimes resemble typical western pimpleback morphologically; however, no surviving populations are currently known from which to obtain tissue samples. Shell height and width proportions among specimens from the upper Trinity River average higher (94.1% and 65.2% sl) than for all other pimpleback groups; however, individual shell height proportions of individual pimplebacks were occasionally greater.

Conservation Status: Small populations are believed to still persist in Eagle Mountain Reservoir and Lake Lewisville, Tarrant County, and probably do so in other impoundments in the Dallas-Fort Worth area. However, drought conditions in 1999 and 2000 devastated mussel populations throughout the region. In 1996, C.M. Mather and J.A.M. Bergmann discovered a surviving population in the Central Trinity River just upstream of Lake Livingston. Those tissue samples obtained from that survey were lost due to a freezer break-down at HOH and no additional collections or surveys have been conducted at that site since.

PIMPLEBACK *Quadrula pustulosa* (Lea 1831) (Figs. 37-41, 46).

Type Locality: Alabama River.

Systematics: Because of the extreme variability and wide array of forms, pimpleback has been given a long list of historical synonyms and the disposition of some still remains to be resolved. Parmalee and Bogan (1998) discussed synonymy.

Distribution: Range extends from New York to the Dakotas and south to Texas and Louisiana in the Mississippi River Basin, and the Tombigbee and Cahaba rivers of Alabama (Parmalee and Bogan 1998). Mather and Bergmann (1994) considered specimens from Big Cypress Bayou and its tributaries to be this species and Vidrine (1993) and Shafer et al. (1992) also considered specimens found just downstream of the Texas-Louisiana border to be pimpleback as well. White and White (1977) identified it from Lake Texoma in the Red River. Specimens from Sanders Creek, Lamar County, Texas, appear morphologically to be pimpleback (perhaps more than other pimpleback-complex populations in Texas). Collections by HOH in Big Cypress Bayou produced only *Q. nodifera*-form. Similarly, the record in Howells et al. (1996) for the Neches River in southeastern Texas also referred to the *Q. nodifera*-form. It is possible that if true *Q. pustulosa* occurs in Texas, it is restricted to the Red River drainage (assuming *Q. nodifera* is either included under western pimpleback or is taxonomically distinct).

Original Description: *Unio pustulosus* Lea 1831.

"Shells rather elongated, equilateral, inflated, tuberculated on posterior half; valves thick; beaks elevated and granulated at tip; cardinal teeth rather large; lateral teeth short, thick, and straight; nacre pearly white and iridescent." Note: Although Lea's description states the specimen is "rather elongate", his measurements (2.2 inches in shell length and 2.1 inches in breadth) and associated illustration do not indicate an elongate shell. Both Lea and others produced a wide array of subsequent descriptions of species now combined under *Q. pustulosa* and too numerous to list here.

Shell Description Given by Simpson (1914):

"Shell subquadrate, subrhomboid, subtriangular or suborbicular, generally inflated, solid, inequilateral; beaks full and high, turned forward over a lunule, their sculpture a few coarse corrugations; anterior end rounded; base straight or lightly curved; posterior end squarely or obliquely truncated, usually well-angled behind the ligament; posterior ridge only moderately developed, rounded; there is often a slight radial depression above it; surface, excepting the anterior part, usually more or less covered with warty or lachrymose tubercles, sometimes nearly or quite smooth; epidermis tawny or tawny-greenish in young shells, often with a wide, broken, bright green ray, dirty brownish in old shells; psuedocardinals strong, triangular, more or less ragged, two in the left valve and three in the right; lateral of the right valve sometimes partially double; beak cavities deep, compressed; muscle scars impressed; nacre white, thinner and iridescent behind." Because of the wide distribution and extremely polymorphic nature of this species, numerous others have described it since Simpson's summary.

Current Redescription:

Size – To at least 102 mm shell length (Cummings and Mayer 1992).

Shape – Quadrate, subrhomboidal, to nearly oval or circular.

Proportions (means and ranges from specimens from a variety of locations) – Shell height 96.1% sl (88-108) and shell width 62.2% sl (54-69); occasionally shell height actually exceeds shell length.

Thickness – Moderately thick to very thick; evenly thick across the shell or thinner posterio -ventrally; solid.

Beaks – High, elevated well above the hinge line, often turned forward.

Beak sculpture – Extremely variable and usually absent in all but the smallest individuals; sculpture lacking to one or two slightly- to well-developed nodules; when nodules are worn or poorly formed, they may be mistaken for single- or double-looped patterns.

Posterior ridge – Prominent to obscure, without an anterior sulcus.

Disk sculpture – Extremely variable from entirely smooth, with only a few tiny pimples, to heavily covered with small to large pustules that may be round or misshapen.

Beak cavity – Deep.

Pseudocardinal teeth – Two left, heavy, massive, large, erect, striated or grooved, posterior tooth often smaller and triangular, anterior tooth larger and often chisel-like; one right tooth, large, grooved, triangular, often with anterior or posterior denticles, or both.

Lateral teeth – Slightly curved, relatively heavy, mean length 41.6% sl (range 40-52), right lateral tooth not flanged posteriorly.

Interdentum - Short, but broad.

Muscle scars - Anterior adductor muscle scars very deeply impressed; posterior adductor muscle scars deeply impressed.

Soft Tissues: Off-white.

Shell Coloration: Externally yellowish-brown, greenish-brown, yellow-green, light to dark brown or black; sometimes with alternating light and dark growth and rest bands; usually rayless, but some smaller individuals may have one or more green rays extending down from the beak. Internally, white, sometimes stained; iridescent posteriorly.

Habitat: This species occurs from small streams to larger rivers reservoirs and lakes, on most bottom types, at variable depths, and in moderate flow rates to standing waters.

Biology: Reproduction occurs from June through August (Howard 1914). Glochidia are

produced in conglutinate masses (Oesch 1984); glochidia were described by Utterback (1915-16). Hosts (summarized by Watters 1994) and includes ictalurid catfishes and white crappie *Pomoxis annularis*.

Conservation Status: Pimpleback is often one of the more abundant unionids surviving throughout much of its range. In Texas, a small population (that may be pimpleback) was present in a small creek in Lamar County (Red River Drainage) and it has been reported from another small Red River tributary in Red River County. Though reported from Lake Texoma (White and White 1977), none have been collected in Texas waters there in recent years. The *Q. nodifera* types reported from Big Cypress Bayou and the Sabine, Neches, and Trinity rivers may or may not be pimpleback.

Summary

It would appear that in Texas waters, there are several taxonomically valid taxa within the pimpleback-complex including: Texas pimpleback, golden orb, smooth pimpleback, and western pimpleback. However, the status of a number of other morphological forms remains uncertain.

Pimpleback may be represented in Texas in some tributaries of the Red River. Although specimens from Lamar County, Texas, closely resemble pimpleback, the variability of the species and absence of comparative genetic analysis makes their current taxonomic status little more than an educated guess. The identity of pimpleback-complex specimens from Big Cypress Bayou (also a Red River tributary), called pimpleback by several authors, remains uncertain as well.

Pimpleback-complex specimens from the Trinity River drainage remain enigmatic and may be associated with smooth pimpleback, western pimpleback, possibly pimpleback, or perhaps a combination of these species or even a distinct taxon (at least at some level of differentiation). Starch gel electrophoresis found several alleles not present in any other pimpleback species examined, but so few enzyme systems and specimens were studied that it is uncertain if this is meaningful.

Western pimpleback populations from the Neches and Sabine rivers are similar to each other morphologically, yet quite different from other populations from the San Jacinto River drainage and adjacent Buffalo Bayou that are also assumed to be western pimpleback. The limited amount of electrophoretic analysis done to date is insufficient to provide useful information. Additionally, apparent western pimplebacks from the Neches River with purple nacre may raise questions about associations to purple pimpleback that is generally found east of the Mississippi River.

The status of *Q. nodifera* or *Q. pustulosa* cf. *nodifera* from eastern Texas and Louisiana is also problematic. Whether it is only a form of western pimpleback, pimpleback, or a unique taxon is unresolved.

The ultimate taxonomic disposition of many of these is important to our view of the conservation status of some species. For example, fewer than 20 living smooth pimplebacks have been found in the Colorado River basin in the past decade. Slightly more have been documented in the Brazos, but in both drainages, their numbers are declining rapidly. If these are all that survives of this species, then listing their status as threatened, if not endangered, would appear to be in order. However, if the Trinity River pimplebacks prove to be smooth pimpleback, the presence of additional populations in an additional drainage basin indicates the status of the species is somewhat more secure and protective listings less pressing. Members of the pimpleback-complex are extremely variable morphologically and only biochemical genetic studies will be able to resolve long-standing questions about them.

