FRESHWATER BIVALVES OF THE LOWER RIO GRANDE, TEXAS

RAYMOND W. NECK AND ARTIE L. METCALF
Texas Parks and Wildlife Department, 4200 Smith School Road, Austin, Texas 78744, and Department of Biological Science, University of Texas at El Paso, El Paso, Texas 79968

ABSTRACT.—The bivalve fauna of the lower portion of the Rio Grande consists of nine species of unionids, two species of fingernail clams, and the introduced Asiatic clam. The native fauna has been affected by river impoundment, agricultural redistribution of water, and water pollution. Species characteristic of lentic waters are derived from the Mississippian (Interior Drainage) Faunal Zone, but species typical of lotic waters are derived from the Mexican Gulf Coast Faunal Zone. *Key words*: bivalves; Rio Grande, Texas.

Although the Rio Grande is one of the longest river systems in North America, little is known of the freshwater bivalve fauna in this drainage system. Early international boundary survey expeditions (Bartlett, 1854; Emory, 1857; Dall, 1896; discussion by Taylor, 1967) did not collect specimens in this area with the exception of *Uniomerus tetralasmus manubius* (Gould, 1856). However, two new species (*Anodonta henryiana* and *Unio berlandieri*) were described by Lea (1857) from shells collected by Jean Louis Berlandier during the 1830s or 1840s when Berlandier lived in Matamoros (Geiser, 1948; Berlandier, 1980). Lt. D. N. Couch conducted an expedition into southern Texas and northern México for the Smithsonian Institution in 1853-54, at which time he purchased part of the collection of Berlandier.

Only limited bivalve collecting activities in the lower Rio Grande have been repdorted since the middle nineteenth century. Singley (1893) listed only two species, *Anodonta grandis* and *Lampsilis teres*, from the lower Rio Grande. Interestingly, no records of the two taxa described by Lea (1857-*Anodonta henryiana* and *Unio berlandieri*) were given. These omissions are puzzling because one of Lea's species (*U. berlandieri*, now known as *Cyrtonaias tampicoensis*) is by far the most abundant native bivalve in this area. Strecker (1931) merely repeated the same species listed by Singley (1893), and credited the records to Singley and Frierson. Metcalf and Stern (1977) reported six living species with three or four additional species in the "lower mainstream of the Rio Grande" but gave no details on collection localities. No data are available on the fish host of any unionid in the lower Rio Grande (Fuller, 1974), and few such records are known for Texas (Shira, 1913).

The Rio Grande is an important stream biogeographically (Neck, 1982), because the fauna differs somewhat from the drainages to the

north and south (Pilsbry, 1909; Strecker, 1931). A survey of the freshwater bivalves of the lower Rio Grande is herein presented. The study area includes the Rio Grande below and including Falcon Lake as well as distributaries of the river. Collecting localities were sampled in the counties of Cameron, Hidalgo, Starr, and Zapata.

Waters of the lower Rio Grande exhibit limited habitat diversity and have experienced significant human modification. Most of the length of the lower Rio Grande has a sandy substrate, although sandstone cobbles and gravels occur upstream from Roma, Starr County. The predominant waterways are abandoned river channels, known locally as resacas. Under present conditions, these vary from highly silted, shallow ditches to artificially deepened pools used for storage of irrigation or municipal water. Irrigation water is distributed to agricultural fields via open gravity canals and small lateral canals with clay bottoms, although the major distribution canals are concrete-lined. Part of the lower Rio Grande was inundated following impoundment of water behind Falcon Dam in 1954. Drainage ditches function to remove runoff water and lower the water table where landforms are characterized by low elevation and where there may be potentially damaging salinity levels.

Methods

Following an analysis of freshwater habitats present in the lower Rio Grande, representative sites of each habitat were located and sampled using standard collection procedures for bivalves. Procedures included visual inspection, dragging rakes and nets along benthic substrates, in-water sampling using hands and feet, and an Eckman dredge. Temporarily dry habitats were sampled by pedestrian survey.

Species collected are discussed below; habitat occurrence is summarized in Table 1. Representative shells have been deposited in the Dallas Museum of Natural History and the Museum of Arid Land Biota of The University of Texas at El Paso.

