#47

STATUS SURVEY OF TEXAS HEELSPLITTER, *Potamilus amphichaenus* (FRIERSON, 1898)

by

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FINAL REPORT

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ABSTRACT

Texas heelsplitter, Potamilus amphichaenus (Frierson, 1898), occurs in the Sabine River of Texas and Louisiana and the Neches and Trinity rivers of Texas. Reports from other rivers in Texas, Oklahoma, and Louisiana are believed to represent misidentifications of other species. Both pink papershell (P. ohiensis) and fragile papershell (Leptodea fragilis) have been confused with Texas heelsplitter.

The taxonomic validity of Texas heelsplitter has been questioned. Some authorities recognize it as a distinct species, several suspect it may only be a local form of pink papershell, and still others are uncertain. Morphologically, certain examples of both Texas heelsplitter and pink papershell are distinct; however, many intermediate forms also occur. Preliminary electrophoretic analysis using horizontal starch gel techniques was unable to resolve this problem. Unfortunately, tissue samples only recently became available (July 1994) and sample size is small (two Texas heelsplitters). It is therefore recommended Texas heelsplitter be retained as a valid taxon until additional genetic studies can be completed.

Texas heelsplitter has been, and remains, a rather rare species. Only about 150 specimens appear to have been documented since the species was described in 1898. Among these, only about 50 have been found within the last 15 years and among those, only two were alive when found. The present survey found Texas heelsplitter alive in both the Sabine (July 1994) and Neches (December 1993) rivers, but failed to find living examples in the Trinity River system where specimens were collected as recently as December 1989.

The biology and ecology of Texas heelsplitter is largely unknown. At present, river bed scouring and subsequent silt and sand deposition appear to have negatively impacted some locations where the species was previously known to occur. Texas heelsplitter has been found in a number of Texas reservoirs and appears to tolerate impoundment, but some reservoirs within its range have experienced problems with growths of noxious vegetation and fluctuating water levels (natural and deliberate). Pollution problems have probably impacted areas within its range as well. Texas heelsplitter is not harvested commercially and there is no particular evidence commercial musseling, which does occur in the Sabine River and portions of the upper Trinity River system, has negatively impacted the species.

Conservation recommendations include continued survey work (both within the general range of Texas heelsplitter and at specific previous collection sites), obtaining better understanding of its biology and ecology, as well as educational and public awareness. Additionally, designated mussel sanctuaries on the Sabine River are either known to contain Texas heelsplitters or probably do, as may others in the Neches River drainage. Sanctuary monitoring programs may help document future status of this species. Lastly, both state and federal regulatory agencies need to evaluate listing Texas heelsplitter as threatened or endangered.

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FOREWORD

When agreement among U.S. Fish and Wildlife Service and Texas Parks and Wildlife Department's (TPWD) Resource Protection Division indicated a study of the status of Texas heelsplitter (Potamilus amphichaenus) was needed, work was initially passed to Dr. Raymond W. Neck of the Houston Museum of Natural History in 1993. Neck immediately began examining museum and reference collection specimens, previous published and unpublished records of the species, and ultimately produced redescriptions of Texas heelsplitter and two additional, similar freshwater mussels for which published descriptions were insufficient for comparative purposes. Neck's field work in 1993 was confounded somewhat by rainfall and subsequent flooding in critical geographic areas into mid-1993. Unfortunately, just after drafting a preliminary version of this manuscript in fall 1993, illness struck and he was unable to complete the project.

In early 1994, I was originally contacted about finalizing this report. Because Dr. Raymond Neck and I, in conjunction with Dr. Harold Murray (Trinity University, San Antonio, Texas), had been working on a book covering freshwater mussels of Texas since mid-1992 and TPWD had been surveying unionid populations throughout Texas since January 1992, this was a logical progression. Literature and reference specimen records already documented by Neck provided direction to localities for TPWD field surveys in 1994.

However, during the TPWD-phase of this project in spring 1994, it became apparent not all authorities were in full agreement on the taxonomic status of Texas heelsplitter. Some were convinced it was unquestionably valid, several others believed it to represent only a southeastern Texas morph of pink papershell (Potamilus ohiensis), and many others were simply unsure. This in turn suggested biochemical genetic analysis would be needed to better resolve the taxonomic question. Unfortunately, tissue from only a single Texas heelsplitter was on hand and no tissue from pink papershell was available. High water conditions precluded collection of additional living specimens until July 1994, when an additional Texas heelsplitter and a group of pink papershells were collected.

Preliminary electrophoretic analysis has thus far failed to find any significant differences between Texas heelsplitter and pink papershell. However, these data are very limited in scope to date. Only eight enzyme systems and 11 loci among a single Texas heelsplitter and four pink papershells have been examined so far. More work is clearly needed. The taxonomic status of Texas heelsplitter remains unresolved.

Neck's redescriptions (largely unmodified) have been included herein, but until additional electrophoretic or other biochemical analyses can be performed, it is recommended Texas heelsplitter tentatively be considered a valid species. Other analyses are ongoing and will be presented at a future date.

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INTRODUCTION

History of Current Report

This status report describes the results of analysis of scientific literature, museum specimens, and field locality surveys designed to determine the population status of Texas heelsplitter, Potamilus amphichaenus (Frierson, 1898). This freshwater mussel was initially described by Lorraine S. Frierson in 1898 and is restricted to several river drainages in eastern Texas and western Louisiana. The present status study was begun in 1993 by the Houston Museum of Natural Science for the Texas Parks and Wildlife Department (TPWD) under contract No. 333-0208 and was completed by TPWD Inland Fisheries Branch's Heart of the Hills Research Station (HOH) in 1994.

Conservation Concern for Texas Heelsplitter (Potamilus amphichaenus)

Previous concern for the conservation status of Texas heelsplitter has been evinced in the scientific and legal literature. The first listing of Texas heelsplitter as a species of conservation concern was by Stansbery (1971:14) without specific comments on this species; neither Heard (1970) nor Athearn (1970), who discussed unionids in the Gulf drainage, listed this species. Stern (1976:159, Table 7) included Texas heelsplitter on a list of species "now believed extirpated from Louisiana drainages," but provided no details (the thrust of his investigations was farther east than the distribution of Texas heelsplitter). This species was included in a listing of the restricted and declining nonmarine mollusks of Texas (Neck 1984), but no judgments or analyses regarding population status or environmental threats were discussed.

On 6 January 1989, the United States Fish and Wildlife Service (USFWS) listed Texas heelsplitter as a Category 2 species [Federal Register 50 CFR Part 17, 54(4): 554-579], stating "information now in possession of the Service indicates that proposing to list as endangered or threatened is possibly appropriate, but for which conclusive data on biological vulnerability and threat are not currently available to support proposed rules."

Study Design

This study was divided into four primary parts, the last of which was included in mid-1994 when questions about taxonomic status arose:

1) Initially, all information available in the scientific literature was examined for significant material concerning the physical description, habitat preference, geographical distribution, and population changes (due to natural or anthropogenic changes in the natural habitat) of Texas heelsplitter.

2) Subsequently, specimens of Texas heelsplitter in museum and university collections were examined to discover new locality records, verify previously reported locality records, and to re-describe this somewhat enigmatic species. Additionally, other specimens taken by TPWD, in private collections, or reported in published literature (but not examined during the initial phase of this investigation) were also documented.

3) Efforts were also made (1993-1994) to examine locations within the geographical range of Texas heelsplitter to determine present population conditions, changes from past conditions, and preferred habitat of this species.

4) Lastly, questions concerning the taxonomic validity of Texas heelsplitter were addressed by electrophoretically examining tissue samples from Texas heelsplitter and several other similar unionids.

Report Format

The format of this report differs somewhat from most similar status-survey reports covering unionids in two ways. First, both the original description of Texas heelsplitter and subsequent descriptions are incomplete in that certain important features are lacking. Second, descriptions of two similar unionids (which have been confused with Texas heelsplitter) are also somewhat incomplete, thereby making comparisons and distinctions difficult. In the original description of Texas heelsplitter, Frierson (1898) reported this species was "one of the most distinct and remarkable Unios in the United States." Despite this statement and the reality of its distinctiveness, the identity of Texas heelsplitter has remained a mystery to many workers. Due to this confusion and the general lack of recognition of this species, the original description by Frierson, history of generic nomenclature, a compilation of the illustrations of this species, a new (more detailed) description, and points of distinction from related species are presented herein.

DESCRIPTION AND IDENTIFICATION OF TEXAS HEELSPLITTER

Original Description

The original description by Frierson (1898) was presented as follows:

"Shell large, oblong oval, thin, slightly inflated, gaping for one-half its length at the anterior and basal part, and at the upper part of the posterior end, and covered with a shining black or brownish epidermis which is decidedly wrinkled in places; growth lines strong and irregular; beaks but slightly prominent; hinge line evenly curved; hinge teeth but feebly developed, there being a single, compressed, rather sharp cardinal in the left valve of the young shell which becomes blurred and shows a tendency to split up in the older shells, and two rather short, faint laterals, the interior of which is the stronger, these being placed at the extreme posterior end of the hinge plate, with one cardinal, and sometimes a faint one above it, and a single, compressed, short lateral in the right valve, laterals ending abruptly at the posterior end, with the inner edges slightly curved upwards; area between the teeth narrow and rounded; muscle scars distinct, and quite deep for so thin a shell; posterior retractor scar completely united with the adductor, dorsal scars to the number of five or six extending in a row from the cavity of the beaks just behind their greatest projection towards the anterior base; pallial line showing a tendency to break up into several lines, and distinct traces of a posterior sinus; nacre clouded, varying from deep violet to bluish and white.

Length 106, height 63, diam. 36 mm.

Habitat, Sabine River at Logansport, Louisiana.

This is one of the most distinct and remarkable Unios in the United States. In its general structure, the hinge characters, the row of dorsal cicatrices, the incipient pallial sinus, and the gaping shell it shows relationship with Unio tenuissimus, and its nacre is something like that of this species, but the female shell is considerably swollen in the posterior-basal region, and it reminds one a little of a short Unio rectus. The posterior opening, however, is its most remarkable character, commencing about midway up the end of the shell, and extending nearly to the ends of the laterals. This gap ends abruptly above, more or less so below: the edges of the shell are reflected outwards, and considerably

lamellated, and in old shells the remains of former reflected apertures may be seen. The opening in a fully adult shell is about one-fourth inch in length, and is as distinct is that of Schizothoerus nuttalli of the west coast of the United States, and occupies about the same relative position that it does in this marine bivalve. It may possibly group with Unio , but it is quite likely that it will have to be made the type of a new group, related to that species, or the alatus and tampicoensis groups."

Subsequent Descriptions

The only other detailed descriptions of Texas heelsplitter were presented by Simpson (1900:575; 1914:186). The first description by Simpson (1900:575) was very short but contained the only published description of the animal (soft parts). It was presented as follows:

"Shell rather thin, elongate, elliptical, compressed, decidedly pointed behind, the point raised above the center of the shell; beaks low, their sculpture very feeble; there is a conspicuous postdorsal wing in young shells, and sometimes vestiges of an anterior wing; young shell rather dull and faintly rayed; there is a decided anterior basal and posterior gap; hinge teeth very imperfect; pseudocardinal almost wanting, even in young shells; laterals faint, sometimes wanting in the adult shell; nacre coppery to purplish; female shell not inflated at post base.

Animal with large, very thin, light brown branchiae, free nearly the whole length of the abdominal sac; palpi large, thin, nearly semi-circular; mantle thin, with a large crenulate border; marsupium projecting slightly below the inner gills."

A later description by Simpson (1914:186) was more detailed in the description of the shell but contains no mention of the soft parts. This description was presented as follows:

"Shell large, long elliptical, subinflated, subsolid, with moderately full, but not high beaks, whose sculpture alas not been seen; with a long, narrow gape on the anterior base and a most decided one behind just above the posterior point; posterior ridge full, rounded; surface with irregular growth marks; epidermis dark brown to jet black, smooth and shining on the middle of the disk, somewhat roughened and lamellar on the rest of the shell, especially on the posterior slope; left valve with one rather feeble, subcompressed pseudocardinal, sometimes with a smaller one above it, and a remote lateral whose inner edge is curved upward; beak cavities shallow, with an irregular row of large muscle scars running down towards the anterior base; anterior scars large, shallow; posterior scars small, somewhat elongated; pallial line wide, with a distinct sinus behind; nacre bluish and purplish, somewhat clouded. The female shell differs but slightly from that of the male, being a little fuller just behind the middle of the base and having the blunt posterior point a trifle higher.

Length 120, height 70, diam. 45 mm. The above measurements are from a large, male shell."

History of Generic Placement

In the original description, Frierson (1898) placed the Texas heelsplitter in the subgenus Lampsilis of the genus Unio [i.e., Unio (Lampsilis) amphichaenus]. Subsequent workers have placed this species in the following genera: Lampsilis (Simpson 1900:575; 1914:186; Wright and Walker 1902), Leptodea (Burch 1973; 1975; Branson 1984), Proptera (Frierson 1927:87; Strecker 1931; Parks 1938; Branson 1973; Littleton 1979; Vidrine 1985, 1993), Potamilus (Neck 1984, 1986, 1990; Turgeon et al. 1988; Vidrine 1989), and Lastena (Hoggarth 1988). The present American Fisheries Society nomenclature (Turgeon et al. 1988) follows use of Potamilus.