LITERATAURE CITED

Aebersold, P.B., G.A. Winans, D. J. Teel, G.B. Milner, and F.M. Utter. 1987. Manual for starch gel electrophoresis: a method for the detection of genetic variation. National Oceanographic and Atmospheric Administration, National Marine Fisheries Service, NOAA Technical Report NIMFS 61, Seattle, Washington. 19 pp.

Conrad, T.A. 1836. Monography of the family Unionidae, or naiades of Lamarck (fresh water bivalve shells) of North America, illustrated by figures drawn on stone from nature. J. Dobson, Philadelphia, Pennsylvania:11, Plate 6.

Conrad, T.A. 1841. Descriptions of three new species of *Unio* from the rivers of the United States. Proceedings of the Academy of Natural Sciences of Philadelphia 1(2):19-20.

Cummings, K.S., and C.A. Mayer. 1992. Field guide to the freshwater mussels of the Midwest. Illinois Natural History Survey, Champaign. 194 pp.

Gould, A.A. 1855. New species of land and fresh-water shells from western (N.) America. Proceedings of the Boston Society of Natural History 5(15):228-229.

Howard, A.D. 1914. Experiments in propagation of freshwater mussels of the *Quadrula* group. U.S. Bureau of Fisheries Document 801:1-52.

Howells, R.G. 2000a. Reproductive seasonality of freshwater mussels (Unionidae) in Texas. Pages 35-48 *in* R.A. Tankersley and five coeditors. Freshwater mollusk symposia proceedings. Part I. Conservation , captive care, and propagation. Ohio Biological Survey Special Publication, Columbus. 274 pp.

Howells, R.G. 2000b. Preliminary analysis of freshwater mussel shell remains associated with archeological sites 41MM340 and 41MM341, Milam County, Texas. Prepared for the Center for Archaeological Research, Austin, Texas. 6 pp.

Howells, R.G., R.W. Neck, and H.D. Murray. 1996. Freshwater mussels of Texas. Texas Parks and Wildlife Press, Austin. 218 pp.

Howells, R.G., C.M. Mather, and J.A.M. Bergmann. 1997. Conservation status of selected freshwater mussels in Texas. Pages 117-128 *in* K.S. Cummings, A.C. Buchanan, C.A. Mayer, and T.J. Naimo, editors. Conservation and management of Freshwater mussels II: initiatives for the future. Proceedings of a UMRCC symposium 16-18 October 1995, St. Louis Missouri. Upper Mississippi River Conservation Committee Symposium, Rock Island, Illinois. 293 pp.

Lea, I. 1831. Observations on the naiades. Transactions of the American Philosophical Society 4:76-77, plate 7.

Lea, I. 1859. Descriptions of eight new species of Unionidae, from Georgia, Mississippi, and Texas. Proceedings of the Academy of Natural Sciences of Philadelphia 11:112-113, 154-155.

Mather, C.M., and J.A.M. Bergmann. 1994. Freshwater mussels of the Cypress Bayou System, Northeast Texas. Malacology Data net 33(5/6):139-145.

Neck, R.W. 1982. Preliminary analysis of the ecological zoogeography of the freshwater mussels of Texas. Pages 33-42 *in* J.R. Davis, editor. Proceedings of the symposium on recent Benthological investigations in Texas and adjacent states. Texas Academy of Science, Austin. 278 pp,

Neck, R.W. 1990. Geological substrate and human impact on bivalves of Lake Lewisville, Trinity River, Texas. The Nautilus 104:16-25.

Neves, R.J. 1993. A state-of-the-unionids address. Pages 1-10 *in* Conservation and management of freshwater mussels. Proceedings of a UMRCC symposium, 12-14 October 1992, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois. 189 pp.

Oesch, R.D. 1984. Missouri naiades. A guide to mussels of Missouri. Missouri Department of Conservation, Jefferson City. 270 pp.

Parmalee, P.W., and A.E. Bogan. 1998. The freshwater mussels of Tennessee. The University of Tennessee Press, Knoxville. 328 pp.

Shafer, D., A. Miller, and M. Farr. 1992. A survey for freshwater mussels (Family: Unionidae) in the proposed Red River waterway, Texas and Louisiana, between Shreveport, Louisiana and Daingerfield, Texas, August 27-September 2. U.S. Army Engineers Waterways Experiment Station, Environmental Lab, Vicksburg, Mississippi. 12 pp.

Shaklee, J.B., and C.P. Keenan. 1986. A practical laboratory guide to the techniques and methodology of electrophoresis and its application to fish fillet identification. Commonwealth Scientific and Industrial Research Organization, Marine Research Laboratories, Report 177, Hobart, Australia. 59 pp.

Simpson, C.T. 1914. A descriptive catalogue of the naiades, or pearly fresh-water mussels. B. Walker, Detroit, Michigan. 1540 pp.

Strecker, J.K., Jr. 1931. The distribution of naiades or pearly fresh-water mussels of Texas. Baylor University Museum Bulletin 2, Waco. 71 pp.

Taylor, D.W. 1967. Freshwater mollusks collected by the United States and Mexican boundary surveys. The Veliger 10:152-158.

Turgeon, D.D., and 13 coauthors. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks. American Fisheries Society Special Publication 26, Bethesda, Maryland. 526 pp.

Utterback, W.I. 1915-16. The naiades of Missouri. American Midland Naturalist 4:1-29, 41-53, 97-152, 181-204, 244-273, 311-327, 339-354, 387-400, and 432-464.

Valentine, B.D., and D.H. Stansbery. 1971. An introduction to the naiads of the Lake Texoma region, with notes on the Red River fauna. Sterkiana 42:1-40.

Vidrine, M.F. 1993. The historical distributions of freshwater mussels of Louisiana. Gail Q. Vidrine Collectables, Eunice, Louisiana. 225 pp.

Watters, G.T. 1994. An annotated bibliography of the reproduction and propagation of the Unionioidea (Primarily of North America). Ohio Biological Survey, Columbus. 158 pp.

White, D.S., and S.J. White. 1977. Observations on the pelecypods of Lake Texoma, Texas and Oklahoma, after more than thirty years of impoundment. The Southwestern Naturalist 22:235-254.

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

Table 1. Banding patterns recorded during horizontal starch gel electrophoretic examination of selected pimpleback mussels (*Quadrula* spp.) (Family Unionidae) performed at Heart of the Hills Research Station, Ingram, Texas, in 1993 and 1994. Specimens of *Q. asperata* from Alabama and *Q. refulgens* from Mississippi were included.