Collection Localities

The following localities were examined for freshwater mussels during this study. No localities were examined in Willacy County, which possesses no permanent water.

Cameron County.—Resaca de Los Fresnos, San Benito; Resaca del Rancho Viejo at Tandy Road; Resaca de la Palma, Resaca de la Palma State Park; Town Resaca at Texas Highway 4, Brownsville; lake, Arroyo Colorado State Park; numerous drainage ditch and irrigation canal localities within and peripheral to Brownsville.

Hidalgo County.—Crow Lake, 2 km. W La Joya at U.S. Highway 83; Lake Edinburg, 8 km. N Edinburg; Monte Alto Reservoir, 5 km. N Monte Alto; Llano Grande Lake at FM 1015; Rio Grande, above and below Anzalduas Dam; Rio Grande, Santa Ana National Wildlife Refuge.

Starr County.—Pond, 3.6 km. S Garciasville; Rio Grande, immediately below Falcon Dam, Chapeño gaging station, Fronton, and Roma.

Zapata County.—Falcon Reservoir: Falcon State Park and U.S. Highway 83 (5 km. S Zapata).

Species Accounts

Anodonta imbecilis Say, 1829.—This thin-shelled mussel is found in the shallow portions of large resacas, even those with fluctuating water levels. Shell color is horn brown to pale honey brown with green rays present in some individuals. Lea (1857) described *Unio henryiana* from Matamoros; subsequent workers (Frierson, 1927) have considered it as synonymous with *A. imbecilis*. The taxonomic relationship of *henryiana* to central Texas populations of *A. imbecilis* (described as *Anodon horda* Gould, 1855) is unclear.

Anodonta grandis grandis Say, 1829.—This large, thin-shelled unionid is quite rare in the present-day lower Rio Grande, although it is one of only two species reported by Singley (1893) and Strecker (1931). *Anodonta grandis* is not present in impounded water in the lower Rio Grande as it is in central and northern Texas. Whether this difference in adaptability is due to genetic or environmental factors is unknown. Ellis et al. (1930) reported "*Anodonta limneana*" [*sic*] from canals at Mercedes, Texas. This taxon correctly is *A. linneana* Lea, 1852, now considered a synonym of *A. grandis* (Frierson, 1927).

Uniomerus tetralasmus manubius (Gould, 1855).—This species is known from the upper part of the study area only. Gould (1855) described *Unio manubius* from a locality in "Chihuahua, 60 miles from Camp Ringgold." Taylor (1967) has located the type locality as Puntiagudo, Nuevo León, on the Río Agualeguas about five kilometers northeast of the present town of General Treniño. *U. manubius* was illustrated by Johnson (1964: p. 32, fig. 5) and has been treated as a subspecies (Frierson 1927) or variety (Simpson, 1900, 1914) of *tetralasmus*. Morrison (1977) considered *manubius* a synonym of *declivus* (Say, 1831), which may be the proper specific epithet for Rio Grande populations (also see Frierson, 1903). *U. tetralasmus* has not been found in the resacas of the lower Rio Grande or elsewhere in the drainage since the initial description, except for specimens collected in the 1920s by R. D. Camp (specimens in the Corpus Christi Museum—Neck, 1987). Given the ability of various species of *Uniomerus* to withstand desiccation of habitat (see summary by van der Schalie, 1940), this species should be abundant in resacas. The absence of *Uniomerus* from these lentic, clay-bottomed bodies of water may indicate that *manubius* is particularly adapted to ponded areas of intermittent streams in upland sandstone areas similar to those of the type locality.

Megalonaias gigantea (Barnes, 1823).—This large mussel is quite rare, possibly extinct, in the lower Rio Grande. Historically restricted to the breaks of the lower Rio Grande in the vicinity of present Falcon Dam, no living specimens were recovered in this study. However, fresh valves were recovered at Chapeño, 2.3 kilometers below Falcon Dam (in

December 1975 and May 1976). No specimens have been recovered from Falcon Reservoir.

