# Geological Substrate and Human Impact as Influences on Bivalves of Lake Lewisville, Trinity River, Texas

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## ABSTRACT

The bivalve fauna of Lake Lewisville (Elm Fork Trinity River), Denton County, Texas, consists of 16 species. Present are the introduced Asian clam and 15 native unionids. Relative abundances of species in different areas of the reservoir are related to inundation history and geological substrate. Inundation has locally extirpated some species while other species have flourished. Utilization of shell material for the cultured pearl industry is documented. Ecological, taxonomic, and zoogeographical notes are presented for each species.

*Key words:* Freshwater bivalves; Lake Lewisville; Trinity River; faunal changes; commercial utilization.

## INTRODUCTION

Little is known of the detailed distributions of the freshwater mussels of Texas. Two comprehensive lists have been published (Singley, 1893; Strecker, 1931), but these compilations are in need of updating. Even recent treatments of North American unionids (Burch, 1973, 1975) do not adequately cover the Texas fauna. The only studies of freshwater bivalves from north central Texas localities cover Lake Texoma (Valentine & Stansbery, 1971; White and White, 1977) and Lake Arrowhead (Neck, 1989b). Murray (1972, 1978) has summarized the unionids present in two reservoirs in central and southern Texas. Localized faunal surveys of freshwater bivalves of other portions of Texas have been published recently (Neck, 1986, 1987, 1989a; Neck & Metcalf, 1988).

Below is a summary of a survey of the mussel fauna of Lake Lewisville, a reservoir in north central Texas on the Elm Fork of the Trinity River (figure 1). The purposes of this survey were to determine relative abundance of resident species, intra-reservoir distributions of various species, and human impact upon this fauna. Justifications for the nomenclature used are provided where proper usage has been unclear; nomenclature follows Turgeon *et al.* (1988).

Previous reports of freshwater bivalves from the upper Trinity River drainage have been published. Flook and Ubelaker (1972) reported nine species from a single locality in Lake Lewisville. Strecker (1931) reported fourteen species from the Elm Fork of the Trinity River "near Lewisville, Denton County." The naiad fauna of Dallas County (which borders the southern edge of Denton County) was studied by Read (1954; Read & Oliver, 1953). A survey of unionids of several reservoirs of Tarrant County (Fort Worth, to the west of Dallas County) is available (Mauldin, 1972).

## STUDY AREA

Lake Lewisville (figure 2) is located in north central Texas in central Denton County, approximately 24 kilometers southeast of Denton and 35 kilometers northwest of Dallas. Impounded watercourses include the mainstem and lower reaches of some tributaries of the Elm Fork of the Trinity River. The Elm Fork of the Trinity River is formed from the coalescence of many small tributaries in Cooke, Montague, Clay, and Archer Counties to the west of Denton County.

Lake Lewisville has a dual history; information below is from Dowell and Breeding (1967). The original impoundment (Lake Dallas) was created by Garza Dam built during 1924 through 1927; deliberate impoundment of water began 16 February 1928. The area of the original impoundment was 44.5 km$^2$ at spillway elevation. Original capacity was 2.4 million cubic meters (drainage area 3,018 km$^2$). Accumulation of sediment became a severe problem in the original Lake Dallas. By 1952, capacity of the reservoir had decreased 19.3% to 1.9 million cubic meters. Hydrochemical and vegetational conditions of Lake Dallas were reported by Harris and Silvey (1940).

Construction of a second dam downstream near Lewisville was begun in November 1948 and completed in August 1955. Impoundment of water began 1 November 1954. Following a prolonged filling period during a severe drought, a passageway was created through Garza Dam on 28 October 1957. The combined reservoir system has a surface area of approximately 94.28 km$^2$ at conservation pool level (156 meters above mean sea level). Surface area of the flood pool (161 m msl) is 158.17 km$^2$. Capacity of the combined reservoir system is 5.7 million cubic meters at conservation pool and 12.2 million cubic