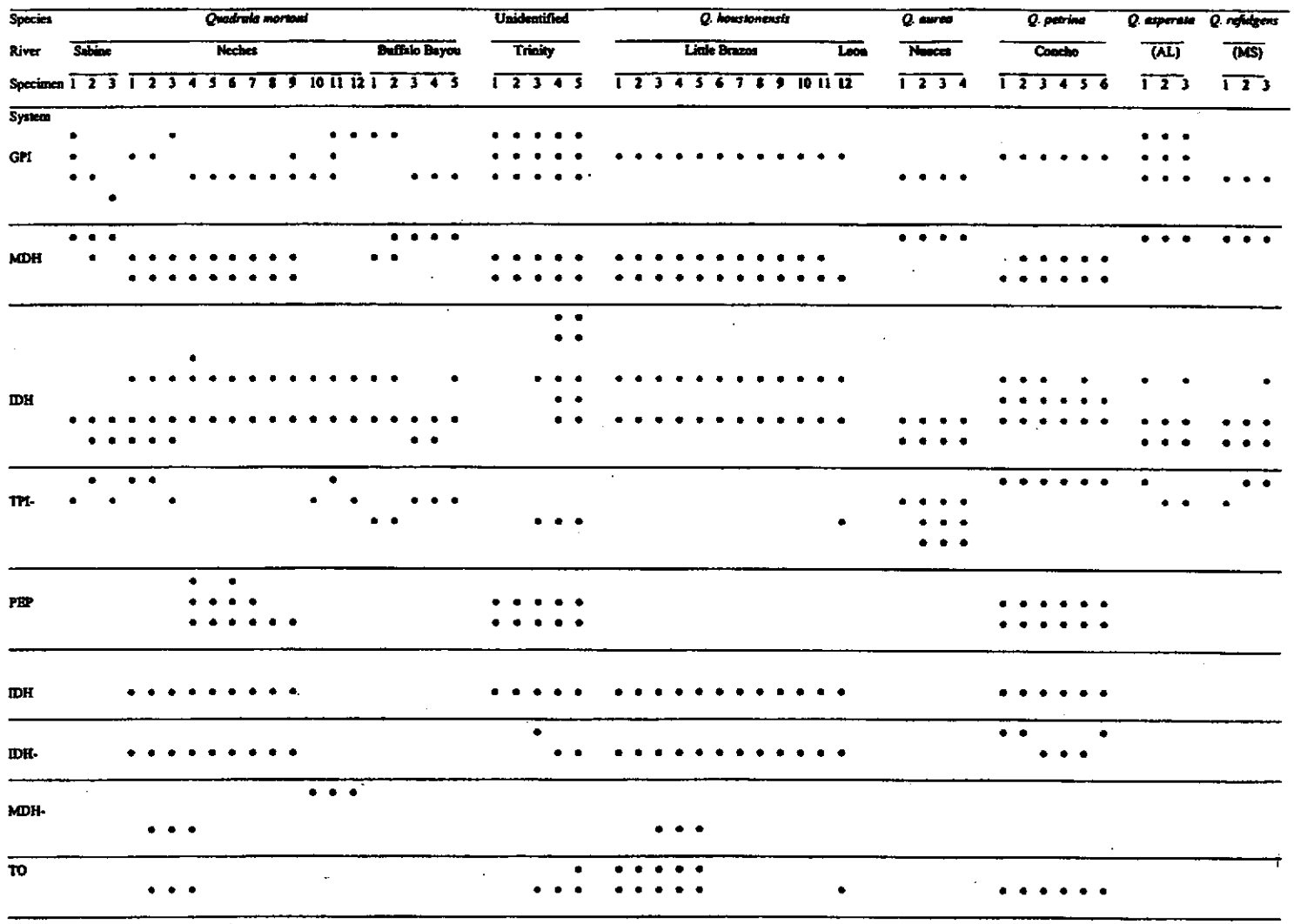

Table 2. Measurements of shell length (sh), height (sh), and width (sw), and lateral tooth length (lt) from selected pimpleback species. All measurements are in mm. Specimens are from Texas unless otherwise noted.

Texas pimpleback
Q. petrina – (typical)

sl	sh	sw	lt	Source
104	82	55	35	Concho R.
95	73	47	29	Concho R.
82	71	46	27	Concho R.
84	71	44	31	Concho R.
67	53	34	23	Concho R.
63	51	35	22	Concho R.
95	72	48	35	San Saba R.
95	72	47	35	San Saba R.
85	63	42	31	San Saba R.
75	55	36	30	San Saba R.

Golden orb
Q. aurea

sl	sh	sw	lt	Source
67	46	28	28	Guadalupe R.
62	48	26	23	Guadalupe R.
63	47	31	26	Guadalupe R.
56	41	26	19	Guadalupe R.
38	29	16	13	Guadalupe R.
58	46	27	23	Frio R.
58	50	33	25	Nueces R.
54	45	28	23	Nueces R.
62	48	30	26	Nueces R.
43	35	20	17	Nueces R.

Smooth pimpleback
Q. houstonensis

sl	sh	sw	lt	Source
65	58	42	20	L. Marble Falls
49	44	31	21	L. Marble Falls
50	46	32	17	L. Marble Falls
40	35	26	13	L. Marble Falls
58	51	34	18	L. Marble Falls
43	38	28	14	L. Marble Falls
56	51	39	19	Lake LBJ
50	43	30	17	Little Brazos R.
38	34	24	13	Little Brazos R
33	29	19	11	Navasota R.

Texas pimpleback
Q. petrina – (gravel-bar)

sl	sh	sw	lt	Source
68	46	26	20	Concho R.
64	43	26	24	Medina R.
56	36	21	20	Blanco R.

Q. mortoni?
("*nodifera*" form)

sl	sh	sw	lt	Source
66	52	43	31	Big Cypress B.
62	52	40	24	Big Cypress B.
65	53	38	23	Big Cypress B.

Western pimpleback
Q. mortoni

sl	sh	sw	lt	Source
70	61	39	27	Neches R.
58	53	38	22	Neches R.
57	54	35	22	Neches R.
53	46	31	26	Neches R.
60	50	41	23	Neches R.
44	42	30	18	Neches R.
41	37	25	17	Neches R.
58	52	36	24	Neches R.
52	49	32	26	Neches R.
40	40	26	15	Neches R.
37	34	21	14	Sabine R.
70	58	44	25	Sabine R.
55	45	35	24	Sabine R.
55	47	32	22	Sabine R.
44	36	25	18	Sabine R.

Western pimpleback
Q. mortoni

sl	sh	sw	lt	Source
52	42	30	20	E. San Jacinto R.
58	51	34	20	W. San Jacinto R.
59	50	33	23	W. San Jacinto R.
62	53	34	23	W. San Jacinto R.
47	40	25	17	W. San Jacinto R.
79	75	53	37	L. Houston
84	73	46	37	L. Houston
73	65	44	31	L. Houston
73	66	48	36	L. Houston
73	68	48	30	L. Houston
66	51	37	22	Buffalo Bayou

Table 2. Continued

Pimpleback
Q. pustulosa

sl	sh	sw	lt	Source
66	64	42	29	St. Croix R., MN
66	58	41	34	St. Croix R., MN
58	54	33	28	St. Croix R., MN
48	48	33	18	St. Croix R., MN
46	45	30	19	Ouachita R., AR
42	39	24	18	Ouachita R., AR
46	44	3	19	Ouachita R., AR
40	37	24	20	Ouachita R., AR
57	51	35	26	Mississippi R., MO
56	53	34	23	Mississippi R., MO
50	48	34	21	Mississippi R., MO
42	42	28	17	Mississippi R., MO
70	66	38	30	Licking R., KY
77	80	42	38	Kentucky L., TN
73	79	41	35	Kentucky L., TN
86	80	58	34	Kentucky L., TN

Quadrula sp(p). - (Trinity River)

sl	sh	sw	lt	Source
62	58	39	21	Eagle Mountain Reservoir
59	51	37	19	Eagle Mountain Reservoir
48	44	29	18	L. Grapevine
59	59	36	21	L. Lewisville
60	56	38	20	L. Lewisville
53	49	36	19	L. Lewisville
59	56	36	23	L. Lewisville
52	51	35	17	L. Lewisville
40	37	29	12	L. Lewisville
40	39	29	14	L. Lewisville

Table 3. Means and ranges in proportions (% shell length) of shell height and width and length of lateral teeth of selected pimpleback species (*Quadrula* spp.) calculated from measurements given in Table 2.

Species	*N*	Shell height	Shell width	Lateral teeth	Source
Texas pimpleback (typical) *Q. petrina*	10	78.7 (73-87)	51.4 (48-56)	35.4 (31-41)	Concho & San Saba R. (TX)
Texas pimpleback (gravel-bar) *Q. petrina*	3	66.3 (64-68)	39.0 (38-41)	34.3 (29-38)	Concho, Medina, & Blanco R. (TX)
Golden orb *Q. Q. aurea*	10	77.6 (69-86)	47.2 (42-57)	39.7 (34-43)	Guadalupe, Frio, & Nueces R. (TX)
Smooth pimpleback *Q. houstonensis*	10	88.9 (88-92)	60.2 (58-70)	34.0 (31-43)	Colorado, Little Brazos, & Navasota R. (TX)
Western pimpleback (typical) *Q. mortoni*	15	89.7 (82-100)	61.7 (56-68)	40.9 (36-50)	Neches & Sabine R. (TX)
Western pimpleback *Q. mortoni*	10	87.8 (81-95)	59.5 (53-67)	40.7 (34-49)	San Jacinto R. (TX)
Western pimpleback (*nodifera*) *Q. mortoni*?	3	81.7 (79-84)	62.7 (58-65)	40.3 (39-47)	Big Cypress Bayou (TX)
"Trinity River" pimplebacks *Quadrula* sp(p).	10	94.1 (86-100)	65.2 (60-73)	34.5 (30-39)	Trinity R. (TX)
Pimpleback *Q. pustulosa*	16	96.1 (88-108)	62.2 (54-69)	41.6 (40-52)	St. Croix R. (MN), Mississippi R. (MO), Ouachita R. (AR), Licking R. (KY), Kentucky L. (TN)