Quadrula apiculata speciosa (Lea, 1862).—Metcalf (1982) reported this western species of the widespread *Quadrula quadrula* complex from the Rio Grande between Falcon Dam and Chapeño. In the present survey, it was collected in Falcon Reservoir, Resaca de Los Fresnos in San Benito, and Lake Monte Alto (Delta Lake). Shells of the Rio Grande population tend to be less inflated than those of specimens from the rest of Texas, but most closely resemble shells found in the Nueces River (the next river system to the north). Such flattening may indicate that these shells are from a native population adapted to the relatively fast waters of the Falcon Breaks. In a comprehensive analysis of the *Quadrula quadrula* complex, Neel (1941) considered *apiculata* to be a phase of *Q. quadrula*. Treatment of *apiculata* as a species follows Bereza and Fuller (in Roback et al., 1980).

Popenaias popei (Lea, 1857).—This species is also quite rare in the lower Rio Grande. Modern records of living specimens are restricted there to Chapeño below Falcon Dam, although specimens collected by R. D. Camp, allegedly from near Brownsville, are in collections of the Corpus Christi Museum. The "*Unio popei*" discussed and illustrated by Chamberlain (1930) and referenced by Ellis et al. (1930) is, in reality, the following species.

Cyrtonaias tampicoensis berlandieri (Lea, 1857).—This unionid is the largest and most abundant bivalve in the lower Rio Grande (given the apparent modern absence of the normally larger *A. grandis*). These two characteristics make the absence of records of *C. t. berlandieri* from the Rio Grande in Singley (1893) and Strecker (1931) most remarkable. Lea (1857) described *Unio berlandieri* from Matamoros, Tamaulipas, México. This taxon has been considered synonymous with, or as a subspecies of, *Cyrtonaias tampicoensis* (Lea, 1838) by various workers. Growth rates and blood physiology of *Cyrtonaias* from the lower Rio Grande were discussed by Chamberlain (1930) and Ellis et al. (1930), respectively (although identified as *Unio popei*). Nacre color varies from clean white with faint iridescence to deep purple; intermediate colors include white with pink and purple suffusion to pale purple or pink. Pure white nacre is rare in Rio Grande specimens; pink to purple suffusion is almost always present. Nacre color is apparently under genetic control, as variation occurs in all size classes from a single locality.

Potamilus salinasensis (Simpson, 1908).—This enigmatic taxon is extremely rare in the lower Rio Grande; only weathered shells were found just below Falcon Dam. This species has been confused with *Potamilus purpuratus* (Lamarck, 1819) but has white nacre. An alternative name for this taxon is *Potamilus fimbriatus* (Frierson, 1907)

(*fide* Bereza, 1980). Generic placement of this species remains uncertain; general shell appearance resembles that of a small *Leptodea fragilis*.

Lampsilis teres (Rafinesque, 1820).—This wide-ranging species is fairly common in the larger resacas, being second in abundance to *Cryptonaias*. Both Chamberlain (1930) and Ellis et al. (1930) studied specimens of this species from canals at Mercedes. The phenotype found in the lower Rio Grande is quite different from the plethora of those found in the eastern United States, a fact recognized by Chamberlain (1930); shells are robust and exhibit a matte-banana yellow color with no hint of greenish rays. Old individuals in permanent water develop a gap between the valves, which would jeopardize survival during extremely low water periods. Brown staining, which increases with age, is observed in some individuals. A constriction of the ventral shell margin occurs posterior to the umbonal area. The constriction is more pronounced in younger shells, but even in these shells it is not prominent. Parmalee (1967) associated such a constriction with *L. fallaciosa* (Smith, 1898), a distinction not considered valid by others (Valentine and Stansbery, 1971). According to characters listed by Morrison (1978), the *Lampsilis teres* population in the lower Rio Grande combines features of nominate *teres* and *anodontoides* (Lea, 1831.) Although Ortmann and Walker (1922) rejected *teres* in favor of *anodontoides* based on comments by H. A. Pilsbry, Johnson (1972) has cited reasons for using *teres*.