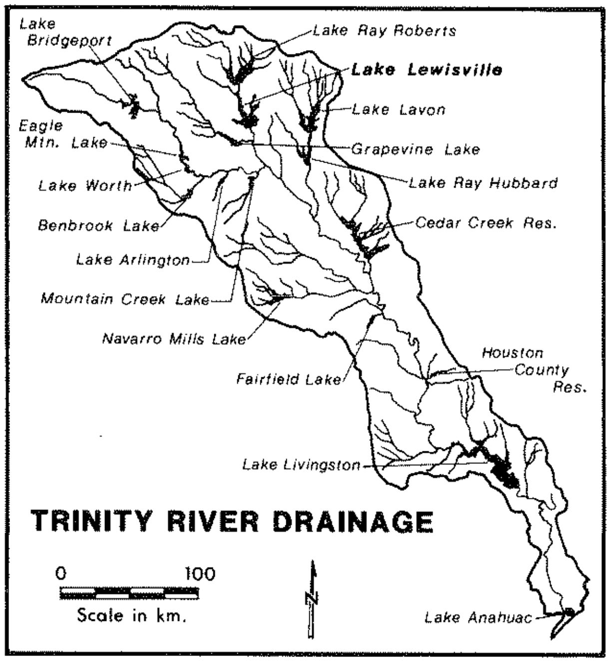


**Figure 1.** Map of Trinity River drainage, Texas, showing location of Lake Lewisville and other reservoirs.

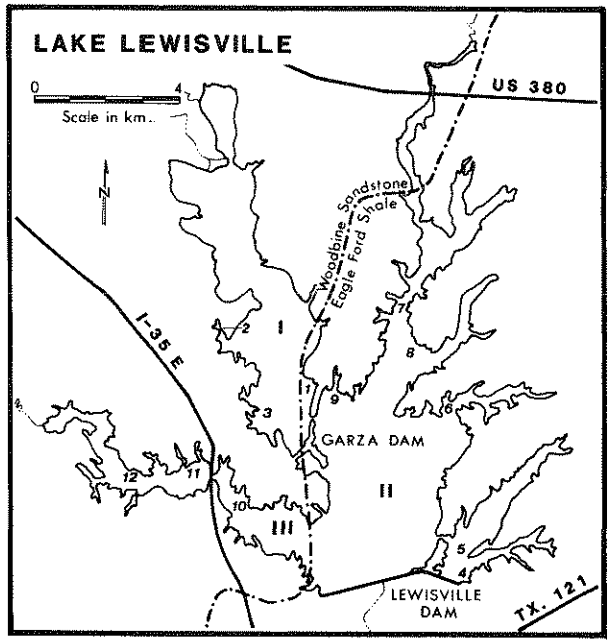


**Figure 2.** Map of Lake Lewisville, Texas, showing geological substrate, reservoir subdivisions (Roman numerals), and collecting localities (Arabic numbers).

meters at spillway level. Drainage area above the dam is 4,300 square kilometers. Shoreline of the conservation pool is approximately 295 kilometers. Primary purposes of the reservoir are flood control, municipal/industrial water supply, and recreation.

More recently Smith (1973) studied the physicochemistry of Lake Lewisville. Variation in water physiochemical parameters was found to be due more to the original characteristics of the basin rather than the length of impoundment. Algal species composition was fairly uniform throughout the surveyed portions of the reservoir. Water temperature varied seasonally from 5.0 °C to 28.5 °C and pH varied from 7.3 to 8.4. Alkalinity varied from 90 to 107 mg/L (mostly bicarbonate) for area II and from 116 to 151 mg/L for area I. Nitrate levels varied from 0.354 to 3.588 mg/L, while phosphate levels ranged from 0.017 to 0.165 mg/L. The Lake Dallas basin (area I) had greater turbidity and higher nutrient enrichment (phosphate and bicarbonate) than area II.

This reservoir has suffered from a lack of name standardization. Originally both the combined impoundment and the dam structure were known as Garza-Little Elm Reservoir and Garza-Little Elm Dam. In 1955 the name of the dam was changed to Lewisville Dam although the reservoir name was unaltered. Subsequently the U.S. Army Corps of Engineers (which operates the dam and reservoir) has changed the name of the reservoir to Lake Lewisville.

The surface geology of the area covered by Lake Lewisville is rather simple (Winton, 1925). The eastern portion is underlain by the Eagle Ford Formation and alluvial deposits, whereas the western portion is underlain by the Woodbine Formation and limited alluvial areas. All deposits are Upper Cretaceous except for the Pleistocene and Recent alluvial terraces. The Eagle Ford consists of a series of black oily shales with a few thin ledges of sandstone. The Woodbine is somewhat variable (Winton, 1925); several layers of indurated sandstone are separated by softer sandstone, loose sand, and clay layers. The Eagle Ford/Woodbine contact is aligned approximately along a NNE to SSW line and passes very close to the axis of Garza Dam, which formed Lake Dallas.

Climate of the study area is transitional between maritime-subtropical and continental-temperate. The nearest recording weather station is at Denton, where the average monthly temperature varies from 7.2 °C in January to 29.3 °C in August. Extreme temperatures recorded are 45 °C and −19.4 °C. Annual precipitation averages 804 mm, but has varied from 384 mm in 1963 to 1,433 mm in 1957. The growing season is 226 days (27 March to 8 November). Weather records for any particular year often are far from the mathematical "norms" because this region is characterized by dramatic year-to-year fluctuations. Fluctuations in precipitation usually are larger than those in temperature. Major droughts occurred in the 1930's and 1950's.

Drought during the mid 1950's was severe enough that 1.2 million cubic meters (98,470 acre-feet) of water were diverted from the Red River into Lake Dallas. Water was pumped from the Red River in Cooke County into Pecan Creek through which the water flowed by gravity into the Elm Fork of the Trinity River (Dowell & Breeding, 1967:36).

## METHODS

Twelve survey sites (Appendix) were chosen in a manner that all major areas of the reservoir were sampled. Most of the sites were located in various recreation parks built by the U.S. Army Corps of Engineers. Time of sampling activities (Winter 1977 through Fall 1978) coincided with an extended drought, which resulted in substantial lowering of the reservoir level. Many hectares of reservoir bottom were exposed to air. Bivalve shells were extremely abundant and readily counted.