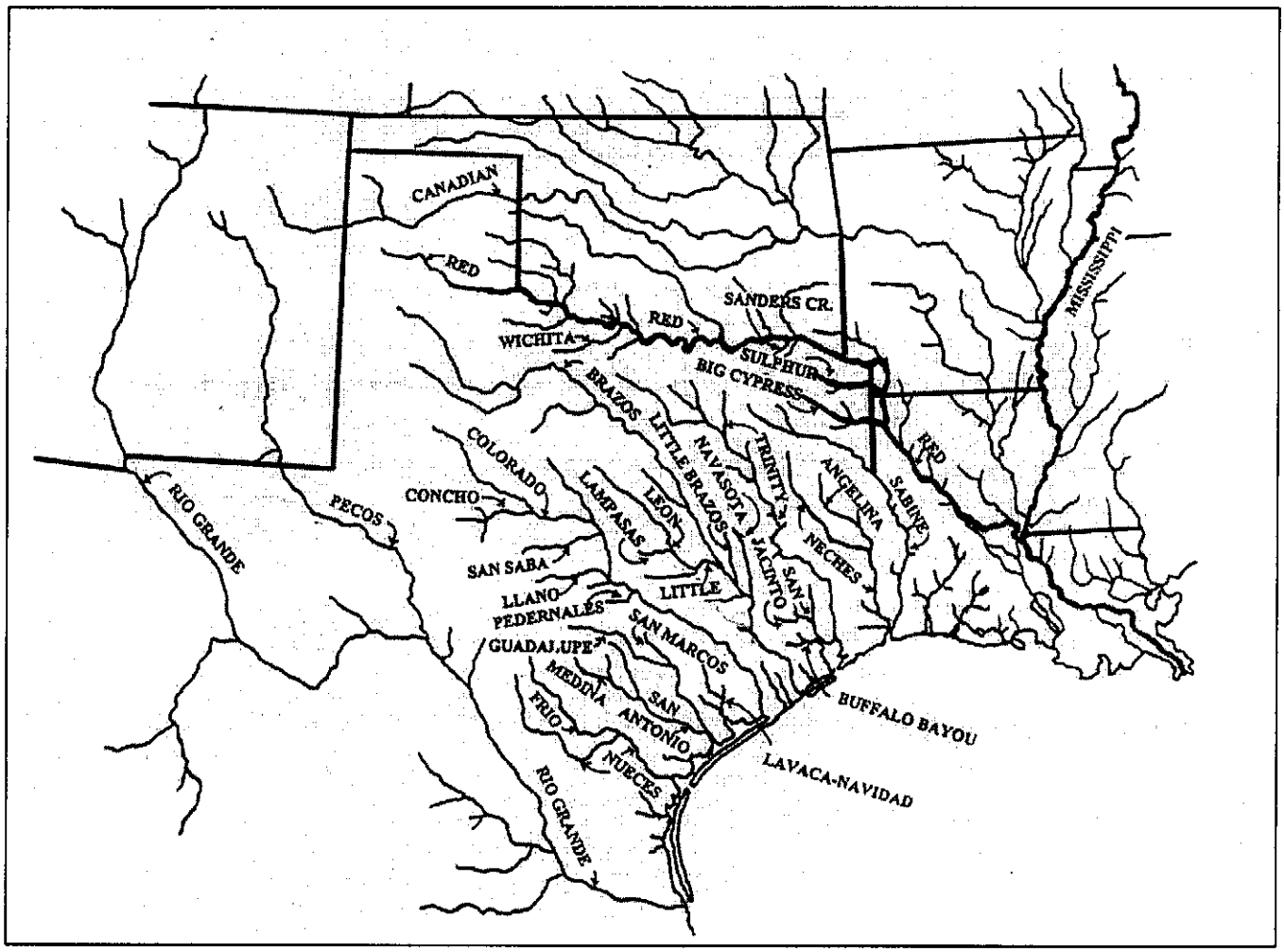

Figure 1. Major river systems of Texas. The Mississippi River drainage (including the Red, Sulphur, and Big Cypress Systems) are shown in bolder lines. Except for the Canadian River, all other Texas river systems are isolated from the Mississippi Drainage Basin that covers most of the interior of the U.S.

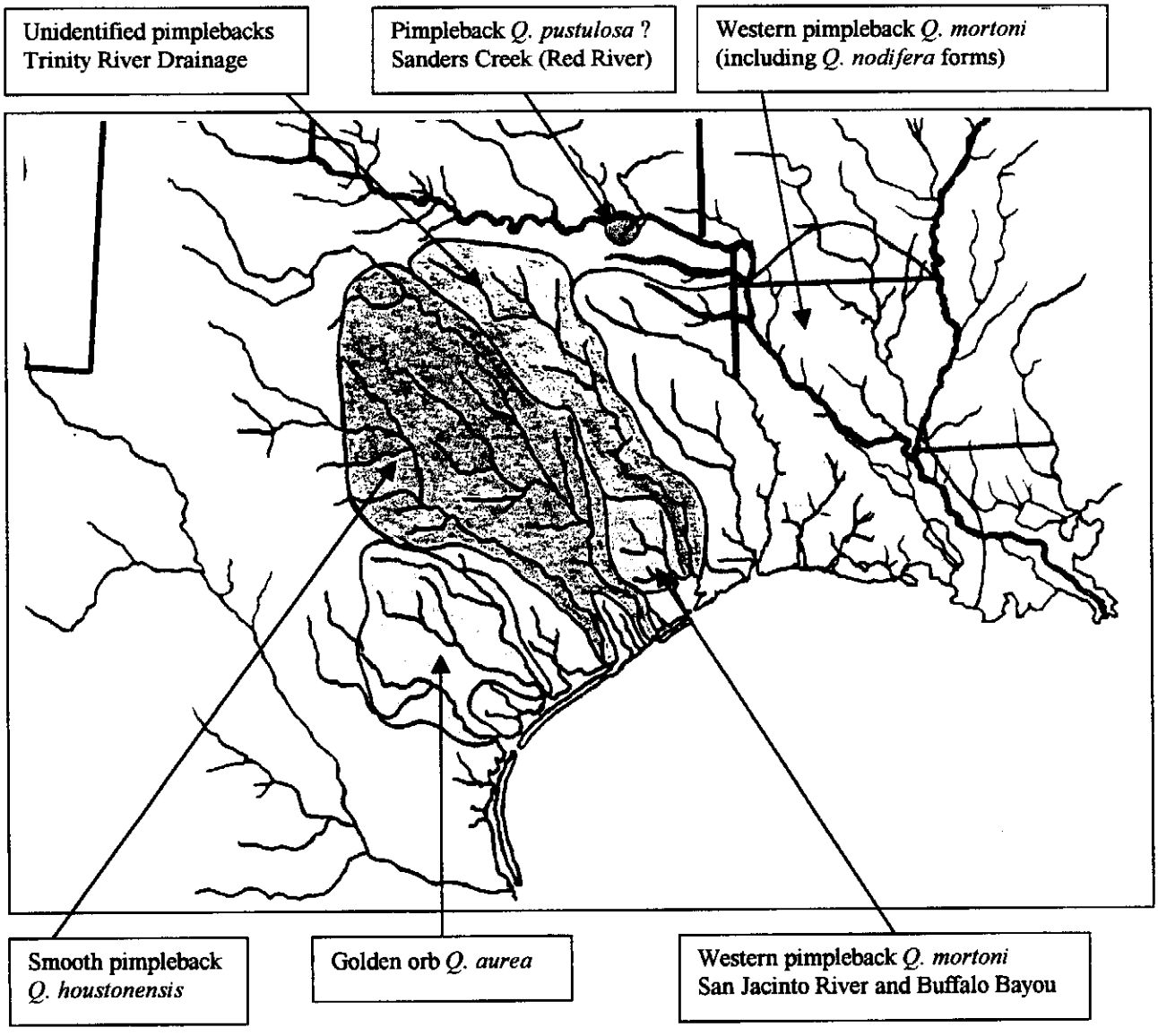

Figure 2. Probable historic distributions of selected pimpleback species (*Quadrula* spp.) that occur in Texas, except Texas pimpleback *Q. petrina*. Louisiana and Arkansas distributions of western pimpleback *Q. mortoni* are from Vidrine (1993).