Published Illustrations and Photographs

The photograph that accompanied the original description (Frierson 1898) revealed a shell elliptical in overall shape. The illustrated specimen had substantial erosion of the periostracum and parts of the prismatic layer in the dorsal portion of the exterior of the left valve. The interior of the right valve as illustrated revealed an essentially intact nacre with inset muscle scars and an incipient sinus in the dorso-posterior portion of the pallial line. A new photograph of this same specimen (USNM 159935) was published by Johnson (1972:163, plate 27, fig. 1).

Burch (1973) published a line drawing of Texas heelsplitter, although the drawing of this species is labeled Leptodea laevissima (p. 135: fig.133b); the drawing that is labeled Leptodea amphichaena (p. 134: fig. 132b) is actually Potamilus ohiensis (laevissima = ohiensis). The mislabeling of these species was merely an inadvertent switching of the labels for figures 132 and 133; the various couplets in the identification key are correctly labeled. This error was corrected in the revised edition in which P. amphichaenus is correctly labeled (as Leptodea amphichaena) (Burch 1975:121, fig. 201).

Mauldin (1972:72, fig. 23, 24) illustrated a pair of valves from Eagle Mountain Reservoir (West Fork of Trinity River), Tarrant County, Texas. Although she labeled these valves as Potamilus laevissimus, they are actually P. amphichaenus [Personal examination of this pair of valves (TCU 111) by RWN].

Vidrine (1993) presented color photographs of three specimens from the Neches River, Texas. Black-and-white and color photographs of additional Neches River specimens are presented by Howells, Neck, and Murray (In Press).

No other published illustrations were located during preparation of this manuscript. The photograph of a pair of valves collected in the Navasota River and identified by Littleton (1979:77, plate 16) as Potamilus amphichaenus appears to represent a pair of valves of P. ohiensis. The exterior of the left valve is not eroded from acid etching (as is the one in Frierson 1898), but the periostracum has been lost over much of the shield area below the umbo. The interior of the right valve is intact and retains the luster of the nacre. However, no incipient sinus is present, the pallial line appears to be relatively uniform in expression, and the muscle scars are not sharply notched (see additional discussion of specimens from the Brazos River basin under Geographical Range herein).

New Description of Texas Heelsplitter

The following new description of Texas heelsplitter is presented to increase detail in the description of valves of this species and to facilitate the separation of it from related species that are similar in appearance (detailed descriptions of these related species are presented in a later section of this report).

Texas Heelsplitter
Potamilus amphichaenus (Frierson, 1898)
Fig. 1.

Shell elliptical, slightly truncated anteriorly, ventral margin is broad flattened curve (arc of an ellipse), valves thin, wings absent or barely recognizable; moderately obese dorsally (in shield area) but valves rapidly approach each other ventrally, forming sharp V-shape in ventral cross-section; anterior valve gape commences about one-fourth of height below dorsal margin, extending ventrally to ventral margin directly below pseudocardinal teeth with broadest gape at ventro-anterior corner; posterior gape commences at level of dorsal margin of posterior adductor muscle scar, continues ventrally to about two-thirds towards ventral margin, expands rapidly and remains broad with gradual but noticeable narrowing, widest gape is just above posterior ridge; beaks inequipartate,

slightly expressed above hinge line, sculptured with cone-shaped pustules that occasionally have lateral processes pointed toward beak, pustules arranged in an initial pair followed by two single pustules that are slightly ventral of posterior ridge, pustules often worn or eroded away on mature shells or shells from habitats with acidic waters; beak cavity shallow; posterior ridge slightly expressed in young shell, becoming almost obsolete at margin of mature shells, meets shell margin at about dorsal point of widest point in posterior gape, broad shelf present dorsal of posterior ridge toward hinge line; periostracum shiny, originally gray-brown to horn-brown with faint, very thin green-brown rays or dark honey brown with slightly darker brown, very thin rays; growth rings initially faint to unrecognizable, later becoming lightly expressed concentric lines of uniform width but with heavier expression both dorso-anteriorly and dorso-posteriorly, rest lines slightly higher in relief and brown-black in color, radiating lines of wrinkles (analogous in position to rays) occur on either side of posterior ridge and approach margin of shell for entire length of posterior gape, these "wrinkle rays" are faint to unrecognizable in the oldest region of the shell near the umbo; single, thin pseudocardinal tooth in left valve, greatest height near anterior margin, very low ridge runs from anterior end of tooth to dorsal margin of anterior adductor muscle scar; pair of pseudocardinal teeth in right valve, posterior larger and almost ventral of anterior tooth which is about two-thirds length and height of posterior tooth, very low ridge runs from anterior margin of anterior tooth to dorsal margin of anterior adductor muscle scar; two left and one right lateral teeth almost form a straight line with pseudocardinals, widest point of arc between end of lateral(s) and pseudocardinal(s) is immediately ventral of beaks; paired lateral teeth in left valve roughly coequal in length but offset such that dorsal tooth is more anterior and ventral tooth is more posterior, ventral tooth of greater height; umbo muscle scars form line that approaches posterior margin of beak cavity, individual scars distinct but variable in shape, round or oblong with longest diameter of individual scars perpendicular or slightly oblique to axis of row of scars; anterior adductor and anterior pedal retractor muscle scars broadly joined except for cleft that separates dorsal third; posterior pedal retractor and posterior adductor muscle scars joined broadly, only slight notch of separation on anterior margin, very lightly expressed low extension of lateral tooth touches posterior pedal retractor muscle scar at dorso-anterior margin; pallial line distinct anteriorly but becoming faint posterior of mid-point, approaches point one-fourth anterior from ventro-posterior corner of anterior adductor muscle scar before deflection to meet scar at mid-point of ventral margin; pallial line indented to form broad sinus below posterior adductor muscle scar; nacre pink, pink-purple, or purple and iridescent in mature shells, pigment expressed slightly more dorsally, lighter colored in young, but not white.

The above re-description is largely a more detailed account of the physical characters of the shell of Texas heelsplitter. Not described before are some of the details of the pattern of the muscle scars and the pallial line. Most noteworthy as new in the above description is the account of the sculpture of the umbo. Frierson (1898) makes no mention of the type of sculpture present on the umbo of this species. Simpson (1900:575) simply described the umbos as "beaks low, sculpture very feeble." In a later description, Simpson (1914:18,6) stated that the "sculpture has not been seen."

Biochemical Genetic Identification

In July 1994, David Van Meter (TPWD, HOH) used horizontal starch gel electrophoresis (techniques follow Research Staff 1989) to examine tissue from a single Texas heelsplitter (Sabine River, Panola County, Texas; 5 July 1994) and four pink papershells (P. ohiensis; Arrowhead Lake, Clay County, Texas; 12 July 1994) along with several specimens each of bleufer (P. purpuratus) and fragile papershell (Leptodea fragilis). Results (Table 1) indicated bleufer and fragile papershell were clearly distinct from each other and from Texas heelsplitter and pink papershell. However, virtually every allele found in Texas heelsplitter was also present in pink papershell. The only exception found at PEP-1 (Table 1) was an apparent heterozygote in Texas heelsplitter but only the faster allele in pink papershell. Larger sample sizes may well show the slower allele in pink papershell as well. No clear distinction between Texas heelsplitter and pink papershell was evident.

It is important to realize electrophoretic analyses can definitely show two organism are different, but they cannot conclusively demonstrate they are the same. Failure to find a difference may only reflect on small sample size and the limited number of enzyme systems and loci examined (i.e., a difference may exist which has simply not been found yet). Very clearly, additional work will be needed to determine if Texas heelsplitter and pink papershell are similar but distinct species, or if they are only forms of the same species.

SIMILAR SPECIES

Overview of Similar Species

Several species of freshwater mussels that occur in the same river systems and often occupy similar habitat areas as Texas heelsplitter are sufficiently similar in general appearance they may be, and certainly have been, confused with it. Most problematic are pink papershell and fragile papershell.

1) Pink papershell:

This species was known for many years as Potamilus laevissimus (Lea 1830). Neck (1986, 1990) reported Texas heelsplitter specimens from Lake Tawakoni (Sabine River drainage) and Lake Lewisville (Little Elm Fork of the Trinity River) were differentiated from specimens of pink papershell from the Red River (the next river system to the north) by the following characters:

> Texas heelsplitter: "1) less compressed laterally; 2) more prominent sinus in the posterior portion of the pallial line; 3) prominent umbo scars; 4) much lower wings, anteriorly and especially posteriorly; 5) large gape between the valves, especially anteriorly; and 6) decreased prominence of pallial line anteriorly."

2) Fragile papershell:

Although the classical form of this species is readily separable from Texas heelsplitter, certain specimens (particularly those that are inflated and have reduced wings) are superficially similar and may cause some confusion. Additionally, some fragile papershells become atypically dark in color in some geographic areas.

New Descriptions of Similar Species

The similarity of overall appearances of Texas heelsplitter, pink papershell, and fragile papershell, as noted above, can cause uncertainty in identification of a particular pair of valves, especially if they are young or injured. The following descriptions of shells of these two similar species are offered as comparative re-descriptions in order to identify and highlight differences between these two species and Texas heelsplitter that are constant despite age or growth history of the valves being compared.

Pink Papershell
Potamilus obiensis (Rafinesque 1820)
Fig. 2.

> Shell ovate-elliptical, rounded anteriorly, ventral margin continuous curve (arc of an oval), valves somewhat thin but sturdy, wings slightly to greatly expressed (always higher than beak unless broken), shell compressed, only slightly expanded below posterior ridge, valves approach ventral margin as sharp V-shape but only slight contrast with dorsal outline; valves gape anteriorly; posterior gape

commences at level of dorsal margin of posterior adductor muscle scar, continues ventrally to about two-thirds toward ventral margin, expands gradually to a point and almost unnoticeably narrows, widest gape is just above posterior ridge; beaks inequipartate, only barely expressed above hinge line, ornamented with pair of pustules in the form of low cones, anterior member of first or both pairs may be substantially smaller or even obsolete, pustules frequently become worn or etched away; beak cavity very broadly open, almost to actually obsolete; posterior ridge almost obsolete, recognizable as slight break in curve of valve immediately below level of hinge, meets shell margin at dorsal point of posterior gape, no shelf between posterior ridge and hinge line; periostracum shiny gray-brown to orange-brown, light honey brown ventrally in mature shells, very narrow brownish rays fading into darker ventral margin of mature shells, growth rings regularly spaced but only slightly expressed, rest rings marked by channel or a low but definite ridge with hint of shallow channel; "wrinkle rays" may be present on dorso-posterior slope or entire ventral slope in mature shells; single pseudocardinal tooth in left valve, greatest height at anterior margin, ridge toward anterior adductor muscle scar essentially obsolete, pair of pseudocardinals in right valve, definitely subequal, gracile posterior tooth is essentially ventral of anterior tooth which is about one-half length and one-third height of posterior tooth, ridge toward posterior adductor muscle scar essentially obsolete; lateral teeth (two in left valve, one in right valve) form obvious arc with pseudocardinals, widest point of arc is posterior of umbo, immediately ventral of anterior end of lateral tooth (dorsal lateral in left valve); paired lateral teeth roughly coequal in length but offset such that dorsal tooth is more anterior and ventral tooth is more posterior, ventral tooth of greater height; umbo muscle scars variably expressed, usually very shallow, irregularly-shaped scars that form line that approaches well posterior of nearly absent umbo cavity and very near anterior end of dorsal lateral tooth; anterior adductor and anterior pedal retractor muscle scars broadly joined, small cleft extends about one-tenth from dorsal margin; posterior adductor and pedal retractor muscle scars totally joined, very low ridge from dorso-anterior margin does not connect with lateral tooth; pallial line equally expressed along length of shell, approaches ventro-posterior corner of anterior adductor muscle scar before deflection to meet scar at mid-point of ventral margin; very slight inward curve of pallial line below posterior adductor muscle scar, does not form distinct sinus; nacre pink-purple to deep purple or mauve when fresh, relatively uniform in color, only very slightly more intense along inner margins of muscle scars, iridescence stronger in young shells and beyond pallial line in mature shells.

Fragile Papershell
Leptodea fragilis (Rafinesque 1820)
Fig. 3.

Shell oval, may be truncate or angular (consisting of about three straight segments) posteriorly, ventral margin curved anteriorly but flattened posteriorly due to extension of ventroposterior projection, valves thin, posterior wing usually present (may be large) but may become worn away in old specimens subjected to water and sediment buffeting, anterior wing usually absent except in immature shells where small, umbo may be below, on, or above line connecting dorsal lip of wings; moderately to strongly obese dorsally (in shield area) but valves rapidly approach each other ventrally, forming strong V-shape in ventral cross-section: valves in mature individuals may gape, at least posteriorly, anterior gape narrow if present and begins one-fourth distance below hinge line and extends to ventral margin, posterior gape noticeable but somewhat narrow over almost entire posterior edge (widest gape near dorsal portion at level of midpoint of posterior adductor muscle scar); umbos inequipartate, only slightly raised above hinge line, ornamented with series of four ridges, first often concentric, next two double-looped but somewhat straightened with two isolated slightly raised pustules, fourth almost straight with raised pustules (may be separated in middle into two short ridges), ridges frequently worn or etched away; umbonal cavity broad, very shallow but definite, posterior ridge flattened, becomes flexion point for flaring or dorsal portion of shell into prominent posterior wing; periostracum shiny to semi-shiny to silky, yellow-horn to gray-horn colored

(dorso-posterior portion becomes light to medium brown due to rough, flaky nature of periostracum near margin and slope leading into posterior wing), rays absent to barely discernible to prominent, rays may be gray-green or dull greenish, usually more prominent on posterior portion of shell, growth rings usually faint but regularly-spaced when observed, more prominent on anterior third of shell; single gracile to flattened pseudocardinal tooth in left valve, a low flat process just posterio-ventrally may function as "flat tooth"; pair of pseudocardinal teeth in right valve but anterior (dorsal) tooth is very small to obsolete, occasionally absent; lateral teeth usually two in left valve, one in right, almost straight (form sight angle with pseudocardinals) with slight ventral curve at posterior end, ventral lateral tooth larger (higher and longer) than dorsal in left valve (dorsal lateral absent in some populations); umbo muscle scars variable in number, shape, and degree of expression, shape may be irregular, circular, or oval in a line (straight or slightly curved) that meets hinge line at or slightly posterior of posterior end of umbonal cavity; anterior adductor and anterior pedal retractor muscle scar are completely joined as are posterior adductor and posterior pedal retractor muscle scars; pallial line runs from ventro-posterior corner of anterior adductor muscle scar to mid-point of posterior margin of posterior adductor muscle scar, line slightly less distinct along posterior margin; nacre white to light pinkish iridescent with more intense pinkish-brown dorsally near muscle scars and lateral teeth, may be whitish-blue iridescent in young shells.