Toxolasma parvus (Barnes, 1823).—This small species is quite rare in the lower Rio Grande area where it inhabits shallow, protected areas of resacas. Specimens from the lower Rio Grande vary from slightly yellow brown to dark brown in color. Three taxa (*Unio bairdianus* Lea, 1857; *Lampsilis texasensis compressus* Simpson, 1900; *Lampsilis mearnsi* Simpson, 1900) were described from populations in Las Moras Creek and the Devil's River (both part of the Rio Grande system). Individuals from the lower Rio Grande resemble shells of specimens illustrated by Murray and Leonard (1962:pl. 37), Parmalee (1967:pl. 19A) and Starrett (1971:pl. 4, fig. 23).

Corbicula fluminea (Müller, 1774).—The Asiatic clam first was collected in the lower Rio Grande in February 1969 (C. Boone, in Murray, 1971), from Falcon Lake. This small clam is uncommon in resacas and irrigation ditches. Absence of this species in irrigation reservoirs some distance from the river indicates a limited survival period in open silt-bottomed canals. Little reproduction occurs in irrigation canals, so the limit of *Corbicula* colonization may be controlled by planktonic larval life length and velocity of water before reaching a suitable reservoir. However, a population does exist in Monte Alto Reservoir. The densest population observed was in sand bars below Anzalduas Dam. Mature specimens from the lower Rio Grande are large with shell lengths up to 52.9 mm (in Llano Grande Lake). Shells have a

pale purplish nacre and a yellow to honey brown periostracum, and are referable to the "white morph" of Hillis and Patton (1982).

Fingernail clams.—No records of the much smaller fingernail clams (family Pisiidae) previously were known from southern Texas. Two species, *Sphaerium partumeium* (Say, 1822) and *Sphaerium transversum* (Say, 1829) were recovered from an urban resaca in Brownsville.

Discussion

The largest numbers of species are found in free-flowing portions of the Rio Grande and the resaca system (Table 1). These two habitats, although impacted by human activities, are the habitats most like the natural aquatic environments of the lower Rio Grande Valley of Texas. Lakes, canals, and Falcon Lake support fewer numbers of species because these artificial habitats present biological and physical barriers that are insurmountable for most of the bivalve species of the lower Rio Grande. No bivalves were found in drainage ditches. Poor water quality (high salinity, pesticide and organic matter levels), periodic low water flow, and excessive siltation make these waterways an environment inimical to establishment and maintenance of bivalve populations. Additionally, periodic maintenance dredging removes whatever individuals were able to colonize these ditches.

The naiad fauna of the lower Rio Grande is derived from two basic zoogeographical zones (Roback et al., 1980). The Mississippian (or Interior Basin) Faunal Zone has provided approximately two-thirds of the taxa represented in this classification (Table 1); they tend to be slow-water species. The other one-third are derived from the Mexican Gulf Coast Faunal Zone; species in this category (Table 1) are characteristic of fast-moving waters with the exception of *Cyrtonaias*. Note that two of the species with Mexican affinity may be endemic to the Rio Grande System (see Table 1).

The ecological differences between the two groups according to biogeographical province may reflect differential ease of dispersal. The broad coastal plain of Texas contains a series of low-gradient streams on soft substrate, whereas the coastal plain of Mexico becomes quite narrow south of the Rio Grande as Cretaceous highlands approach the Gulf Coast. Coastal plain meandering of rivers and migrating freshwater fauna from the south may have been restricted to periods of glacial maxima when additional land was exposed because of depressed sea level.

Several bivalve species reported from the Rio Grande system were not found in the lower Rio Grande area as sampled in this study. Strecker (1931) reported *Potamilus purpuratus* from Val Verde County, but examination of Strecker collections in the Strecker Museum (Baylor University) has revealed that Strecker often confused *P. purpuratus* with *Cyrtonaias tampicoensis berlandieri*. Cheatum (1976) recorded *P.*

TABLE 1. Bivalve species occurrence in several habitats in the lower Rio Grande; River refers to the Rio Grande, Falcon refers to Falcon Lake. The following abbreviations are employed: A = abundant, C = common, O = occasional, R = rare; Mi = Mississippian species, Me = Mexican species, A = Asian species; S = slow water, F = fast water; * may be endemic to Rio Grande system.