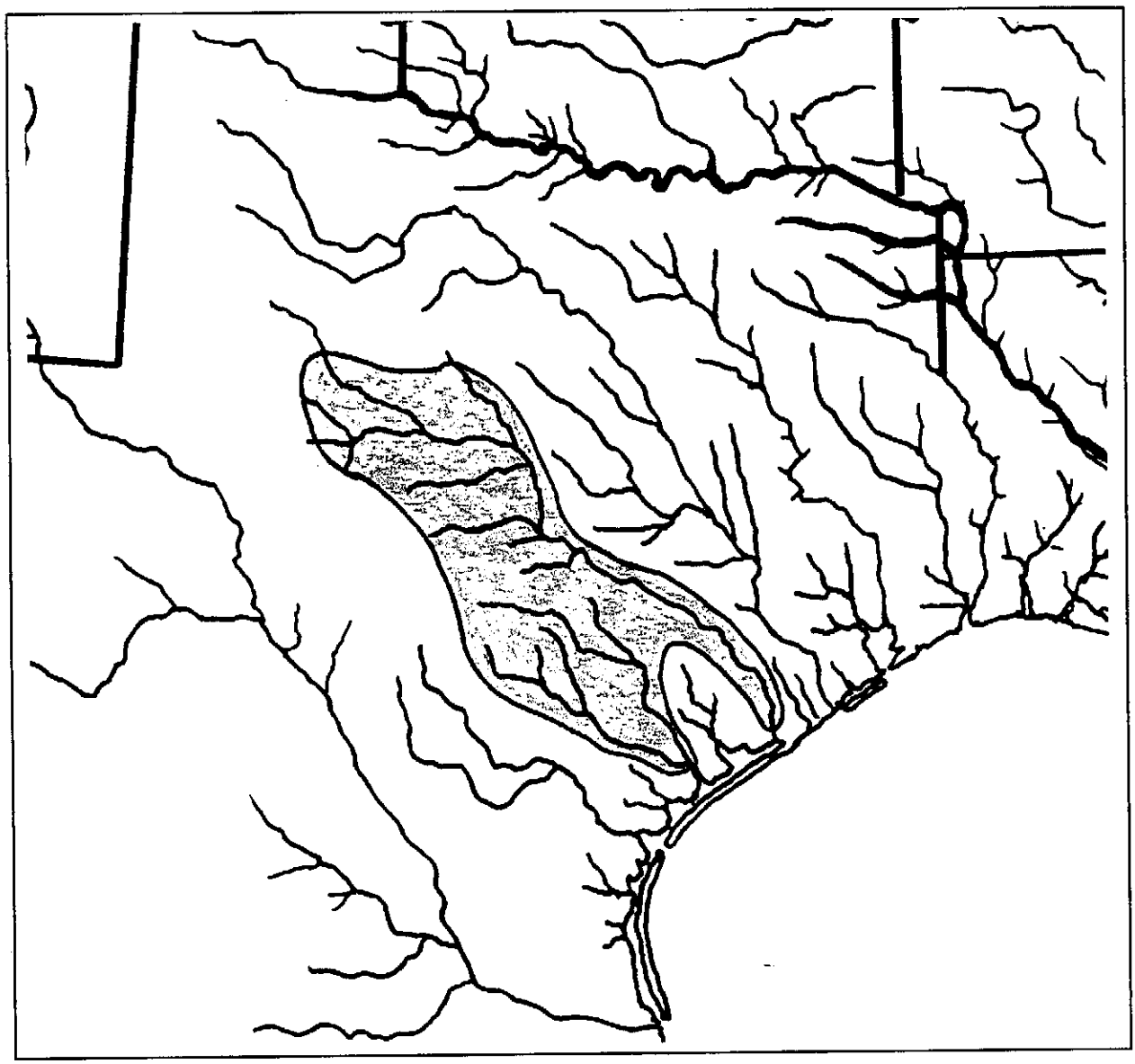

Figure 3. Probable historic distribution of Texas pimpleback (*Quadrula petrina*) in Texas.

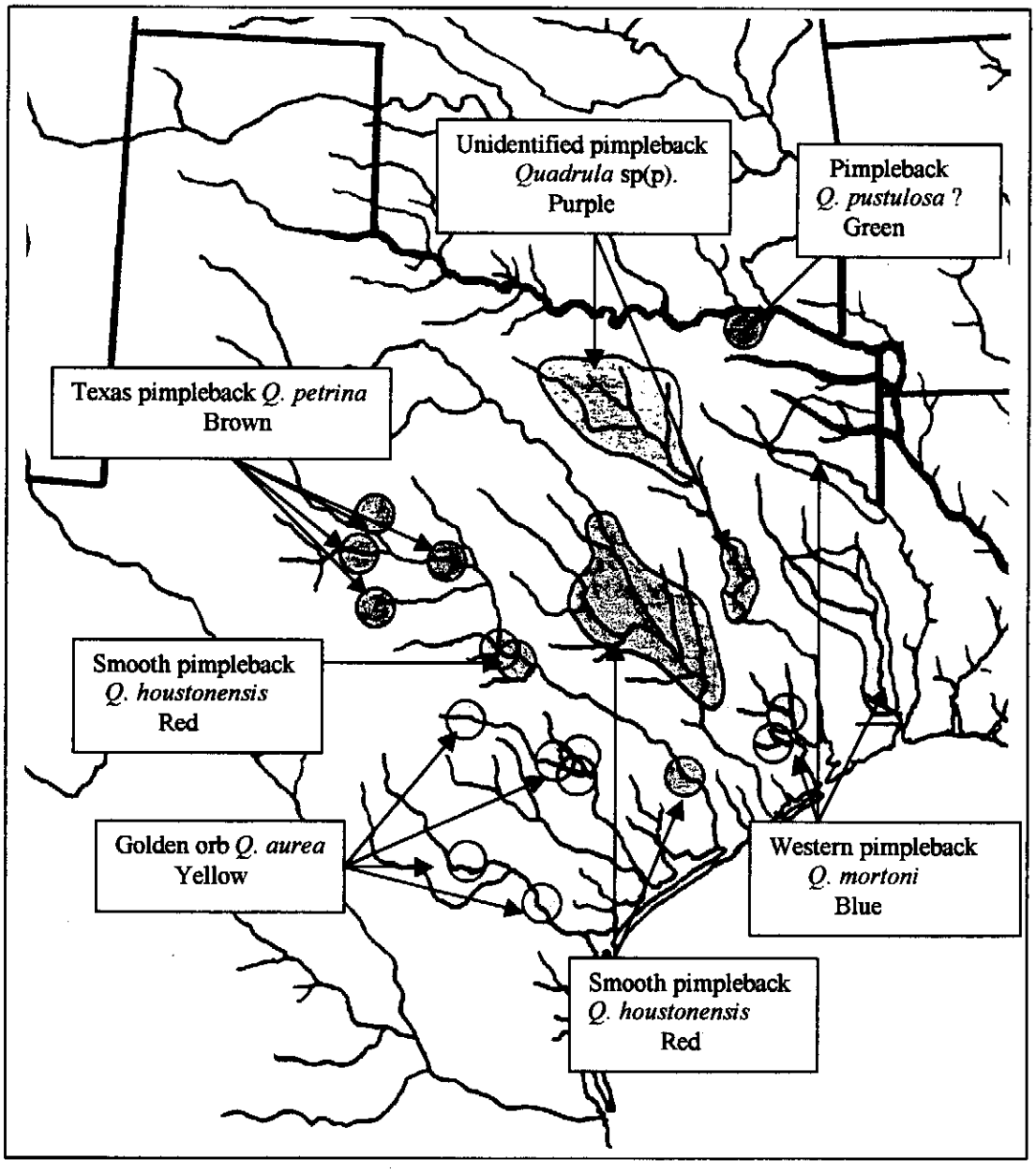

Figure 4. Locations where living or recently dead pimpleback species (*Quadrula* spp.) have been collected in Texas since 1990. Specimens from Big Cypress Bayou taken by Heart of the Hills Research Station Staff were *Quadrula nodifera*-form exclusively; others have identified pimpleback specimens from this system as pimpleback *Q. pustulosa*; this form also occurs in the Sabine and Neches Drainages, and possibly in the Trinity River.

PLATE 1. TEXAS PIMPLEBACK (*Quadrula petrina*)

Figure 5. Texas pimpleback *Quadrula petrina*; Concho River, Concho County, Texas; 67 mm sl. This specimen is particularly brightly colored.

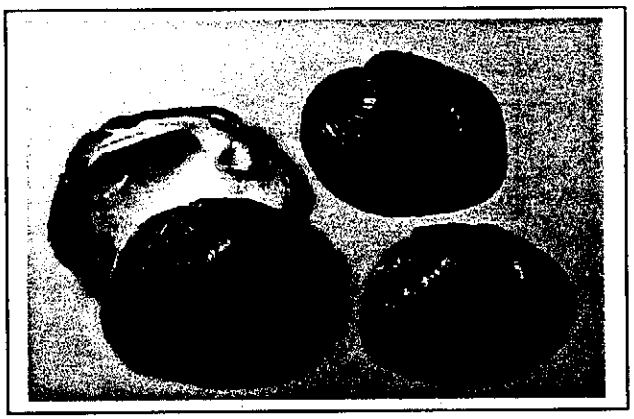

Figure 6. Texas pimpleback *Quadrula petrina*, Concho River, Concho County, Texas; 69, 76 mm sl. Right specimen has vague pustules on the central disk; most are apustulose.

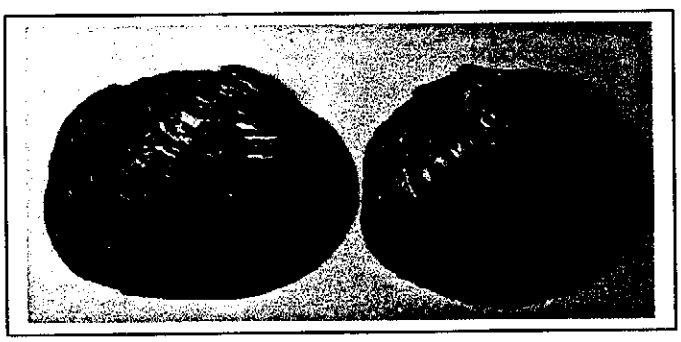

Figure 7. Texas pimpleback *Quadrula petrina*; Concho River, Concho County, Texas; 86, 90 mm sl. These have a typical range in shape from subrectangular to oval.