Summary of Differences Among These Similar Species

The detailed descriptions of the three similar species presented above can be concentrated into several major differences in the shell characters of these mussels (Table 2, Fig. 4).

Texas heelsplitter typically has a dark brown epidermis which lightens to a yellow-brown approaching the umbos. Shell deposited in richly organic substrates may stain black with time. Shell shape is characterized by a rather straight hinge line and is strongly curved ventrally presenting a somewhat "D-shaped" but posteriorly-pointed appearance. Despite its common name, this species is never strongly winged. Very low anterior or posterior wings may be present if not eroded, but they rise above the hinge line only very slightly. Nacre coloration is typically purple, but is clearly bolder dorsally and fades nearly to white ventrally.

Pink papershell may have a brown periostracum, often (but not always) with greenish tints, and this coloration may or may not lighten toward the umbos. It often shows a small anterior wing and may a strongly elevated posterior wing; however, both wings may be eroded or absent. Overall shell shape tends to be decidedly more oval, without a less obviously straight hinge line. Nacre coloration is often evenly purple throughout and not specifically more pale ventrally.

Generally, fragile papershell has a yellow to yellow-horn periostracum, but specimens that have stained dark brown to black are occasionally encountered in some highly-organic substrates. Fragile papershell may have a weak anterior wing and a prominent to strong posterior wing; however, wings are frequently broken or eroded away. The nacre is generally white iridescent with pink-brown highlights dorsally (not purple and almost never covering the entire interior). Umbo muscle scars have the long diameter along the same axis as the line of scars. There is no hint of a sinus along the dorso-posterior portion of the pallial line.

All three species, like most unionids, are extremely variable. Further, all three are thin-shelled species and accordingly are somewhat prone to shell damage and subsequent malformed development. It may not always be possible to quickly identify every specimen based on superficial morphology.

GEOGRAPHIC RANGE

Localities in Scientific Literature
(Table 3, Fig. 6)

Strecker (1931:45) reported Frierson (apparently in litt. or personal communication) "says ... amphichaena inhabits all of the river systems of Texas west to and including the Brazos." Parks (1938) included Texas heelsplitter as one of the freshwater mussels occurring in the Big Thicket, apparently due to the reports summarized in Strecker (1931). It has been cited as one of several species indicative of the Sabine Subprovince, which includes the drainages of the Sabine, Neches, Trinity, and San Jacinto rivers (Neck 1982). In an initial listing of the restricted and declining nonmarine mollusks of Texas, Neck (1984:3) included Texas heelsplitter as one of the aquatic mollusks "that appear to be limited to the San Jacinto, Trinity, and Sabine-Neches systems" in Texas, although he acknowledged "unverified reports [in] the Brazos River" (Neck 1984:12). Specimens examined by R.W. Neck in museum and reference collections and others subsequently included by TPWD place the range of Texas heelsplitter in the Sabine River of Texas and Louisiana, and Neches and Trinity rivers of Texas, but not from the San Jacinto River or Brazos River drainages. Literature records of Texas heelsplitter include the following river drainages of Texas and Louisiana:

Sabine River drainage, Texas and Louisiana (Table 3, Fig. 6):

Frierson (1898, 1899b, 1911) reported Texas heelsplitter from the Sabine River, but the only locality ever stated was Logansport, DeSoto Parish, Louisiana. Simpson (1914:186) later reported the type locality as "Saline [sic] River, Texas," not only misspelling the name of the river, but also placing the type locality in the wrong state (although Logansport is directly across the Sabine River from Texas). Frierson (1899b) reported collecting additional specimens in the Sabine River at Logansport, Louisiana, just "out of sight of the town." Vidrine (1980:384, 433) reported the species from the Sabine River at Louisiana Highway 8, Burr Ferry, Vernon Parish, Louisiana, and Newton County, Texas. Neck (1986) reported five specimens from three localities in Lake Tawakoni, Hunt and Rains counties, Texas.

Neches River drainage, Texas (Table 3, Fig. 6):

Strecker (1931:45) listed no localities for Texas heelsplitter within this river system, but did note the "possible occurrence" of this species in the Neches River (Strecker 1931:71). Seven individuals were found in the Neches River at Evadale, Hardin and Jasper counties at U.S. Highway 96, eight kilometers east of Silsbee, Hardin County, on 5 January 1978 (Roback et al. 1980:612613, Table 6). Vidrine (1980:384, 443) included that locality and one additional locality in the Neches River drainage: Neches River backwater canals east of the Neches River at US Highway 96, Jasper County. Howells (In Press) reported several shells found in B.A. Steinhagen Reservoir (Dam B), Tyler County, during 1993, with an additional living specimen taken on the eastern side of the reservoir (Jasper County) in December 1993 following a partial draw-down.

Trinity River drainage, Texas (Table 3, Fig. 6):

Frierson (1902) collected three specimens near Shepherd, San Jacinto County, Texas, apparently from the mainstem of the Trinity River. The record of "Leptodea laevissima" from White Rock Lake, Dallas, Dallas County, by Read (1954) may represent an unrecognized collection of Texas heelsplitter [RWN]. The specimen illustrated by, Mauldin (1972:72, fig. 23-24) appears to be a specimen of Texas heelsplitter, although it is labeled Potamilus laevissimus (e.g., P. ohiensis). Neck (1990) reported Texas heelsplitter from 10 of 12 sites surveyed in Lake Lewisville, Denton County. The occurrence of this species in Lake Lewisville was not recognized during an earlier survey of parasites of unionids of this reservoir (Flook and Ubelaker 1972), due to the misidentification of this species as pink papershell [RWN].

Other river systems:

Records of Texas heelsplitter from the Brazos River of Texas (including the Navasota, Little Brazos, Leon, Little, and Bosque rivers) are problematic. Most present workers tend not to accept its presence in this drainage basin, believing them to be misidentified pink or fragile papershells, hybrids, or intergrades. Strecker (1931:45) reported specimens from the North Bosque River in McLennan County (specimens collected by Strecker and Gooch). However, no specimens of Texas heelsplitter could be located in the Strecker Museum at Baylor University, where the majority of Strecker's specimens have been deposited [RWN]. Littleton (1979, fig. 11) reported a pair of valves from the Navasota River at Texas Highway 164 in Limestone County, but also stated that he had seen specimens from the Brazos River. The illustrated valves in Littleton (1979) have been identified as pink papershell [RWN]. Examination of specimens from various museums in Texas reveal that all collections of Texas heelsplitter from the Brazos River are referable to pink papershell [RWN]. A juvenile reported by Howells (1994) from the Little Brazos River, Robertson County, initially thought to be a Texas heelsplitter, may be an atypical fragile papershell.

The reported occurrence of Texas heelsplitter in Oklahoma is questionable and almost certainly erroneous. Branson (1973) reported a single specimen (unclear if that refers to a single valve or a single individual with two valves) collected on 17 April 1959 from Mountain Fork River (a tributary of the Little River, which drains into the Red River), McCurtain County, Oklahoma (T7S, R6E, S10), within 15 kms of the state border with Arkansas. This record was later repeated by Branson (1984) with the caveat that because "this report was based upon a single specimen, the presence of this species in Oklahoma requires verification." The absence of Texas heelsplitter from the Red River, at least in northeastern Louisiana, was noted as early as Frierson (1899a). Texas heelsplitter has not been reported from adjacent Arkansas (Gordon 1980; Gordon et al. 1980; Harris and Gordon 1987, undated). C.M. Mather (pers. comm.; 17 Feb 1993) reported he had not observed Texas heelsplitter in the area of the Branson's reputed collection of this species.

Although Vidrine and Bereza (1977) indicated Texas heelsplitter was found in the Calcasieu River of southwestern Louisiana (immediately east of the Sabine River), Vidrine (1980:255) reported this erroneous record was due to confusion with fragile papershell. Writing from the geographical perspective of Louisiana, Vidrine (1980:255) stated Texas heelsplitter "is only known from the Sabine River and west into Texas." Later reports (Vidrine 1985, 1989; Stansbery and Hoggarth ms.) have similarly restricted the Louisiana distribution of this species to the Sabine River.

The San Jacinto River system, Texas, apparently has not harbored Texas heelsplitter. No published records of the species from the San Jacinto River have been located. Strecker (1931:70-71) listed 24 species and an additional five possible species for the San Jacinto River but Texas heelsplitter was not on this list.

Localities from Museum Specimens
(Tables 3-5, Fig. 6)

Confirmed specimens of Texas heelsplitter [RWN] were examined in various museum and university collections are presented in Tables 3-4. Additional specimens (not seen by RWN) from other museum, university, and private collections are also presented. Localities represented by these specimens include sites in the Sabine (Texas and Louisiana), Neches (Texas), and Trinity (Texas) rivers.

Localities from Field Surveys of this Study

Field surveys to locate additional specimens and reexamine previously reported collection sites were performed by TPWD January 1993 through July 1994 (Fig. 7). Survey techniques are described in Howells (1994 and In Press), produced Texas heelsplitters from several localities (Table 4). High water and flood

conditions during periods in 1993 and 1994 precluded sampling at several locations or permitted only limited examination of these areas. A single living specimen was taken in B.A. Steinhagen Reservoir, Neches River drainage, Jasper County, Texas, in December 1993, and another was found in the Sabine River, Panola County, Texas, in July 1994 (Table 4). Several other recently-dead to long-dead shells were also collected at locations in the Neches and Sabine rivers (Table 4). Field surveys (January 1992 through July 1994) at locations on the Trinity River including reservoirs in the Dallas-Fort Worth area where Texas heelsplitter had been taken previously, San Jacinto River, Brazos River and several of its tributaries, and Village Creek (Hardin County, Texas) failed to locate either living specimens or shells.

Summary of Geographic Range

Confirmation of Texas heelsplitter collections appears to restrict the species to the Sabine, Neches, and Trinity rivers. Given the known occurrence of Texas heelsplitter in the Neches River system, the apparent absence of this species from one of its major tributaries, Village Creek, is very interesting and puzzling. This lacuna in the known geographical distribution of this species appears to be real, due to the amount of sampling that has occurred in Village Creek (Roback et al. 1980:608-611, Tables 3-5; Vidrine 1990; Neck unpublished survey). Village Creek supported a diverse fauna of freshwater mussels including at least 18 species (Roback et al. 1980; Vidrine 1980; Neck unpublished data). Why Texas heelsplitter had never been found in Village Creek is unclear; however, this will likely remain and enigma. Surveys of Village Creek, the adjacent Neches River (below U.S. Highway 96), and nearby Pine Island Bayou by TPWD in April 1994 not only found few living unionids, but observed much of the river bottoms in the area to be heavily covered with deep sand deposits. Sand deposition and other unfavorable environmental factors will likely make the area inhospitable to all unionids in the near future.

ECOLOGY

Little is known of any ecological relationships of Texas heelsplitter beyond the few references to substrate type. Frierson (1899b, 1902) noted the occurrence of Texas heelsplitter in deep sand deposits in the Sabine River at Logansport, Louisiana, and the Trinity River near Shepherd, Texas. Neck (1986) reported Texas heelsplitter was uncommon in "quiescent waters with sandy or mud substrates" in Lake Tawakoni, Sabine River drainage. Collections in B.A. Steinhagen Reservoir on the Neches River (Howells In Press) found dead shell in a soft, mud-bottomed cove with sand and sand-mud shorelines; the only living specimen taken was located in a sandy-bottomed area. When this living individual was placed in a flow-through raceway in the HOH wet lab, it was observed to be relatively inactive on the hard raceway bottom. The animal extended its siphons and occasionally extended its foot to feel the raceway bottom, but made little attempt to crawl around. Bleufers taken at the same time and placed in the same raceway were much more active and attempted to crawl about in another section of the same raceway.

The type locality of Texas heelsplitter supported a diverse freshwater mussel fauna, apparently exhibiting a high density of individuals, according to the notes of Frierson (1899b). Associated species were as follows: giant floater (Anodonta grandis), paper pondshell (A. imbecillis), rock-pocketbook (Arcidens confragosus), squawfoot (Strophitus undulatus), threeridge (Amblema plicata), washboard (Megalonaias nervosa), bankclimber (Plectomerus dombeyanus), southern mapleleaf (Quadrula apiculata), western pimpleback (Q. mortoni), Texas pigtoe (Fusconaia askewi, Wabash pigtoe (F. flava), Louisiana pigtoe (Pleurobema riddelli), Louisiana fatmucket (Lampsilis hydiana), sandbank pocketbook (L. satura), yellow sandshell (L. teres), fragile papershell, threehorn wartyback (Obliquaria reflexa), southern hickorynut (Obovaria jacksoniana), bleufer, deertoe (Truncilla truncata), and little spectaclecase (Villosa lienosa). Similar species assemblages were found

in Lake Lewisville (Neck 1990) on the Trinity River, Lake Tawakoni (Neck 1986) on the Sabine River, and B.A. Steinhagen Reservoir (Howells In Press) on the Neches River (Table 6).