Species	River	Falcon	Resacas	Lakes	Canals	Affinity	Water
Anodonta imbecilis	O	C	C	O	-	Mi	S
Anodonta grandis	-	-	R	R	-	Mi	S
Megalonaias gigantea	R	-	-	-	-	Mi	F
Quadrula apiculata	O	O	O	R	-	Mi	S
Popenaias popei	O	-	-	-	-	Me*	F
Cyrtonaias tampicoensis	A	C	A	A	A	Me	S
Potamilus salinasensis	R	-	-	-	-	Me*	F
Lampsilis teres	C	-	C	-	O	Mi	S
Toxolasma parvus	-	-	O	-	-	Mi	S
Corbicula fluminea	A	C	O	O	O	A	F
Sphaerium partumeium	-	-	R	-	-	Mi	S
Sphaerium transversum	-	-	R	-	-	Mi	S
Total species (12)	8	4	9	5	3	-	-

purpuratus from "as far west in Texas as the Pecos River," but probably made the same mistake (or simply believed Strecker, 1931). Strecker (1931) also reported *Amblema plicata* from Kinney County, but Taylor (1967) considered this to represent *Megalonaias gigantea*. *Truncilla cognata* (Lea, 1860) has been reported by Bereza (1980) and taken by Metcalf (1982). *Quadrula couchiana* (Lea, 1860) is known presently only from fossil shells in the Rio Grande system (Metcalf, 1982), although the original description of the species was made from fresh shells. *Toxolasma texasensis* (Lea, 1857) was reported from Las Moras Creek, Kinney County by Mearns (1907). These species apparently are absent from the lower Rio Grande, although the Falcon Lake area once may have supported populations of them. Other reports of unionids from the upper Rio Grande include Cockerell (1902), Henderson (1933), and Metcalf (1974).

The major human impact on bivalve populations of the lower Rio Grande has been from the varied water projects associated with flood control, distribution of irrigation water, and drainage of water off agricultural lands (Foscue, 1933). Construction of a massive levee system in the 1930s has restricted floodwaters of the Rio Grande to a relatively narrow strip along the natural channel of the river and several artificial floodways. Species adapted to lotic waters, *Megalonaias gigantea*, *Popenaias popei*, and *Potamilus salinasensis*, for example, are particularly rare in the present lower Rio Grande system.

Creation of Falcon Reservoir most likely decimated the lotic habitat of the bivalves in the lower Rio Grande, although this fauna may have been a low density community under natural conditions. Most of the shoreline

of Falcon Reservoir is Tertiary bedrock, generally sandstones. High-energy shorelines support few bivalves except for *Corbicula fluminea*, which is locally abundant, but the massive bars of shells seen in central Texas (Austin, below Longhorn Dam in Colorado River) are not present. Protected coves accumulate sufficient soft substrate (sand and mud) to support low-density populations of *Cyrtonaias tampicoensis berlandieri*, *Anodonta imbecilis*, *Quadrula apiculata speciosa*, and occasionally *Corbicula fluminea*. The variable level of Falcon Lake may favor the Asiatic clam over the four unionid species, because that clam has a greater fecundity, has no requirement of a host fish, and is less dependent on a particular orientation in relation to the substrate-water interface.

Earthen-lined irrigation canals supported dense populations of *Cyrtonaias tampicoensis berlandieri* and *Lampsilis teres* (Garrett, 1929; Chamberlain, 1930); however, these populations were decimated when the major distribution canals were lined with concrete in the 1930s. Concrete-lined canals may harbor clams if silt accumulation is sufficiently deep, but canals that are seasonally dry are unsuitable for unionid populations.

A tendency to deepen and widen resacas in urban areas would appear to increase bivalve habitat area, especially as water levels are maintained at higher levels more consistently. A decline in the abundance of unionids in the resacas east of Brownsville was observed during the 1950s (B. T. Warburton, personal communication). This decline occurred during a period of widespread utilization of DDT. However, survival of unionid populations in present resacas west of Brownsville indicates that other factors were involved in the eastern area, such as increased levels of urban pollutants, for example—petroleum or sewage products.