Figure 8. Texas pimpleback *Quadrula petrina*; Colorado River, San Saba County, Texas; 83, 86 mm sl. Specimens at this site were exceptionally dark. This population was apparently eliminated just before its discovery in 1999.

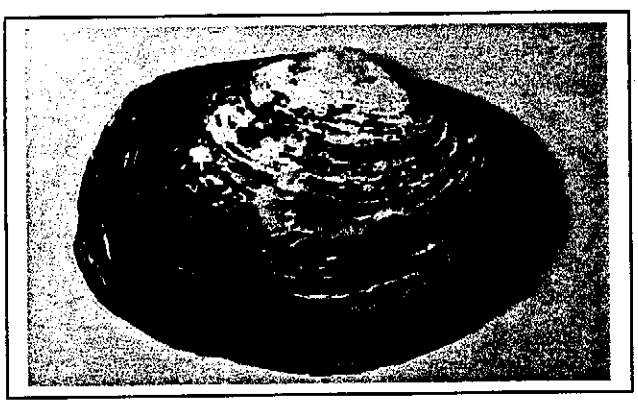

Figure 9. Texas pimpleback *Quadrula petrina*; Concho River, Concho County, Texas; 67 mm sl; somewhat elongate and approaching a gravel-bar morph.

Figure 10. Texas pimpleback *Quadrula petrina*; Medina River, San Antonio River Drainage, Medina County, Texas; 64 mm sl; gravel bar morph. A number of Central Texas unionids have similar morphs with atypically long shells; often considered taxonomically distinct in historic literature.

PLATE 2. GOLDEN ORB (*Quadrula aurea*)

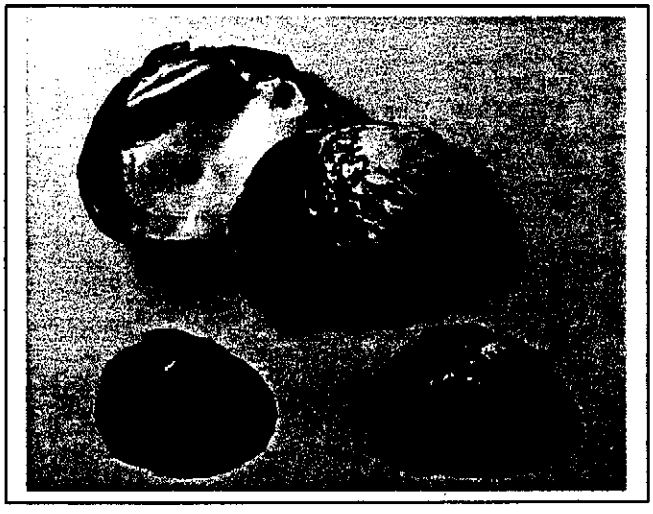

Figure 11. Golden orb *Quadrula aurea*; Guadalupe River, Gonzales County, Texas; 44, 50, 65 mm sl.

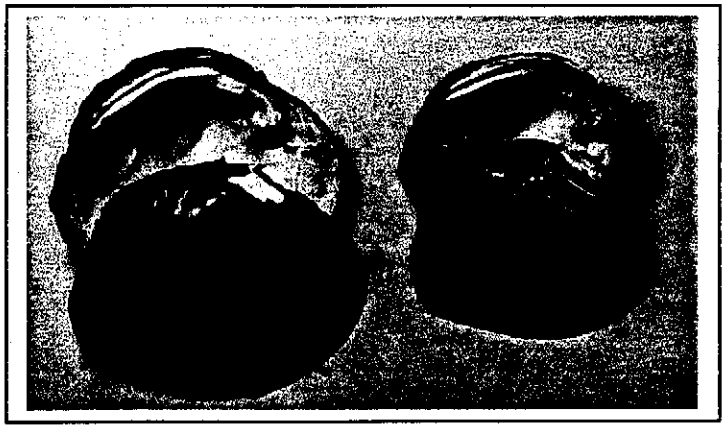

Figure 12. Golden orb *Quadrula aurea*; Lake Corpus Christi Nueces River Drainage, Live Oak County, Texas; 50, 59 mm sl.

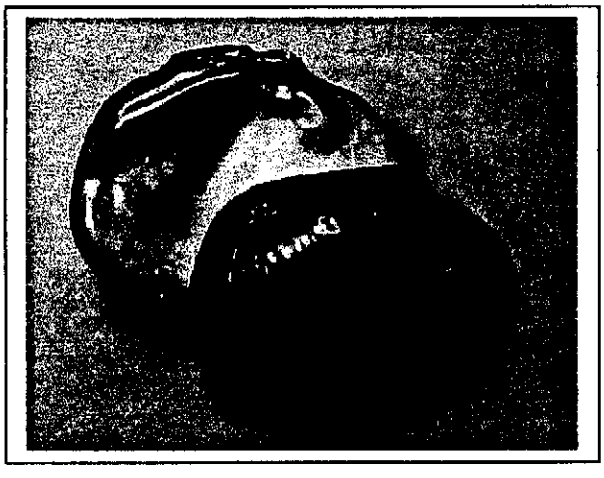

Figure 13. Golden orb *Quadrula aurea*; Frio River, McMullen County, Texas; 59 mm sl. No living specimens have been found at this site in recent years.

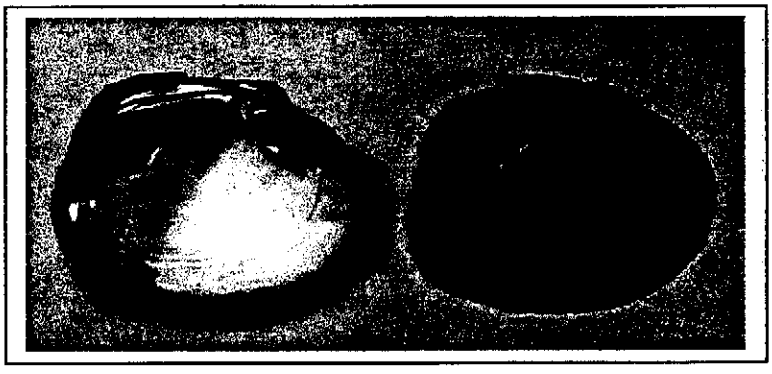

Figure 14. Golden orb *Quadrula aurea*; upper Guadalupe River, Kerr County, Texas, 48 mm sl. This small population appears to have been eliminated in 1998 when the area was dewatered for bridge work. Several specimens taken a short distance downstream in the 1970s were nearly black in color.

Figure 15. Golden orb *Quadrula aurea*; lower Guadalupe River, Gonzales County, Texas, 37 mm sl. Specimen shows vague pustules on the mid-disk and parallel ridges in the posterior field; both traits are infrequently seen.

Figure 16. Golden orb *Quadrula aurea*; lower Guadalupe River, Gonzales County, Texas; 44 mm sl. Specimen has faint green rays.

PLATE 3. SMOOTH PIMPLEBACK (*Quadrula houstonensis*)

Figure 17. Smooth pimpleback *Quadrula houstonensis*; Little Brazos River, Robertson County, Texas; 52, 38 mm sl.

Figure 18. Smooth pimpleback *Quadrula houstonensis*; Lake Marble Falls, Colorado River Drainage; Burnet County, Texas; 50 mm sl.

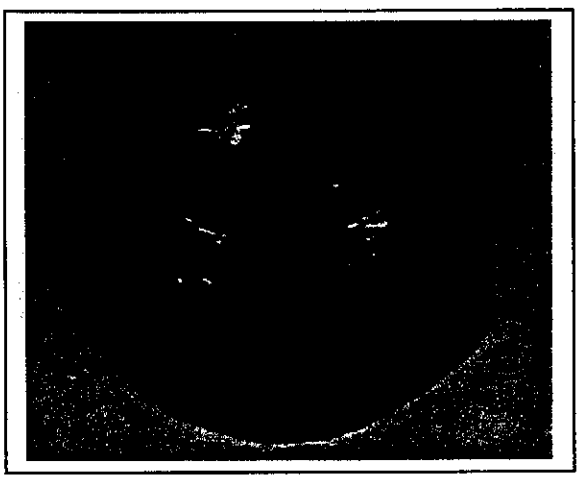

Figure 19. Smooth pimpleback *Quadrula houstonensis*; Inks Lake, Colorado River Drainage, Burnet County, Texas; 56 mm sl.

Figure 20. Smooth pimpleback *Quadrula houstonensis*; Lake Marble Falls, Colorado River Drainage; Burnet County, Texas; 65 mm sl.

Figure 21. Smooth pimpleback *Quadrula houstonensis*; Leon River, Brazos River Drainage, Coryell County, Texas; 33 mm sl. Specimens like this and the example to the right could be mistaken for golden orb *Q. aurea*.