Interestingly, pink papershell has not been reported from the same localities at the same time as Texas heelsplitter. Pink papershell occurs in drainages to the north, west, and east of Texas heelsplitter. The only major exception appears to be reports from the Brazos River system where pink papershell has been reported along with "Texas heelsplitter" specimens of questionable identity. An additional exception is Eagle Mountain Reservoir and Elm Fork, Tarrant County, Texas, on the upper Trinity River drainage. During preparation of this report, specimens examined by RWN from Eagle Mountain Reservoir were found to be Texas heelsplitter (Table 3). However, a collection by TPWD in 1992 at this site produced a single specimen of pink papershell but no Texas heelsplitters [RGH]; subsequent surveys in 1993 and 1994 failed to find either. Strecker (1931) observed pink papershell was not known from the Trinity River although it occurred in adjacent waters. The single pink papershell specimen from Eagle Mountain Reservoir may represent a recent introduction.

No information on suitable host fishes required for glochidial attachment of Texas heelsplitter is known (Fuller 1974:237; Hoggarth 1992). Other species of Potamilus are known to utilize freshwater drum, Aplodinotus grunniens, (Coker and Surber 1911; Surber 1912, 1913, 1915; Howard 1913; Wilson 1916; Howard and Anson 1922). Pink papershell is also known to utilize white crappie, Pomoxis annularis, (Surber 1913; Wilson 1916). Gordon (1989) indicated a published description of the glochidium of Texas heelsplitter was not available. However, Hoggarth (1988:227, fig. 56) illustrated the glochidium based on material obtained from a preserved female taken in the Sabine River in the 1960s.

Vidrine (1980:443; 1989) listed three species of freshwater mites that were found associated with the soft parts of Texas heelsplitter. No details of the exact nature of the symbiotic relationship between these mites and Texas heelsplitter are known at this time.

POPULATION TRENDS

Most unionids in Texas and Louisiana that are characteristic of flowing waters are perceived to be less abundant, and probably have experienced reduction in numbers, but no comparative census data are available for Texas heelsplitter. Stern (1976; 159, Table 7) did include Texas heelsplitter on a list of species "now believed to be extirpated from Louisiana drainages", but no explanation for this classification was provided. Neck (1990) found 40 specimens in Lake Lewisville on the upper Trinity River drainage during a drought. Reexamination of Neck's collection sites in 1994 failed to find any Texas heelsplitters.

Recent surveys (1992-1994) by TPWD have shown mussels have been reduced or extirpated from a disconcerting number of Texas rivers. Although no population estimates exist for past Texas heelsplitter populations, habitat alteration and loss at a number of locations within the range of Texas heelsplitter suggest its numbers have likely declined. Conversely, reservoir construction at some locations may actually have helped Texas heelsplitter survive in numbers greater than might have been present if only riverine habitats had been available.

Specimens documented in scientific collections or scientific literature (Tables 3-5) total only about 150 animals since the original description in 1898. Even allowing some specimens that may have been overlooked during preparation of this report, Texas heelsplitter was and remains a very rare species. Indeed, only about 50 specimens appear to have been documented during the last 15 years, and only two of these were actually found alive; however, several others were very-recently dead (e.g., dried soft tissue still attached to the valves).

IDENTIFIED THREATS

River Bed Scouring

Poor water-release practices by impoundment operators or flooding resulting from land-management practices have resulted in scoured river bottoms in some areas such that only bedrock and heavy cobble bottoms remain. For example, when the TPWD surveyed mussels in the Trinity River from Lake Livingston dam downstream to U.S. Highway 59, only a few southern mapleleafs were found alive. However, long-dead and subfossil shell deposits on one gravel bar demonstrated the area once held a significantly large and diverse unionid assemblage. High-volume water releases or abrupt flow stoppages during high-water periods appear to have, at least in part, been responsible for changing the river bed largely to heavy rocks and deep-shifting sands (undesirable mussel habitat).

Siltation and Sand Deposition

Many factors causing river bed scouring also relate to deposition of sand and silt also creating undesirable mussel habitat or covering existing mussel beds. In B.A. Steinhagen Reservoir on the Neches River, silt and mud have been deposited such that many areas of the reservoir are extremely shallow; some embayments are heavily filled with deep, soft silt (undesirable mussel habitat).

Sand deposition associated with scouring water releases or high rainfall and subsequent damaging erosion of sandy river banks appears to be a major problem in many East Texas waters. The sandy surface soils of East Texas seem very sensitive to even slight disturbances of natural vegetative cover. Urban and residential expansion, highway construction, bridge construction, and lumbering, to name but a few causes, often result in area streams filling with deep sand. Examples of sand-smothered waters within the range of Texas heelsplitter include: Trinity River tributary streams below Lake Livingston (e.g., Long King Creek), some tributary streams off B.A. Steinhagen Reservoir and the contiguous Neches River, lower Neches River from Evadale to Pine Island Bayou, Pine Island Bayou, Village Creek (Hardin County), West Branch San Jacinto River below Lake Conroe (San Jacinto County), and tributary streams of upper Lake Conroe (Walker County).

Impoundments

Impoundment of free-flowing streams alters the habitats occupied by unionids in several significant ways. Ponded water allows accumulation of fine-grained sediments (clays and silts) in areas that were previously coarse-grained substrates (sand) due to the continued entrainment of the fine particles by moving water. Oxygen levels may be depressed with the decline in water movement due to accumulation of organic material (elevating the local BOD) and lack of "fresh" water entering the habitat in some cases. Water depths are typically increased, resulting in many of the same alterations in habitat as decreased water flow. In some instances, the individual mussels in these resident populations of unionids are not killed, but no reproduction occurs following inundation. Lack of reproduction can be due to lack suitable nutrient stores to allow production of gametes and brooding of young. Lack of population recruitment may also involve high mortality of young stages due to lack of suitable host fish or unsuitable benthic substrates.

The impact of inundation of natural habitat of Texas heelsplitter has not been studied by paired surveys of pre- and post-impoundment fauna of a single site or segment of a stream. However, the occurrence of Texas heelsplitter in Lake Tawakoni (Neck 1986), Lake Lewisville (Neck 1990), and B.A. Steinhagen Reservoir (Howells In Press), indicates inundation does not totally destroy suitable habitat of this species. An argument could be made that additional habitat is created following stream inundation due to the increase

in area of benthic substrate and also protection is provided from scouring or sand smothering that is more pronounced in riverine situations. Certainly, some species of unionids found in Texas waters appear to be more abundant following impoundment of free-flowing streams (e.g., giant floater, southern mapleleaf, etc.). However, in relation to inundation impacts on Texas heelsplitter, note should be made that in all three above impoundments, Texas heelsplitter is not abundant and often tends to be found in or near old stream beds that are now permanently inundated but still receive flowing water on a regular basis. Williams et al. (1992) report a congeneric species, inflated heelsplitter (Potamilus inflatus), has been collected only rarely following impoundment construction on the Tombigbee River in Alabama and Mississippi; the few recent collections have been made below dam sites or in portions of reservoirs that still experience flowing water.

Pollution

Occurrence of high concentrations of certain chemicals or lack of oxygen due to chemical consumption of oxygen in habitats occupied by unionids may cause high mortality rates or lack of successful reproduction. Detrimental effects of pollutants on suitable food items normally suspended in the water column or populations of host fish species may also significantly affect populations of freshwater mussels. Damaging effects upon unionids have been demonstrated for acidity increases, runoff, and effluents from wood pulp and paper mills, organic enrichment due to anthropogenic eutrophication, tar and oil, and increased silt loads due to land clearing (Fuller 1974). Environmental pollution problems have been reported in the upper Trinity River in the Dallas-Fort Worth area (Strecker 1931; Read and Oliver 1953) and in Pine Island Bayou and the lower Neches River (Harrel 1993) within the range of Texas heelsplitter.

No specific information on the impact of any of above pollutants on populations of Texas heelsplitter is available at this time. However, in areas where environmental degradation has reduced or extirpated unionid populations, Texas heelsplitter has been likely negatively impacted as well. Urban expansion of Houston, Beaumont, Dallas, Fort Worth, and other cities will likely expand this problem in the future.

Reservoir and River Management Practices

Some reservoirs within the range of Texas heelsplitter do not maintain constant water levels. Water levels may be dropped in one reservoir to maintain levels in another downstream impoundment, to provide downstream water to meet urban and agricultural demands, for maintenance and repair work, or in efforts to eradicate noxious vegetation. Low water levels may also occur naturally during droughts. Natural causes generally occur gradually and allow unionids to retreat as water levels recede. Deliberate lowering of water levels may be more abrupt and is more likely to strand unionids. The large collection of Texas heelsplitters (40 specimens) at Lake Lewisville occurred during a natural drought period (Neck 1990). The December 1993 collection of a living Texas heelsplitter at B.A. Steinhagen Reservoir occurred when the reservoir was lowered deliberately to kill noxious vegetation and a second specimen was found dead upstream during this same time period (C.E. Boone, Houston Museum of Natural Science; pers. comm.). Although droughts and drawdowns are unavoidable, slowly lowering reservoir levels during deliberate drawdowns could potentially allow more unionids to survive than rapid drawdowns.

Exotic Vegetation

Noxious aquatic vegetation has become problematic in some waters within the range of Texas heelsplitter. Examples of noxious aquatic plants include introduced water hyacinth (Eichhornia crassipes), hydrilla (Hydrilla verticillata), and Eurasian watermilfoil (Myriophyllum spicatum). The first two species have prompted control efforts in southeastern Texas and the latter in some North Texas reservoirs. Unionids generally prefer to avoid dense beds of vegetation or vegetative cover; presumably Texas heelsplitter does as

well. Rapid growths of aquatic plants logically limit available mussel habitat. Once aquatic macrophytes have become problematic, failing to apply control efforts may result in mussels being excluded from many areas. However, conversely, attempting to control noxious vegetation (e.g., herbicides, drawdowns) may also pose negative impact problems for unionids.

Exotic Bivalves

Asian clams (Corbicula spp.) occur throughout the range of Texas heelsplitter. While there is little direct evidence of negative impact to unionid survival (including that of Texas heelsplitter), large numbers of Asian clams may represent competition for food and space. The softer, more acid waters of southeastern Texas may help limit Asian clam abundance and subsequent possible impact on Texas heelsplitter.

Zebra mussel (Dreissena polymorpha), which invaded the Great Lakes in the 1980s, has escaped and advanced down the Mississippi River; it has now been reported in Oklahoma, Arkansas, and Louisiana (O'Neil 1994). Although not present in Texas or within the range of Texas heelsplitter at this time, it will likely invade in the near future. Zebra mussel is known to negatively impact unionid populations in invaded waters and will likely pose a threat to Texas heelsplitter in the coming years.

Commercial Musseling

Texas heelsplitter is not deliberately taken by commercial or sport musselers. However, the Sabine River in areas near Texas heelsplitter populations are heavily musseled by commercial harvesters as are some reservoirs in the upper Trinity River drainage (Howells 1993). It is possible commercial harvest activity may indirectly impact Texas heelsplitter negatively; however, no direct evidence has been demonstrated to date.

SUMMARY

Overview of Field Survey Results

Reviews of museum, university, and private collections and reports in published literature place the known number of Texas heelsplitter specimens at about 150, with only about 50 animals reported in the last 15 years of which only two have apparently been found alive. Taxonomic status still remains questionable and additional biochemical genetic studies should be performed to better clarify this issue.

Field surveys by TPWD of Texas mussel populations examined over 50 sites in 1992, over 160 in 1993, and over 140 from January through July in 1994. Many of these covered areas within the range of Texas heelsplitter; however, the species was taken alive at only two locations: B.A. Steinhagen Reservoir on the Neches River and in the Sabine River south of Marshall. High water conditions during a number of efforts precluded sampling several sites including some areas where Texas heelsplitter had historically been reported. Most, but not all, previously reported collection sites were examined.

Although Texas heelsplitter has been and remains a very rare species, it is advantaged by occurrence in three completely disconnected river systems (Sabine, Neches, and Trinity river drainages) in differing geographic regions. Widely separated populations provide some protection against extinction from local catastrophic events.

CONSERVATION RECOMMENDATIONS

1. Survey all previously reported collection sites of Texas heelsplitter.

2. Survey all other possible Texas heelsplitter population sites within its known range.

   River access problems in conjunction with limitations on personnel, funding, equipment, and weather factors makes quick, efficient surveys of many areas difficult. For example, there is little river access on the Trinity River between Dallas and Lake Livingston thus requiring long runs by boat to reach potential sampling sites, or other exceptional efforts. Taking advantage of droughts and low-water periods, deliberate drawdowns, and dam breaks is advisable.

3. Repeat surveys at these collection sites at periodic intervals.

4. Better define ecological requirements.

   As specimens become available, efforts should be made to carefully document associated ecological parameters including both biotic and abiotic factors.

5. Define periods of reproduction.

6. Determine necessary hosts.

   Gravid females obtained during field surveys should be used to provide glochidia for host determination tests.