A button industry, which utilized shells of freshwater mussels, existed in Mercedes from 1928 to the late 1940s (Garrett, 1929). Mussels were collected from reservoirs and irrigation canals. Buttons made from these mussels were considered of marginal quality; development of plastic buttons rapidly replaced demand for shell buttons. Only larger shells of *Crytonaias tampicoensis berlandieri* were acceptable for the manufacturing process. Shells of *Lampsilis teres*, a species that occurred in the same habitats, were not utilized.

Literature Cited

Bartlett, J. R. 1854. Personal narrative of explorations and incidents in Texas, New Mexico, California, Sonora, and Chihuahua, connected with the United States and Mexican Boundary Commission, during the years 1850, '51, '52, and '53. D. Appleton & Co., New York, 1124 pp.

Bereza, D. J. 1980. Note on the taxonomy and systematics of some Unionacea from the Panuco River drainage in Mexico, and the western drainage of Texas. Bull. Amer. Malacol. Union, 1979:67.

Berlandier, J. L. 1980. Journey to Mexico during the years 1826 to 1834 (translated by S. M. Ohlendorf, J. M. Bigelow, and M. M. Standifer). Texas State Hist. Assoc., 2 vols., 672 pp.

Chamberlain, T. K. 1930. Annual growth of fresh-water mussels. Bull. U.S. Bur. Fish., 46:713-739.

Cheatum, E. 1976. Molluscan fauna of the Gore Pit Site in Comanche County, Oklahoma. Plains Anthropol., 21:279-282.

Cockerell, T. D. A. 1902. *Unio popeii*, Lea, in New Mexico. The Nautilus, 16:69-70.

Dall, W. H. 1896. Report on the mollusks collected by the International Boundary Commission of the United States and Mexico, 1892-1894. Proc. U.S. Nat. Mus., 19:333-379.

Ellis, M. M., A. D. Merrick, and M. D. Ellis. 1930. The blood of North American fresh-water mussels under normal and adverse conditions. Bull. U.S. Bur. Fish., 46:509-542.

Emroy, W. H. 1857. Report on the United States and Mexican boundary survey. 34th U.S. Cong., 1(1):1-258.

Foscue, E. J. 1933. Irrigation in the Lower Rio Grande Valley of Texas. Geograph. Rev., 23:457-463.

Frierson, L. S. 1903. The specific value of *Unio declivus*, Say. The Nautilus, 17:49-51.

———. 1927. A classified and annotated check list of the North American naiades. Baylor Univ. Press, Waco, Texas, 111 pp.

Fuller, S. L. H. 1974. Clams and mussels (Mollusca: Bivalvia). Pp. 215-273, *in* Pollution ecology of freshwater invertebrates (C. W. Hart, Jr., and S. L. H. Fuller, eds.), Academic Press, New York, 389 pp.

Garrett, B. 1929. Pearl buttons from Valley clams. Monty's Monthly, 11(6):46-48.

Geiser, S. W. 1948. Naturalists of the frontier. Southern Methodist Univ., Dallas, 2nd ed., 296 pp.

Gould, A. A. 1855. [Untitled species descriptions.] Proc. Boston Soc. Nat. Hist., 5:228-229.

Henderson, J. 1933. *Lampsilis* at old New Mexican camp sites. The Nautilus, 46:107.

Hillis, D. M., and J. C. Patton. 1982. Morphological and electrophoretic evidence for two species of *Corbicula* (Bivalvia: Corbiculidae) in North America. Amer. Midland Nat., 108:74-80.

Johnson, R. I. 1964. The recent Mollusca of Agustus Addison Gould. Bull. U.S. Nat. Mus., 239:1-182.

———. 1972. The Unionidae (Mollusca: Bivalvia) of peninsular Florida. Bull. Florida St. Mus., Biol. Sci., 16:181-249.

Lea, I. 1857. Description of six new species of freshwater and land shells of Texas and Tamaulipas, from the collection of the Smithsonian Institution. Proc. Acad. Nat. Sci. Philadelphia, pp. 101-102.

Mearns, E. A. 1907. Mammals of the Mexican boundary of the United States; a descriptive catalogue of the species of mammals occurring in that region with a general summary of the natural history, and a list of trees. Bull. U.S. Nat. Mus., 56:1-530.