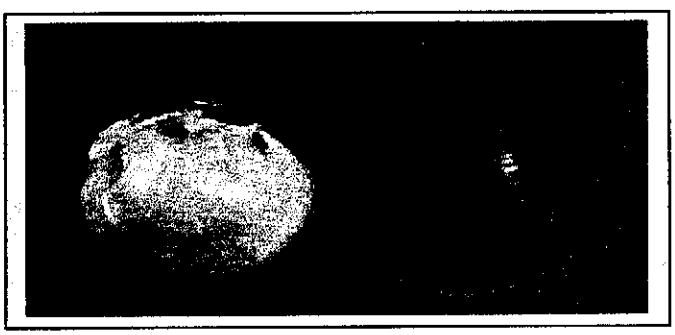

Figure 22. Smooth pimpleback *Quadrula houstonensis*; Little Brazos River, Robertson County, Texas; 30 mm sl.

PLATE 4. WESTERN PIMPLEBACK (*Quadrula mortoni*)
Including *Q. nodifera*-types -
Neches, Sabine, and Big Cypress Drainages

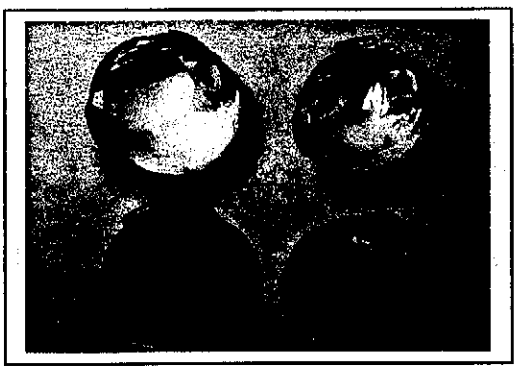

Figure 23. Western pimpleback *Quadrula mortoni*: Neches River, Tyler County, Texas; 58, 59 mm sl. Right specimen may be a "*nodifera*" type.

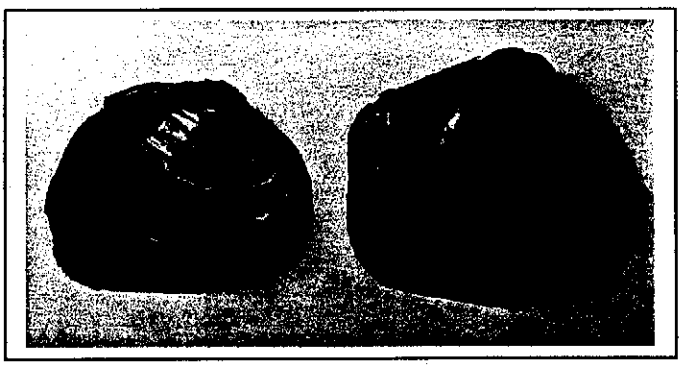

Figure 24. Western pimpleback *Quadrula mortoni*; Neches River, Tyler County, Texas; 60, 70 mm sl. Left specimen may be "*nodifera*."

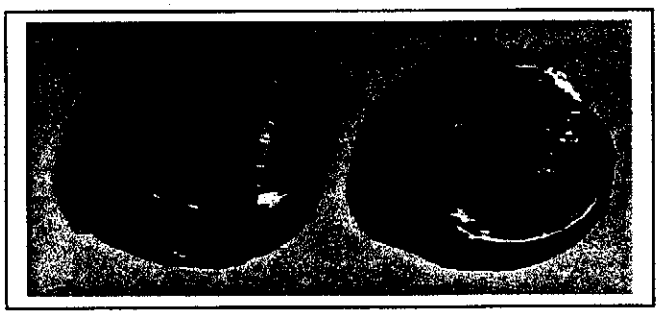

Figure 25. Western pimpleback *Quadrula mortoni*; Neches Neches River, Tyler County, Texas; 61, 63 mm sl. Both may be "*nodifera*" types.

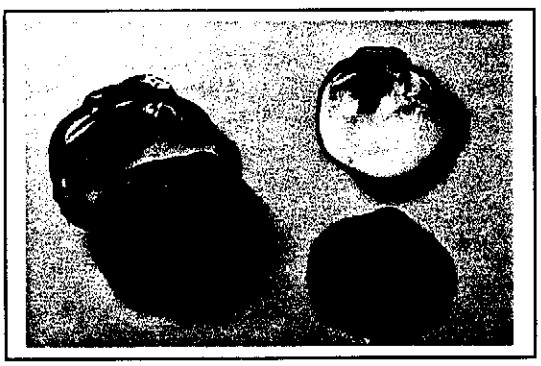

Figure 26. Western pimpleback *Quadrula mortoni*; Neches River, Tyler County, Texas; 43, 52 mm sl.

Figure 27. Western pimpleback *Quadrula mortoni*: Big Cypress Bayou, Camp County, Texas; 61, 64 mm sl. Both may be "*nodifera*" types.

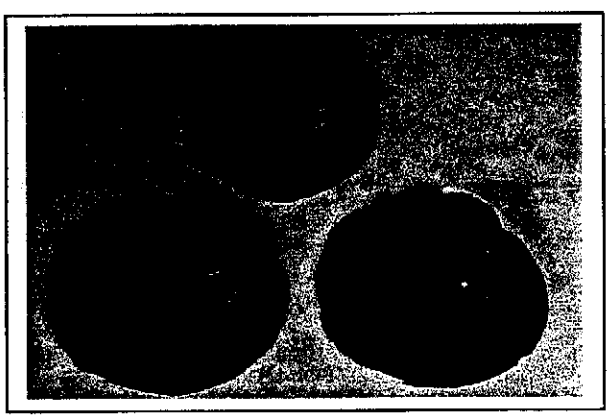

Figure 28. Western pimpleback *Quadrula mortoni*; Sabine River, Harrison County, Texas; 43, 54, 55 mm sl.

PLATE 5. WESTERN PIMPLEBACK (*Quadrula mortoni*) – BUFFALO BAYOU AND SAN JACINTO DRAINAGES

Figure 29. Western pimpleback *Quadrula mortoni*: Buffalo Bayou, Harris County, Texas; 66 mm sl. Typically rectangular with numerous small pimple-like pustules that occasionally elongate into lines or ridges. Rare in 1994; few if any may remain at present. Though quite distinct from Neches and Sabine populations, both this and San Jacinto specimens have usually been considered to be *Q. mortoni*.

Figure 30. Western pimpleback *Quadrula mortoni*; West San Jacinto River, Montgomery County, Texas; 56, 59 mm sl. Rectangular to oval; heavily covered with small pustules. Populations in both east and west river branches have largely been eliminated.

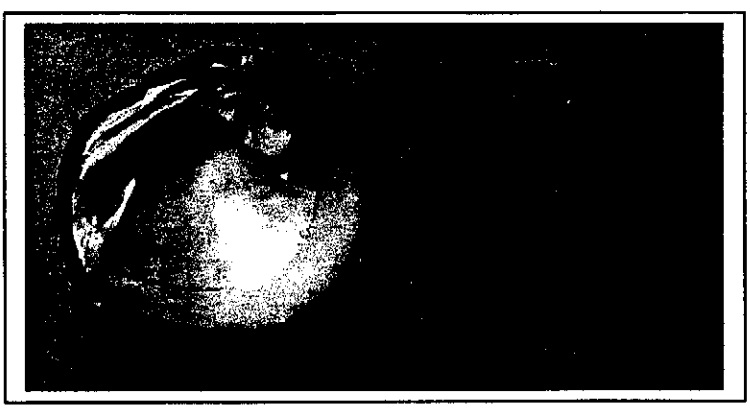

Figure 31. Western pimpleback *Quadrula mortoni*; West San Jacinto River, Montgomery County, Texas; 51 mm sl.

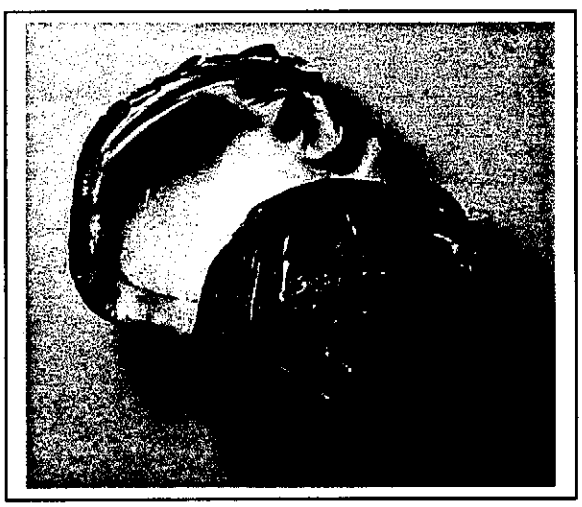

Figure 32. Western pimpleback *Quadrula mortoni*; Lake Houston, San Jacinto River Drainage, Montgomery County, Texas; 80 mm sl. Reservoir specimens are much larger, heavier, and less rectangular than those from the San Jacinto River branches.

PLATE 6. TRINITY RIVER PIMPLEBACKS [*Quadrula* sp(p).]