7. Mussel sanctuaries.

   In 1992 and 1993, TPWD established 28 mussel sanctuaries around the state where mussel harvest is prohibited, including a number within the range of Texas heelsplitter (Fig. 9). Several on the Sabine and Neches rivers are adjacent to previously reported collection sites. Some of these sanctuaries have not been fully surveyed to date and may contain Texas heelsplitters. As field surveys better define the locations of existing Texas heelsplitter populations, it may be desirable to expand or relocate one or more of these sanctuaries to include Texas heelsplitter habitat. Additionally, B.A. Steinhagen Reservoir is operated by the U.S. Army Corps of Engineers which in 1991 prohibited commercial mussel harvest in all reservoirs it operates in Texas. This offers some additional level of protection to the population found in B.A. Steinhagen Reservoir. The sanctuary on the Trinity River below Lake Livingston dam has suffered extensive habitat modification in recent years and appears to protect few unionids at present. If additional Texas heelsplitter populations are located either above or below this site, the sanctuary may be relocated or redefined.

8. Education and public awareness.

   Efforts should be made to provide pamphlets and associated literature to enhance public awareness of this species. Efforts should also focus on enlightening reservoir and river managers not only about the presence of Texas heelsplitter, but ideally should include recommendations for minimal operation impact techniques. Similarly, land owners, developers, highway and bridge construction operations, lumber companies, and the like need to be made aware of habitat losses caused by some of their activities. Recommendations to minimize such impacts should be developed. Information should also be made available to appropriate state and federal departments and agencies that operate within the range of Texas heelsplitter.

9. Legal listing.

No invertebrate has ever been listed by TPWD as threatened or endangered. This includes federally-listed Ouachita rock-pocketbook (Arkansia wheeleri) which was confirmed in Texas for the first time in 1993. TPWD needs to evaluate whether Texas heelsplitter should be included as a threatened or endangered species on state lists. Similarly, this species should be evaluated for inclusion on federal lists.

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Table 1. Genetic loci and alleles found with horizontal starch gel electrophoresis for Texas heelsplitter (Potamilus amphichaenus), pink papershell (P. ohiensis), bleufer (P. purpuratus), and fragile papershell (Leptodea fragilis) in tests performed at Heart of the Hills Research Station, Ingram, Texas, July 1994.

Enzyme system	Bleufer	Pink Papershell	Texas heelsplitter	Fragile papershell
MDH-1-120	-	-	-	X
MDH-1-105	-	X	-	X
MDH-1-100	X	X	X	X
MDH-1-95	X	X	-	-
MDH-1-90	X	X	-	-
MDH-1-80	X	-	-	-
MDH-2-100	X	X	X	-
MDH-2-90	-	-	-	X
GPI-1-105	X	-	-	-
GPI-1-100	X	-	-	X
GPI-1-90	X	-	-	-
GPI-2-100	-	X	X	-
PEP-1-110	-	X	X	-
PEP-1-105	-	-	X	-
PEP-1-100	X	-	-	X
PEP-2-105	X	-	-	-
PEP-2-100	X	X	X	-
PEP-2-95	X	-	-	-
PEP-2-90	-	X	X	-
PGM-1-110	X	-	-	-
PGM-1-100	X	X	X	X
PGM-1-90	X	X	X	X
SOD-1-100	-	X	X	-
SOD-1-90	-	X	-	-
SOD-1-80	X	X	-	X
IDH-1-100	X	X	X	X
FBP-1-100	X	X	X	X
TPI-2-100	X	X	X	X

Table 2. Summary of significant shell differences between Texas heelsplitter (Potamilus amphichaenus), pink papershell (P. ohiensis), and fragile papershell (Leptodea fragilis).

Character	Texas heelsplitter	Pink papershell	Fragile papershell
Nacre	Purple dorsally to white ventrally	Pink to deep purple throughout	White, often with red or pink dorsally
Posterior muscle scar	Sharp V notch dorsally	Broad, shallow notch dorsally	Little or no notch
Pallial line	Fainter in posterior half; with prominent sinus posteriorly	Equal expression along length; only slight hint of sinus	Fainter posteriorly; no sinus
Posterior gape	Large, rapidly expanding	Moderate, gradually expanding	Slight to moderate
Posterior slope	Broad level shelf	High angle into wing	Low angle into wing
Beak cavity	Shallow but definite	Shallow, very broad	Shallow, constricted ventrally
Wings	Very small to to absent	Anterior wing low; posterior wing moderate to large; both wings often eroded and absent	Anterior wing low; posterior wing moderate to large; both wings often eroded and absent
External coloration	Dark brown to black lightening to chestnut on beaks	Light brown to black, often with greenish tint; may or may not lighten on beaks	Typically pale horn yellow, but may stain dark brown to black; occasionally with green rays

Table 3. Specimens of Texas heelsplitter (Potamilus amphichaenus) represented in university and museum collections and refererenced in published literature prior to 1980. Specimens examined by R.W. Neck and verified as Texas heelsplitters are noted with a "*" next to the number of specimens. Whole numbers of specimens represent a matched pair of valves; 0.5 represents a single valve.

Collection data							Data source		
N Specimens	Drainage basin	Location	County/ Parish	State	Date	Collector	Location	Collection number	Comment
2*	Sabine	Sabine R. Logansport	DeSoto	LA	-	L.S. Frierson	Academy of Natural Sciences Philadelphia, PA	77560	paratypes
1*	Sabine	1 mi. N. Deweyville	-	TX	-	R. Newton	Brazos Museum, Lake Jackson, TX	-	
-*	Sabine	Sabine R.	-		-	L.S. Frierson	Los Angelos County Museum, CA	105/33	
1*	Sabine	Sabine R.	DeSoto	LA	-	L.S. Frierson	Museum of Zoology, University of Michigan, Ann Arbor, MI	107936	paratype
-*	Sabine	Sabine R. Logansport	DeSoto	LA	-	-	Texas Memorial Museum, Austin, TX	227	
1*	Sabine	Sabine R. Logansport	DeSoto	LA	-	L.S. Frierson	U.S. National Museum, Washington, D.C.	159935	holotype
2	Sabine	Sabine R.	Shelby DeSoto	TX LA	28 Jul 1964	C.B. Stein/ G. Procell	Ohio State University Museum of Zoology, Columbus	20168	weathered
4	Sabine	Sabine R.	Shelby DeSoto	TX LA	28 Jul 1964	C.B. Stein	Ohio State University Museum of Zoology, Columbus	16293	fresh dead
2	Sabine	Sabine R.	Sabine Sabine	TX LA	26 Jul 1964	C.B. Stein/ R.I. Johnson	Ohio State University Museum of Zoology, Columbus	14425	live
12	Sabine	Sabine R.	Newton Vernon	TX LA	28 Jul 1964	C.B. Stein/ R.I. Johnson	Ohio State University Museum of Zoology, Columbus	12985	fresh dead
5	Sabine	Sabine R.	Shelby DeSoto	TX LA	28 Jul 1964	C.B. Stein	Ohio State University Museum of Zoology, Columbus	14325	fresh dead
-	Sabine	Sabine R. Burr Ferry	Newton Vernon	TX LA	-	M.F. Vidrine	(Vidrine 1980)	-	
1	Neches	_	-	TX	-	-	Brazos Museum, Lake Jackson, TX	-	data missing
-*	Neches	Neches R. Dam B	Jasper/ Tyler	TX	-	P.H. McGee	Houston Museum of Natural Science, TX	-	
7*	Neches	Neches R. Evedale	Jasper/ Hardin	TX	05 Jan 1978	-	(Roback et al. 1980)	-	
3	Neches	Neches Silsbee	Jasper/ Hardin	TX	05 Jan 1978	D. Bereza et al.	(Vidrine 1993)	-	
-	Neches	Neches R.	Jasper	TX	-	M.F. Vidrine	(Vidrine 1980)	-	
1	Neches	Dam B	Tyler	TX	Jun 1967	Frank Simmons	Trinity University, San Antonio	678	
-*	Trinity	Lake Lewisville	Dallas	TX	-	J.M. Flook	Dallas Museum of Natural History, TX	0359	
3*	Trinity	Trinity R. Shepherd	San Jacinto	TX	-	L.S. Frierson (1902)	Dallas Museum of Natural History, TX	-	
-*	Trinity Slough	Parsons	Kaufman	TX	-	E.P. Cheatum	Dallas Museum of Natural History, TX	0404	
1*	Trinity	White Rock Res.	Dallas	TX	-	-	(Read 1954)		
-*	Trinity	Trinity R.	-	TX	-	R.E. Call (#1820)	Museum of Comparative Zoology, Cambridge, MA	5525	

Table 3. Continued.

Collection data							Date source		
N Specimens	Drainage basin	Location	County/ Parish	State	Date	Collector	Location	Collection number	Comment
4+ 1 x 0.5*	Trinity	Eagle Mt. Res.	Tarrant	TX	15 Sep 1971	J.C. Britton/ V.L. Mauldin	Texas Christian University Fort Worth, TX	82	
3*	Trinity	Eagle Mt. Res.	Tarrant	TX	2 Oct 1971	J. Pettit/ V.L. Mauldin	Texas Christian University Fort Worth, TX	111	
1*	Trinity	Eagle Mt. Res.	Tarrant	TX	5 Jul 1975	J.C. Britton	Texas Christian University Fort Worth, TX	2191	
1*	Trinity	L. Worth	Tarrant	TX	17 Apr 1972	V.L. Mauldin/ C. Poschman	Texas Christian University Fort Worth, TX	206	
2+ 1 x 0.5*	Trinity	L. Bridge-port	Wise	TX	12 Aug 1972	J.C. Britton	Texas Christian University Fort Worth, TX	226	
2*	Trinity	L. Bridge-port	Wise	TX	8 Oct 1972	J.C. Britton	Texas Christian University Fort Worth, TX	336A	
1*	Trinity	Denton Cr. Bakers Bridge	Denton	TX	12 Aug 1972	J. Pettit	Texas Christian University Fort Worth, TX	352	
1+ 1 x 0.5*	Trinity	Denton Cr. Bakers Bridge	Denton	TX	18 Jul 1973	J.C. Britton	Texas Christian University Fort Worth, TX	410	
3*	Trinity	L. Grape-vine	Tarrant	TX	31 Oct 1975	K. O'Kane	Texas Christian University Fort Worth, TX	1782	One taken alive
0.5*	Trinity	L. Grape-vine	Tarrant	TX	30 Mar 1974	T. Grunninger	Texas Christian University Fort Worth, TX	566	
-*	Trinity	Elm Fork	Denton	TX	-	-	U.S. National Museum, Washington, D.C.	425331	
1*	Trinity	Elm Fork		TX	-	V.L. Mauldin	(Mauldin 1972)	-	Labeled *lacvissima*
40*	Trinity	L. Lewis ville	Denton	TX	1977-1978	R.W. Neck	(Neck 1990)	-	Dead
1*	Trinity	Trinity R.	Dallas	TX	-	-	Strecker Museum, Baylor University, Waco, TX	-	

Note: B.A. Steinhagen Reservoir on the Neches River is sometimes referred to as "Dam B".

Table 4. Specimens of Texas heelsplitter (Potamilus amphichaenus) reported in collections from 1980 through July 1994.

Collection data							Data source		
N Specimens	Drainage basin	Location	County/ Parish	State	Date	Collector	Location	Collection number	Comment
5	Sabine	Lake Tawakoni	Hunt/ Rains	TX	Oct 1984	R.W. Neck	(Neck 1986)	-	Dead
2	Sabine	Sabine R. Gladewater	Gregg	TX	20 Aug 1984	J.A.M. Bergman	J.A.M. Bergman (pers. comm.)	-	Recently dead
12	Sabine	Sabine R. Carthage	Harrison	TX	08 Aug 1981	J.A.M. Bergman	J.A.M. Bergman (pers. comm.)	-	Recently dead
0.5	Sabine	Sabine R. Carthage	Harrison	TX	17 Aug 1992	J.A.M. Bergman	J.A.M. Bergman (pers. comm.)	-	Recently dead
1	Sabine	Sabine R. Hwy 79	Panola	TX	06 Jul 1994	L. Garcia/ D. Wilson	Texas Parks and Wildlife Dept. Heart of the Hills Research Station, Ingram	-	Recently dead
1	Sabine	Sabine R. Hwy 59	Panola	TX	06 Jul 1994	L. Garcia/ D. Wilson	Texas Parks and Wildlife Dept. Heart of the Hills Research Station, Ingram	-	Live
1	Sabine	Sabine R. below L. Tawakoni	Hunt/ Rains	TX	27 Jun 1994	L. Garcia/ D. Wilson	Texas Parks and Wildlife Dept. Heart of the Hills Research Station, Ingram	-	Dead
0.5	Trinity	Elm Fork Aubry	Denton	TX	04 Oct 1983	J.A.M. Bergman	J.A.M. Bergman (pers. comm.)	-	Recently dead
1	Neches	B.A. Steinhagen Res.	Tyler	TX	03 Mar 1993	R.G. Howells	Texas Parks and Wildlife Dept. Heart of the Hills Research Station, Ingram	-	Long dead
1	Neches	B.A. Steinhagen Res.	Tyler	TX	03 Apr 1993	R. Weinecke	Texas Parks and Wildlife Dept. Heart of the Hills Research Station, Ingram	-	Long dead
1	Neches	B.A. Steinhagen Res.	Tyler	TX	04 May 1993	R.G. Howells	Texas Parks and Wildlife Dept. Heart of the Hills Research Station, Ingram	-	Long dead
1	Neches	B.A. Steinhagen Res.	Jasper	TX	29 Dec 1993	T. Castillo T. Viola	Texas Parks and Wildlife Dept. Heart of the Hills Research Station, Ingram	-	Live
1	Neches	B.A. Steinhagen Res. Sandy Cr. Reservoir	Jasper	TX	04 Jan 1994	J.A. Gartiz	C.E. Boone, Houston Museum of Natural History	37085	Very recently dead

Table 5. Possible specimens of Texas heelsplitter (*Potamilus amphichaenus*) in the collections at the University of Science and Arts of Oklahoma (USAO) and of C.M. Mather (USAO) collected from 1980 through June 1994. Among specimens designated *Potamilus amphichaenus*, *P. ohiensis*, and *P. laevissima* (i.e., Texas heelsplitter or pink papershell), individuals from the Sabine, Neches, and Trinity rivers are listed below.