Metcalf, A. L. 1974. Fossil and living freshwater mussels (Unionacea) from the Pecos River, New Mexico and Texas. Bull. Amer. Malacol. Union, 1973:47-48.

———. 1982. Fossil unionacean bivalves from three tributaries of the Rio Grande. Pp. 43-59, *in* Proceedings of the symposium on recent benthological investigations in Texas and adjacent states (J. R. Davis, ed.), Texas Acad. Sci., Austin, 278 pp.

Metcalf, A. L., and E. M. Stern. 1977. Notes on unionacean mollusks of the Rio Grande system, United States and Mexico. Bull. Amer. Malacol. Union, 1976:42-43.

Morrison, J. P. E. 1977. Species of the genus *Uniomerus*. Bull. Amer. Malacol. Union, 1976:10-11.

———. 1978. The specific distinctions of *Lampsilis anodontoides* Lea and *Lampsilis teres* Rafinesque. (Abstract) Bull. Amer. Malacol. Union, 1977:61 (abstract).

Murray, H. D. 1971. New records of *Corbicula manilensis* (Phillippi) in Texas. The Nautilus, 85:35-36.

Murray, H. D., and A. B. Leonard. 1962. Handbook of unionid mussels in Kansas. Misc. Publ. Mus. Nat. Hist., Univ. Kansas, 28:1-184.

Neck, R. W. 1982. Ecological zoogeography of the freshwater mussels of Texas. Pp. 33-42, *in* Proceedings of the symposium on recent benthological investigations in Texas and adjacent states (J. R. Davis, ed.), Texas Acad Sci., Austin, 278 pp.

———. 1987. Notes on the R. D. Camp mollusk collection in the Corpus Christi Museum. Malacology Data Net (Ecosearch Ser.), 1:145-160.

Neel, J. K. 1941. A taxonomic study of *Quadrula quadrula* (Rafinesque). Occas. Papers Mus. Zool., Univ. Michigan, 448:1-8.

Ortmann, A. E., and B. Walker. 1922. On the nomenclature of certain North American naiades. Occas. Papers Mus. Zool., Univ. Michigan, 112:1-75.

Parmalee, P. W. 1967. The freshwater mussels of Illinois. Illinois St. Mus. Pop. Sci. Ser., 8:1-108.

Pilsbry, H. A. 1909. Unionidae of the Panuco River system, Mexico. Proc. Acad. Nat. Sci. Philadelphia, 61:532-539.

Roback, S. S., D. J. Bereza, and M. F. Vidrine. 1980. Description of an *Ablabesmyia* (Diptera: Chironomidae: Tanypodinae) symbiont of unionid freshwater mussels (Mullusca: Bivalvia: Unionacea), with notes on its biology and zoogeography. Trans. Amer. Ent. Soc., 105:577-619.

Shira, A. F. 1913. The mussel fisheries of Caddo Lake and the Cypress and Sulphur rivers of Texas and Louisiana. U.S. Bur. Fish. Econ. Circ., 6:1-10.

Simpson, C. T. 1900. Synopsis of the naiades or pearly freshwater mussels. Proc. U.S. Nat. Mus., 22:501-1044.

———. 1914. A descriptive catalogue of the naiades, or pearly freshwater mussels. Bryant Walker, Detroit, 1540 pp.

Singley, J. A. 1893. A preliminary list of the land, freshwater, and marine Mollusca of Texas. Ann. Rept. Geol. Surv. Texas, 4:299-343.

Starrett, W. C. 1971. A survey of the mussels (Unionacea) of the Illinois River: a polluted stream. Bull. Illinois Nat. Hist. Surv., 30:267-403.

Strecker, J. K. 1931. The distribution of the naiades or pearly fresh-wate mussels of Texas. Spec. Bull., Baylor Univ. Mus., 2:1-7.

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

Valentine, B. D., and D. H. Stansbery. 1971. An introduction to the naiads of the Lake Texoma region, Oklahoma, with notes on the Red River fauna (Mollusca: Unionidae). Sterkiana, 42:2-40.

van der Schalie, H. 1940. Aestivation of freshwater mussels. The Nautilus, 53:137-138.