Figure 33. Unidentified pimpleback *Quadrula* sp(p).; Lake Lewisville, Denton County, Texas; 50, 59 mm sl.

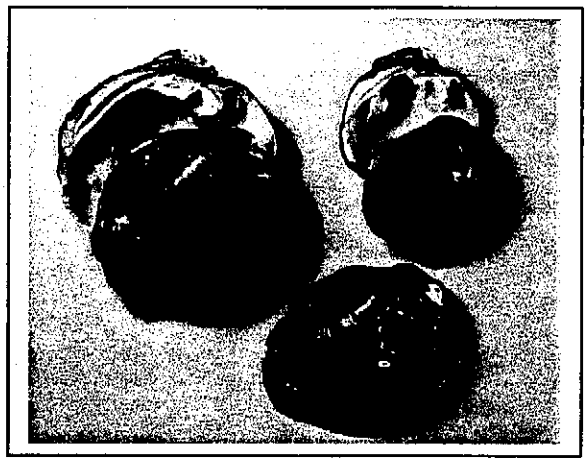

Figure 34. Unidentified pimpleback *Quadrula* sp(p).; Eagle Mountain Reservoir, Tarrant County, Texas; 46, 63, 65 mm sl.

PLATE 7. SANDERS CREEK (RED RIVER) PIMPLEBACKS [*Quadrula* sp(p).]

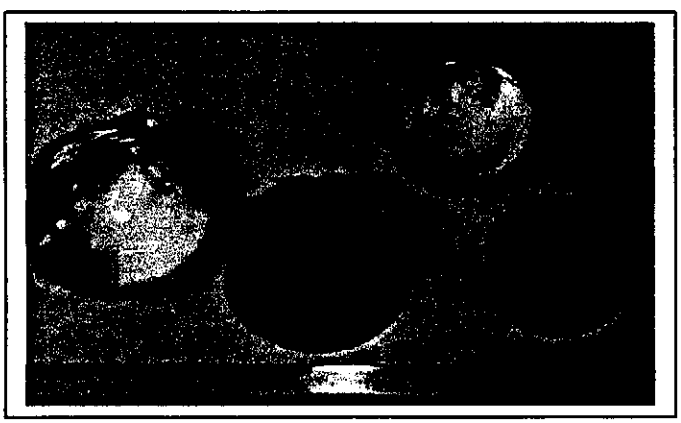

Figure 35. Unidentified pimplebacks *Quadrula* sp(p).; Sanders Creek, Red River Drainage, Lamar County, Texas.

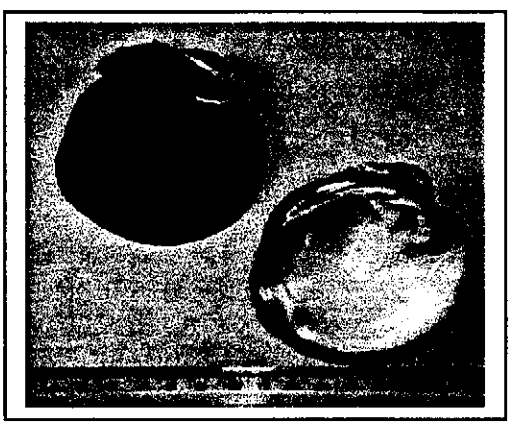

Figure 36. Unidentified pimpleback *Quadrula* sp.; Sanders Creek, Red River Drainage, Lamar County, Texas.

PLATE 8. PIMPLEBACK (*Quadrula pustulosa*) AND ALABAMA ORB (*Q. asperata*)

Figure 37. Pimpleback *Quadrula pustulosa*; Kentucky Lake, Tennessee; 73, 77 mm sl. Specimens are higher than long.

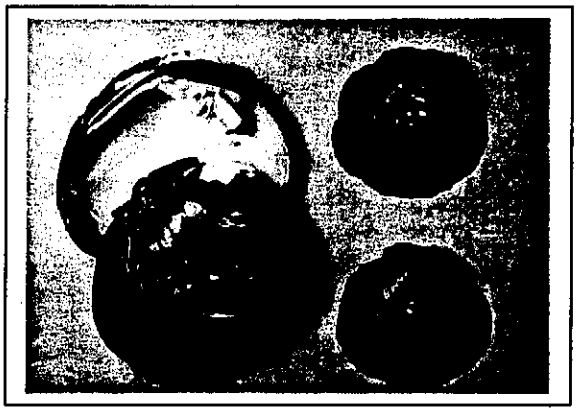

Figure 38. Pimpleback *Quadrula pustulosa*; Licking River, Tennessee; 48, 48, 70 mm sl.

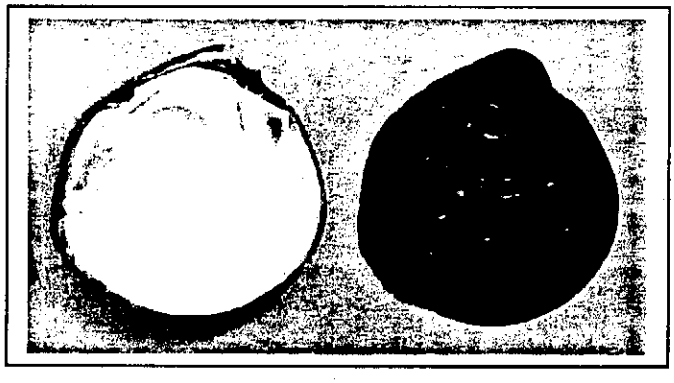

Figure 39. Alabama orb *Quadrula asperata*; Coosa River; Alabama; 49 mm sl. Specimen is higher than long.

Figure 40. Pimpleback *Quadrula pustulosa*; Muskingham River, Ohio; 48, 52 mm sl.

Figure 41. Pimpleback *Quadrula pustulosa*; St. Croix River, Minnesota; 57, 64 mm sl.

PLATE 9. PIMPLEBACKS (*Quadrula* spp.) - INFLATION

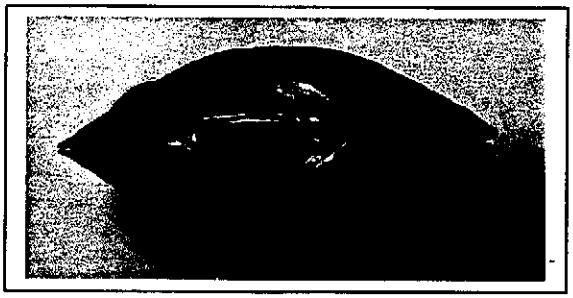

Figure 42. Golden orb *Quadrula aurea*; lower Guadalupe River, Gonzales County, Texas; 44 mm sl.

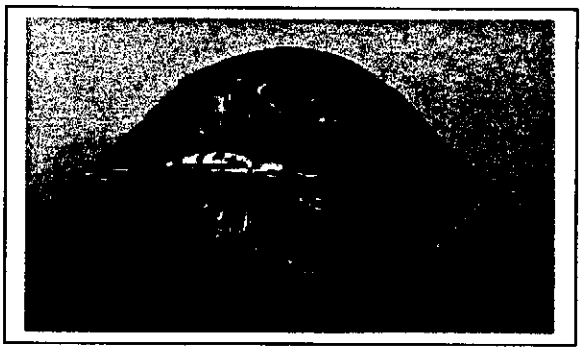

Figure 43. Smooth pimpleback *Quadrula houstonensis*; Lake Marble Falls, Colorado River, Burnet County, Texas; 50 mm sl.

Figure 44. Texas pimpleback *Quadrula petrina*; Concho River, Concho County, Texas; 67 mm sl.

Figure 45. Western pimpleback *Quadrula mortoni*; Neches River, Tyler County, Texas; 52 mm sl.

Figure 46. Pimpleback *Quadrula pustulosa*; Wabash River, Indiana; 69 mm sl. Note green ray.

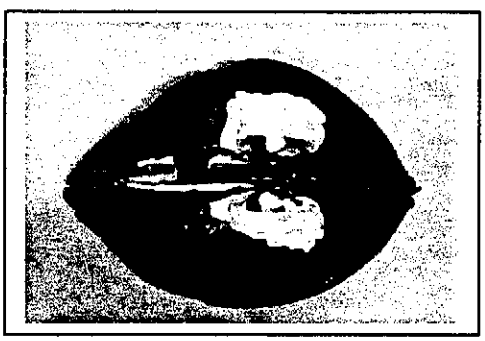

Figure 47. Western pimpleback *Quadrula mortoni* (*nodifera* type); Neches River, Tyler County, Texas; 52 mm sl.

Figure 48. Pimpleback *Quadrula* sp(p).; Upper Trinity River (Lewisville), Denton County, Texas; 50 mm sl.

Figure 49. Western pimpleback *Quadrula mortoni*; West San Jacinto River, Montgomery County, Texas; 56 mm sl.