Collection data							Data source		
N Specimens	Drainage basin	Location	County/ Parish	State	Date	Collector	Location	Collection number	Comment
1	Sabine	Sabine R. Carthage	Harrison Panola	TX	09 Aug 1981	C.M. Mather	C.M. Mather (pers. comm.)	-	
4+ 2 x 0.5	Sabine	Sabine R.	Harrison Panola	TX	09 Aug 1981	C.M. Mather	University of Science and Arts of Oklahoma, Chicksha		
0.5	Trinity	White Rock Cr.	Trinity	TX	17 Aug 1980	C.M. Mather	C.M. Mather (pers. comm.)	-	
2	Trinity	Trinity R. Crockett	Leon	TX	06 Aug 1981	C.M. Mather	C.M. Mather (pers. comm.)	-	
1	Trinity	Richland Cr.	Navarro	TX	11 Aug 1985	C.M. Mather	University of Science and Arts of Oklahoma, Chichsha	-	
2 x 0.5	Trinity	Trinity R. Crockett	Leon	TX	06 Aug 1981	C.M. Mather	University of Science and Arts of Oklahoma, Chicksha	-	
3 x 0.5	Trinity	Trinity R. Crockett	Leon Houston	TX	14 Aug 1986	C.M. Mather	University of Science and Arts of Oklahoma, Chichsha	-	
1+ 1 x 0.5	Trinity	L. Livingston	Walker	TX	28 Dec 1989	C.M. Mather	University of Science and Arts of Oklahoma, Chicksha	-	

Table 6. Bivalves reported to occur with Texas heelsplitter (Potamilus amphichaenus).

Source	Frierson(1899b)	Neck (1986)	Neck (1990)	Howells (1994)
Location	Sabine River	L. Tawakoni	L. Lewisville	B.A. Steinhagen Reservoir
River system	Sabine	Sabine	Trinity	Neches
Species:				
Threeridge (Amblema plicata)	X		X	X
Giant Floater (Anodonta grandis)	X	X	X	X
Paper pondshell (Anodonta imbecillis)	X	X	X	X
Flat floater (Anodonta suborbiculata)	X			X
Rock-pocketbook (Arcidens confragosus)	X			X
Texas pigtoe (Fusconaia askewi)	X			
Wabash pigtoe (Fusconaia flava)	X			
Louisiana fatmucket (Lampsilis hydiana)	X		X	X
Sandbank pocketbook (Lampsilis satura)	X		X	-[c]
Yellow sandshell (Lampsilis teres)	X		X	X
Fragile papershell (Leptodea fragilis)	X	X	X	X
Pond mussel (Ligumia subrostrata)		X		
Washboard (Megalonaias nervosa)	X			X
Southern hickorynut (Obovaria jacksoniana)	X			
Threehorn wartyback (Obliquaria reflexa)	X			X
Bankclimber (Plectomerus dombeyanus)	X	X		X
Louisiana pigtoe (Pleurobema riddelli)	X			
Bleufer (Potamilus purpuratus)	X	X	X	X
Southern mapleleaf (Quadrula apiculata)	X	X	X	X
"Texas" mapleleaf (Quadrula sp.[a])				X
Western pimpleback (Quadrula mortoni)	X		X	X
Pimpleback (Quadrula pustulosa[b])				
Pistolgrip (Tritogonia verrucosa)			X	X
Deertoe (Truncilla truncata)	X		X	-[d]
Lilliput (Toxolasma parvus)			X	
Texas lilliput (Toxolasma texasensis)		X		X
Pondhorn (Uniomerus tetralasmus)		X		
Asian clam (Corbicula spp.)		X	X	X
Fingernail clam (Sphaerium partumeium)		X		

[a] Mapleleafs from this area have historically been considered Quadrula quadrula; however, electrophoretic analysis performed during preparation of this report found them to be different from Q. apiculata populations from numberous Texas populations and from classical examples of Q. quadrula from Tennessee.

[b] Pimplebacks (Q. pustulosa) may have been included in samples from Lake Lewisville and the Neches River below B.A. Steinhagen Reservoir; however, their identity is in doubt.

[c] Sandbank pocketbook was found in the Neches River immediately below B.A. Steinhagen Reservoir.

[d] Fawnsfoot (Truncilla donaciformis), a related species, was found in the Neches River immediately below B.A. Steinhagen Reservoir.

Figure 1. Texas Heelsplitter (Potamilus amphichaenus). All specimens collected by Texas Parks and Wildlife Department and retained at Heart of the Hills Research Station, Ingram, Texas.

A. 111 mm shell length (sl); B.A. Steinhagen Reservoir, Tyler County, TX; 28 Dec 1993.
B. 118 mm sl; Sabine River at U.S. Highway 79, Panola County, TX; 6 July 1994.
C. 155 mm sl; Sabine River below Lake Tawakoni, Hunt and Van Zandt counties, TX; 27 June 1994.

TEXAS HEELSPLITTER
Potnailus amphichaenus

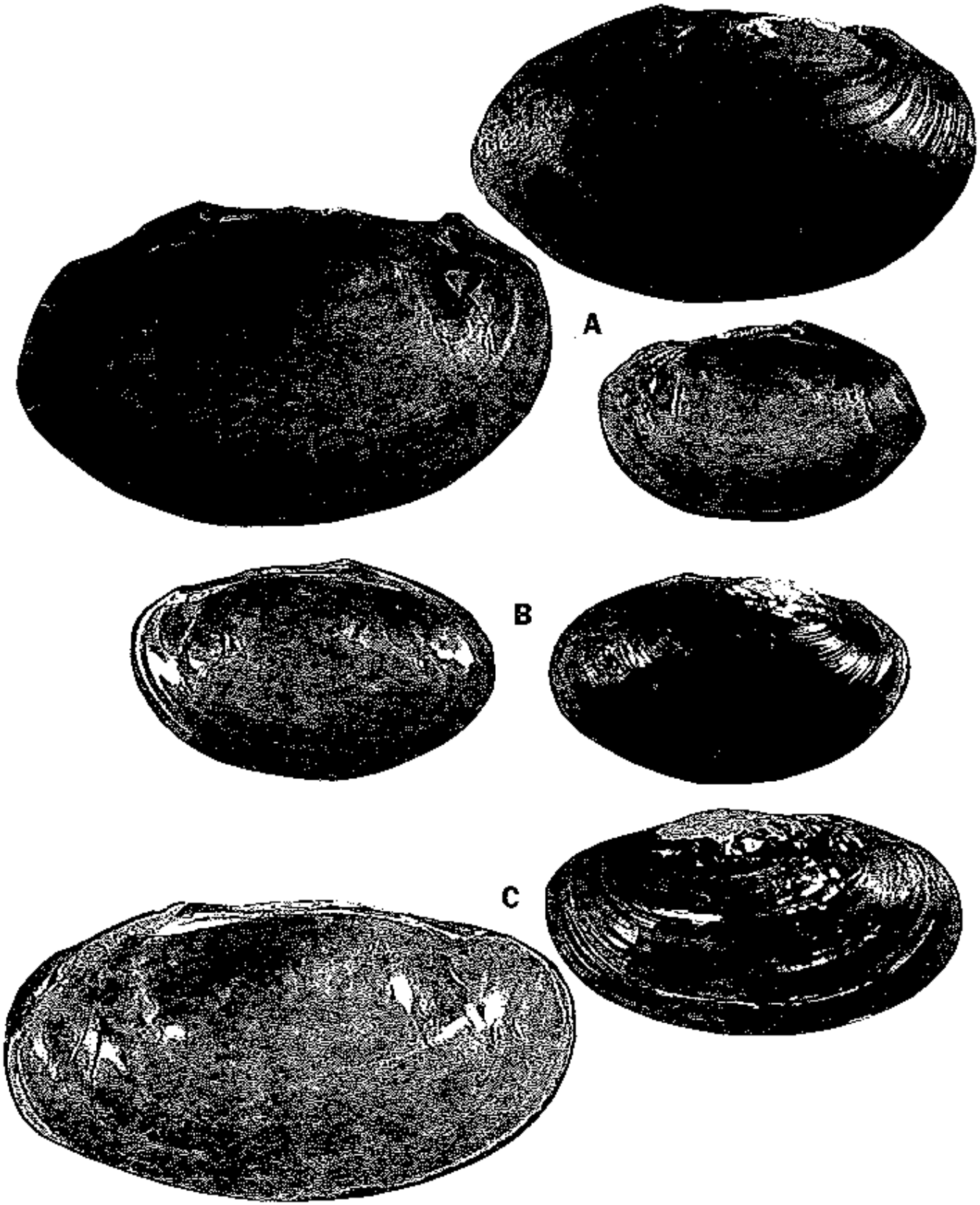


Figure 2. Pink papershell (Potamilus ohiensis). All specimens collected by Texas Parks and Wildlife Department and retained at Heart of the Hills Research Station, Ingram, Texas.

A. 104 mm shell length (sl); Lake Wichita, Archer County, TX; 12 July 1994.
B. 116 mm sl; Lake Wichita, Archer County, TX; 12 July 1994.
C. 123 mm sl; Lake Wichita, Archer County, TX; 12 July 1994.
D. 113 mm sl; Eagle Mountain Reservoir, Tarrant County, TX; 11 May 1992.
E. 127 mm sl; Lake Wichita, Archer County, TX; 18 Jan 1994.

PINK PAPERSHELL
Potamilus obiensis

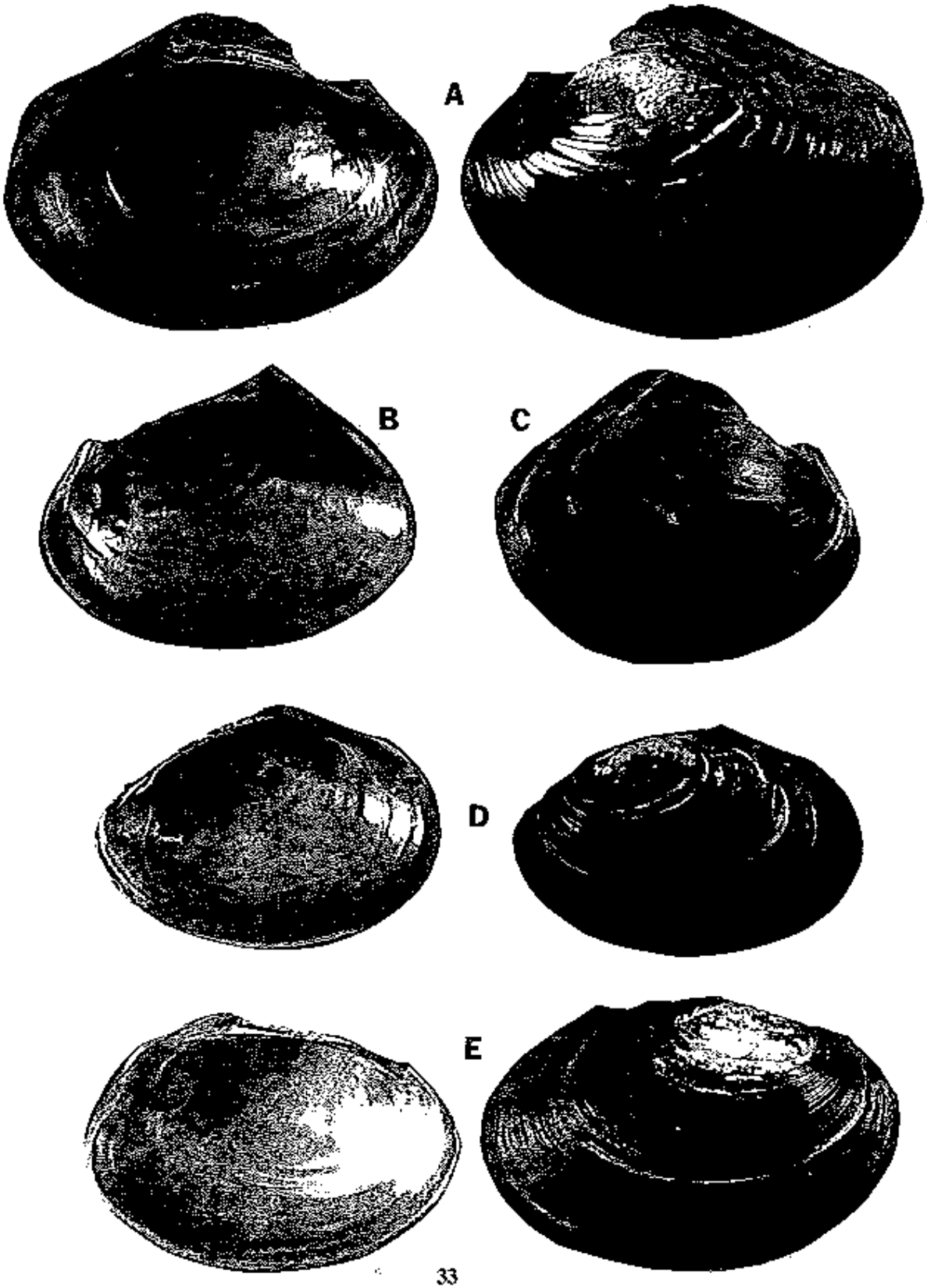


Figure 3. Fragile papershell (Leptodea fragilis). All specimens collected by Texas Parks and Wildlife Department and retained at Heart of the Hills Research Station, Ingram, Texas.

A. 120 mm shell length (sl); Lake Buchanan, Llano County, TX; 10 Dec 1993.
B. 127 mm sl; Lake Fort Phantom Hill, Jones County, TX; 14 Feb 1994.
C. 110 mm sl; Arrowhead Lake, Clay County, TX; 12 July 1994.
D. 119 mm sl; Crook Lake, Lamar County, TX; 8 Aug 1993.
E. 77 mm sl; South Sulphur River, Hopkins County, TX; 23 Jun 1993.
F. 95 mm sl; B.A. Steinhagen Reservoir, Tyler County, TX; 4 May 1993.

FRAGILE PAPERSHELL
Leptodea fragilis

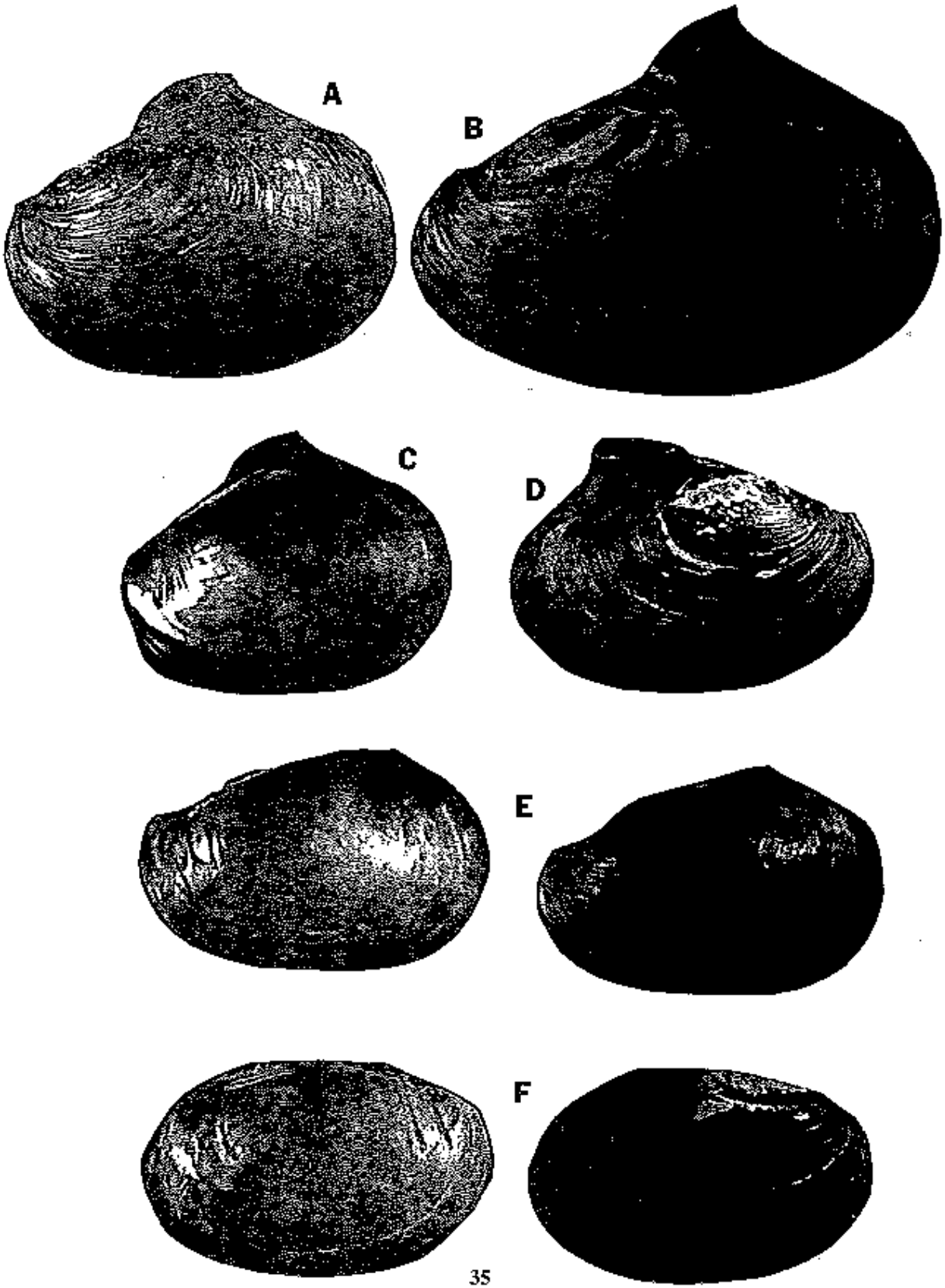


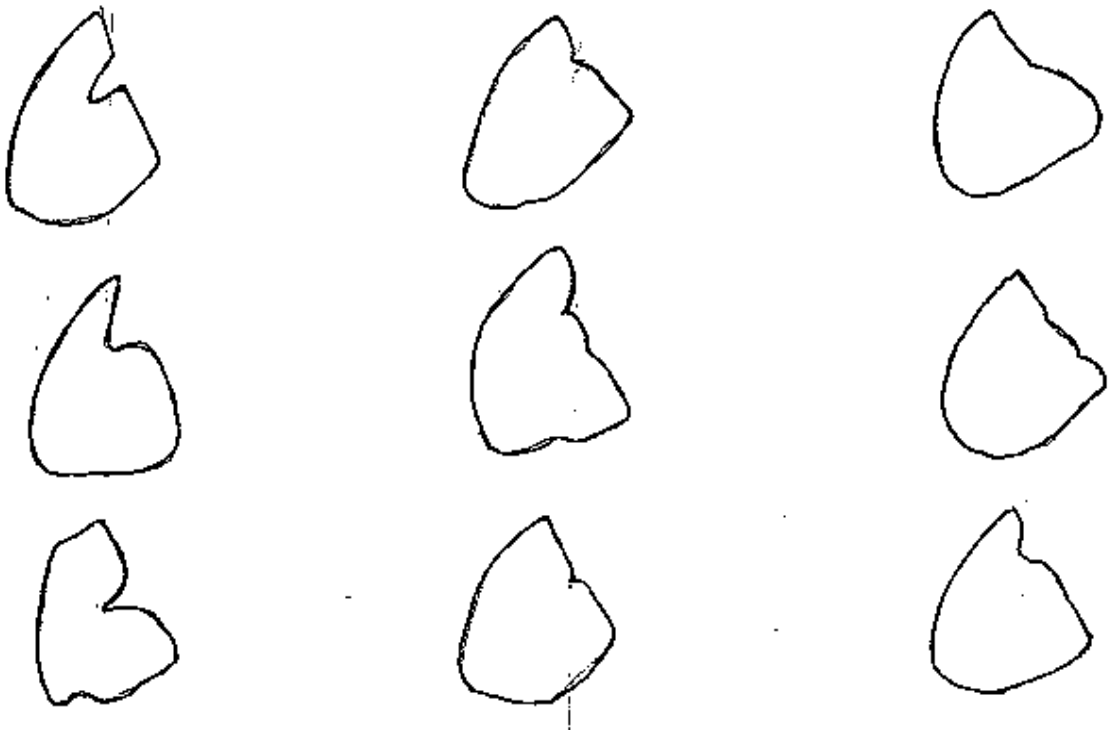
Figure 4. Posterior adductor muscle scar shape in Texas heelsplitter (Potamilus amphichaenus), pink papershell (P. ohiensis), and fragile papershell (Leptodea fragilis). A reference drawing of muscle scar locations on a Texas heelsplitter valve is also shown.

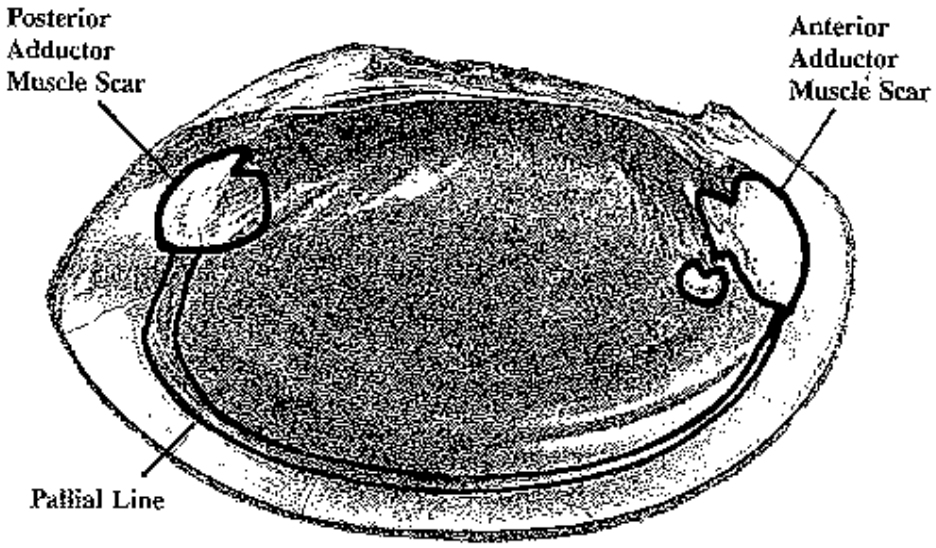
POSTERIOR ADDUCTOR MUSCLE SCAR SHAPE VARIATION

Texas heelsplitter
Potamilus amphichaenus

Pink papershell
P. ohiensis

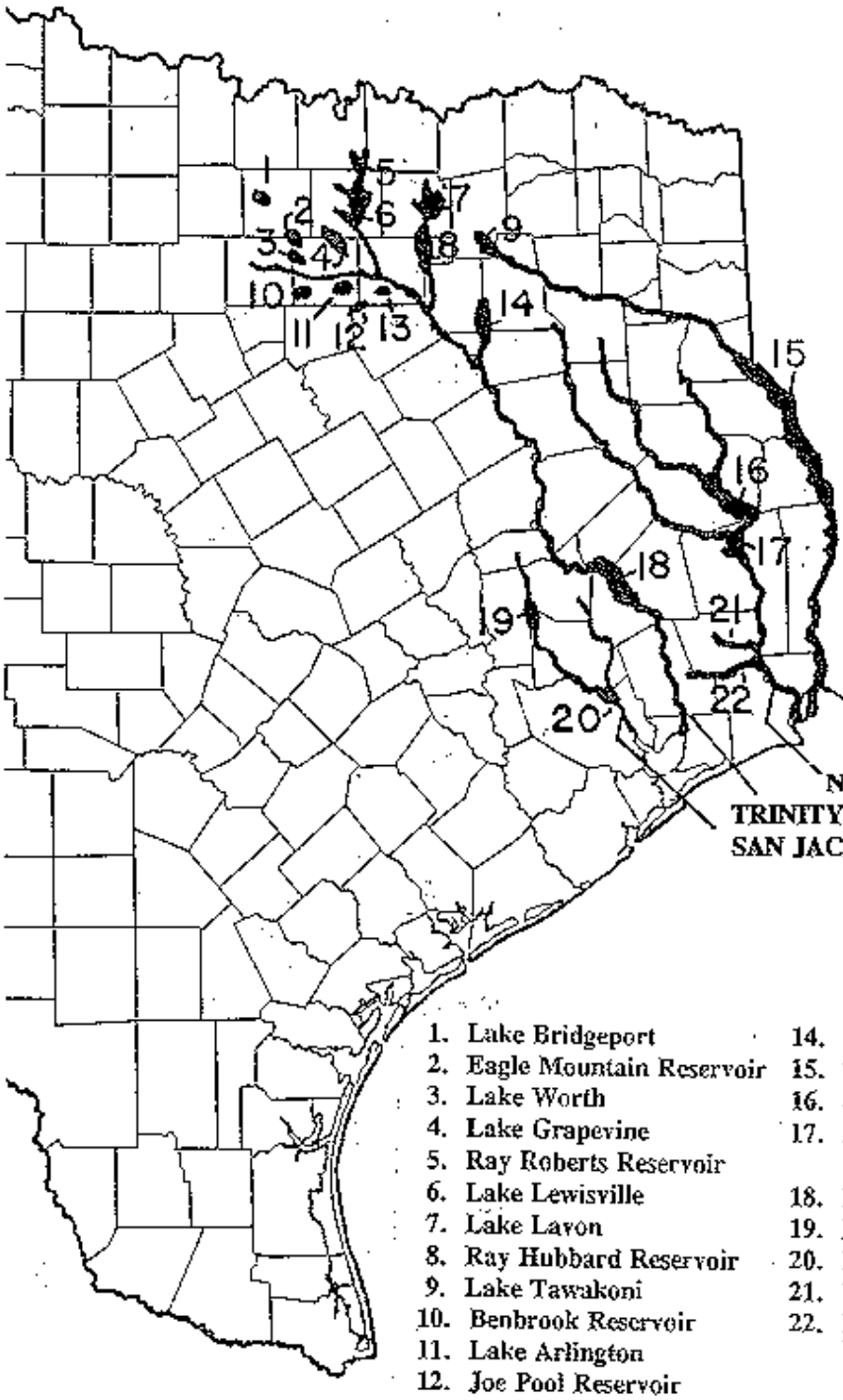
Fragile papershell
Leptodea fragilis





TEXAS HEELSPLITTER
Potamilus amphichaenus

Figure 5. Locations of the Sabine, Neches, Trinity, and San Jacinto rivers and associated reservoirs in eastern Texas.



1. Lake Bridgeport
2. Eagle Mountain Reservoir
3. Lake Worth
4. Lake Grapevine
5. Ray Roberts Reservoir
6. Lake Lewisville
7. Lake Lavon
8. Ray Hubbard Reservoir
9. Lake Tawakoni
10. Benbrook Reservoir
11. Lake Arlington
12. Joe Pool Reservoir
13. Mountain Creek Reservoir
14. Cedar Creek Reservoir
15. Toledo Bend Reservoir
16. Sam Rayburn Reservoir
17. B.A. Steinhagen Reservoir (Dam B)
18. Lake Livingston
19. Lake Conroe
20. Lake Houston
21. Village Creek
22. Pine Island Bayou

Figure 6. Locations of Texas heelsplitter (Potamilus amphichaenus) collection sites, 1898 - 1979, in eastern Texas and adjacent Louisiana waters.

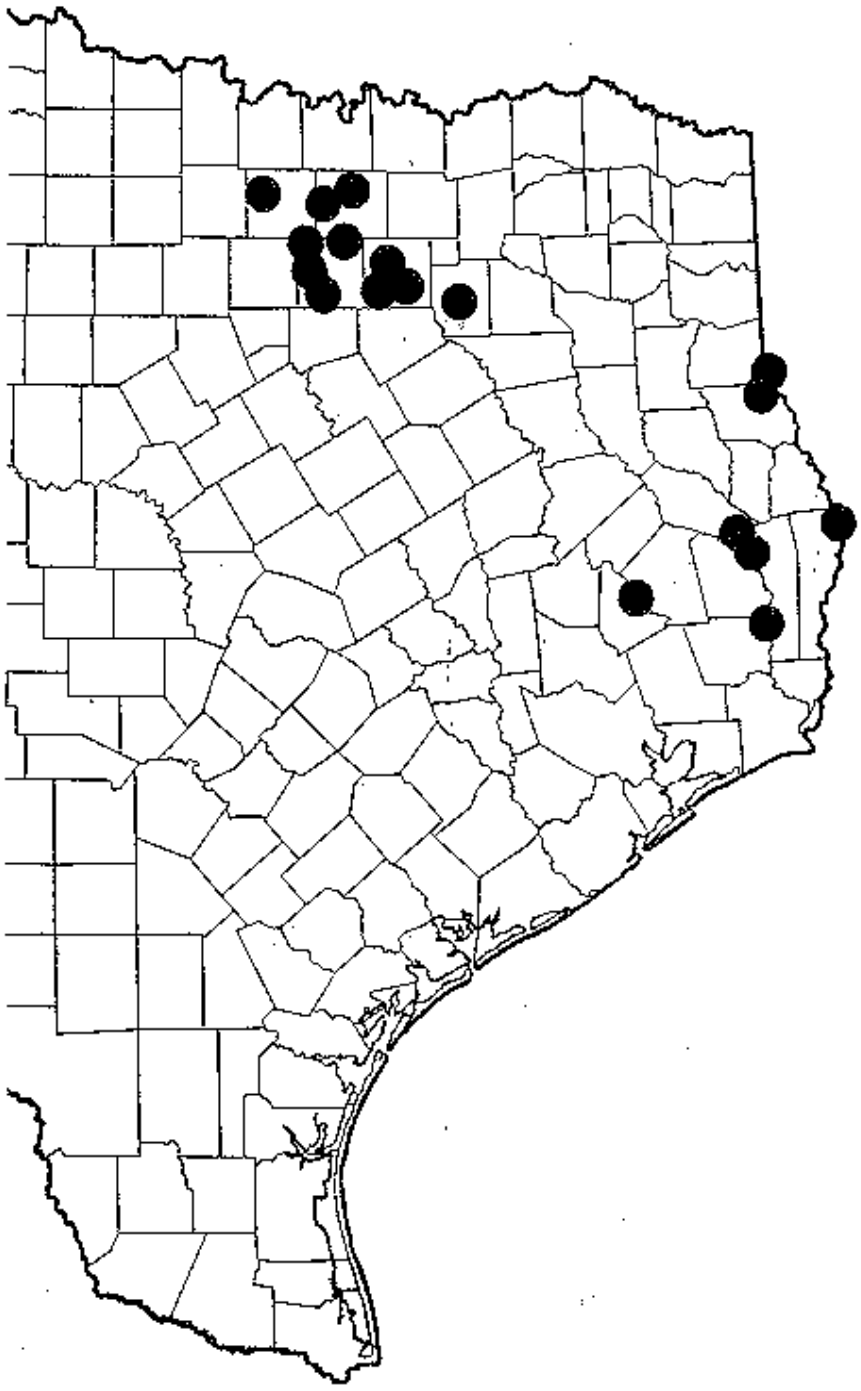


Figure 7. Freshwater mussel survey sites examined by Texas Parks and Wildlife Department, Jan 1992 - July 1994, in the Sabine, Neches, Trinity, and San Jacinto river drainages and Buffalo Bayou in eastern Texas. Mussel survey sites in adjacent river systems were also examined, but are not shown.

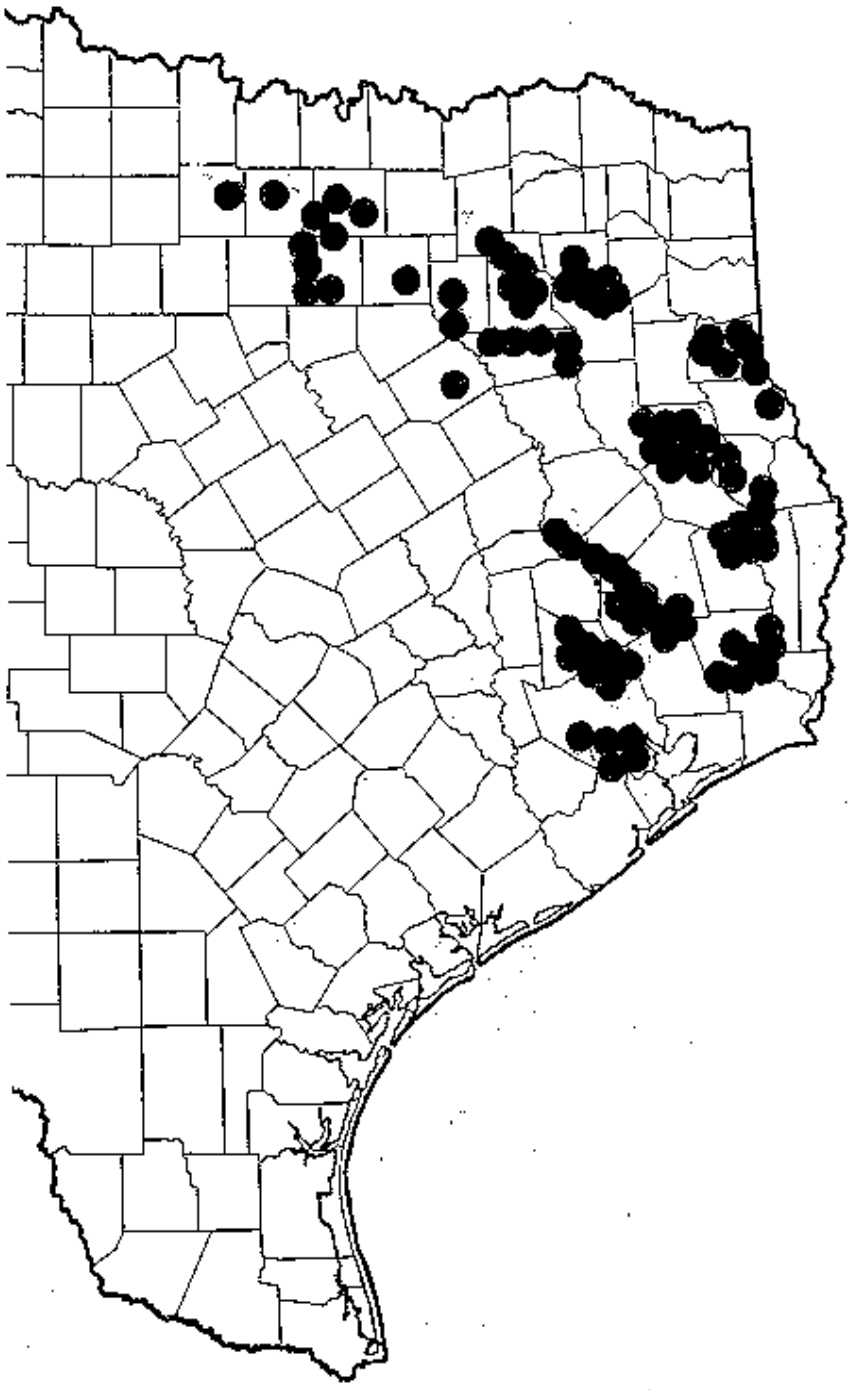


Figure 8. Locations of Texas heelsplitter (Potamilus amphichaenus) collection sites, 1980 - July 1994, in eastern Texas.

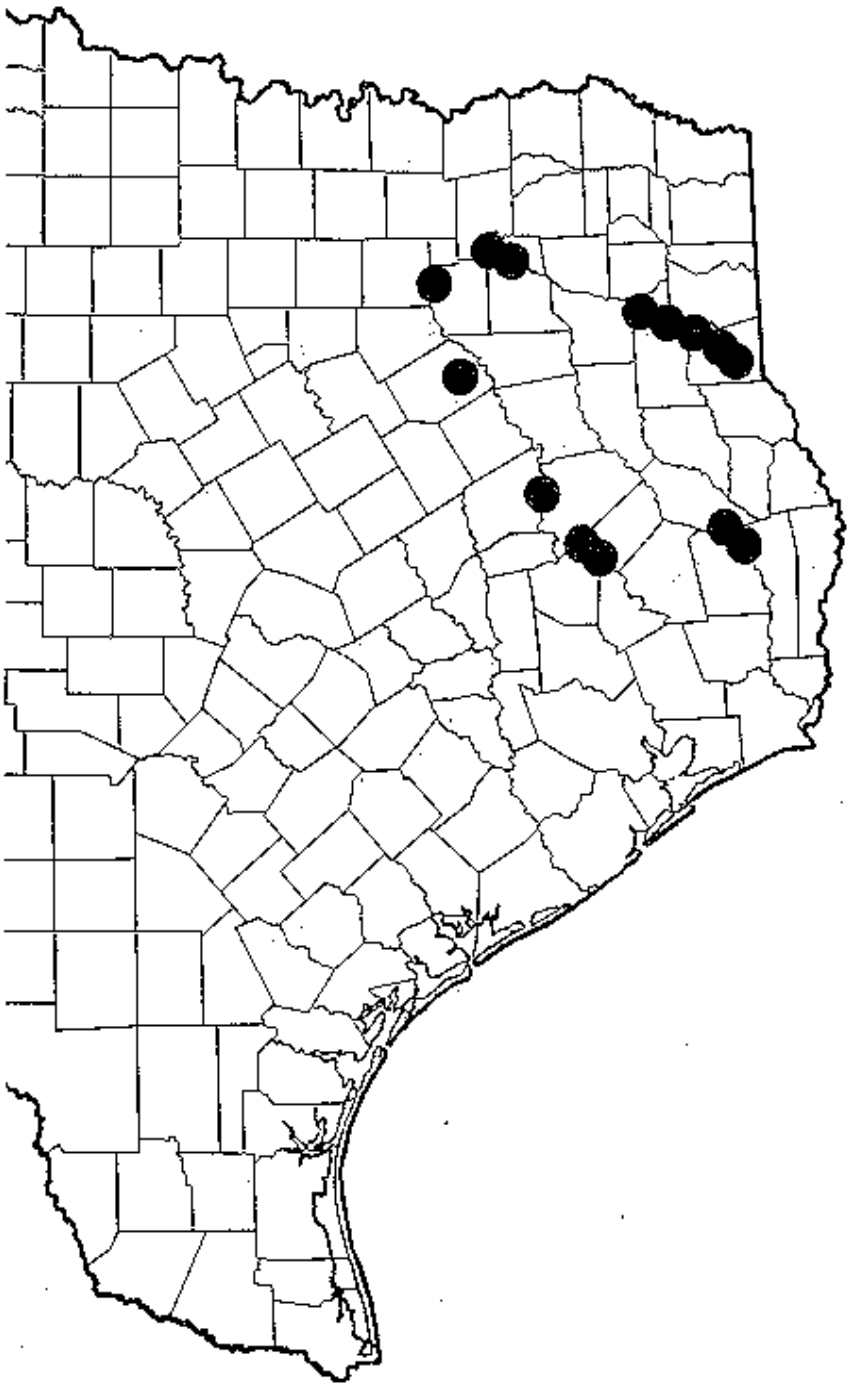


Figure 9. Locations of Texas Parks and Wildlife Department no-harvest mussel sanctuaries (indicated by shading) on the Sabine, Neches, and Trinity river drainages in eastern Texas.