Survey transect areas were four meters wide along the water edge for varying distances. Length of transects varied from 50 to 70 meters, but some were lengthened beyond 70 meters in order to increase sample number. Counts should not be taken as relative densities, but as estimates of relative species occurrence at particular sites. Only paired valves were counted in order to reduce the effect of water movement of "dead" valves to localities unsuitable for the species. Such movement is believed to be of minimal significance because most valve pairs lay *in situ*, partially covered with sediment at the place of death. After counts along the pre-selected transect were completed, additional lengths of adjacent reservoir edge were walked. Additional species at times were added to the list of species occurring at a given sampling area. Such occurrences are not recorded in the relative counts for a particular site (tables 1 and 2).

Representative specimens collected during this study have been deposited in the Dallas Museum of Natural History.

## BIVALVE FAUNA

A total of 16 species were observed at the various sampling stations around the reservoir shore (table 1). All but one, *Corbicula fluminea*, are native members of the Unionidae. No fingernail or pea clams (family Sphaeriidae) were observed during this study. Below is a list of species recovered from Lake Lewisville with nomenclatorial discussion, published habitat notations, and habitat occurrences in Lake Lewisville.

*Corbicula fluminea* (Müller, 1774) was not abundant in Lake Lewisville; no living specimens were found. Favorable habitat areas (moving water over sand or gravel substrate) were in small creeks feeding into the reservoir. A few young shells (7 mm length) were found on sand at Fish-O-Rama (private commercial development). All specimens from Lake Lewisville were referable to the "white form" (Hillis & Patton, 1982).

*Anodonta grandis* Say, 1829, is an extremely variable taxon as several names have been applied to different phenotypes. Read (1954) reported this species to be the "most abundant and widely distributed species in Dallas County," but referred his specimens to *A. corpulenta* Cooper, 1834; Strecker (1931) called all specimens *A. grandis*. Lake Lewisville specimens tended toward the *corpulenta* phenotype (largest specimen measured 148.3 mm in shell length). *A. grandis* was a common species in Lake Lewisville; 106 specimens were taken, and all 12 reservoir localities were represented (table 1).

*Anodonta imbecillis* Say, 1829, occurs in the eastern United States, throughout the entire Mississippi system, and southward through the Gulf drainages into Mexico (Simpson, 1914:396; Burch, 1975:15). Mauldin (1972) reported *A. imbecillis* to be more frequent in ponds and small reservoirs than in large reservoirs. Only 18 individuals of *A. imbecillis* from 8 scattered localities were found in Lake Lewisville (table 1). *Anodonta imbecillis* probably was more abundant in backwater sloughs and pools of small creeks that drain into Lake Lewisville.

*Arcidens confragosus* (Say, 1829) is distributed throughout the Mississippi drainage (Murray & Leonard, 1962). In Dallas Co., Read (1954) found *A. confragosus* only in Parson's Slough in shallow water with a "fair current" over a mixed sand and mud substrate. This species was found at 9 reservoir localities, but only 16 individuals appeared in 7 transects (table 1).

*Amblema plicata* (Say, 1817) was the most abundant naiad in Lake Lewisville; 624 specimens (38.8% of total) were counted at 12 transect locations (table 1). This species was the most abundant bivalve at all locations. *Amblema plicata* occurs throughout much of eastern North America, south to the Nueces River, Texas (Burch, 1975). A number of taxa have been established for the *A. plicata* complex in the United States. Read (1954) reported both *A. costata* Rafinesque, 1820, and *A. perplicata* (Conrad, 1841) from the Elm Fork of the Trinity River in Dallas County. Flook and Ubelaker (1972) recorded both *A. plicata* and *A. costata* for Lake Lewisville, but only 4 of 150 were referred to *A. costata*. These two forms are believed to be either genetic morphs or ecophenotypes; in either case no taxonomic rank is recognized herein.

*Quadrula mortoni* (Conrad, 1834) is restricted to the eastern half of Texas (Strecker, 1931). This species is represented in Lake Lewisville by pustulate and non-pustulate forms, which are known from reservoirs in neighboring Tarrant County (Mauldin, 1972). Some of the less angulate specimens, particularly those with a large number of pustules, approach *Quadrula pustulosa* (Lea, 1829). However, specimens similar to *Q. pustulosa* from Lake Lewisville differ from *Q. pustulosa* from southeastern Texas in general shape of shell as well as number, form, and arrangement of pustules. Specimens of *Q. mortoni* differ from *Q. pustulosa* by being broader and somewhat flatter along the dorsal portion of the valves. Individuals of *Q. mortoni* (pustulate and non-pustulate) in Lake Lewisville are most abundant on a sand substrate, even if the sand exists only as a shallow bar over bedrock shale (as in area II).

Shells referred to typical *Q. mortoni* in this study can be keyed to *Q. houstonensis* (Lea, 1859) by using Read (1954), who reported the latter taxon to be "not common in Dallas County," from Elm Fork of the Trinity River on gravel bottom in about a meter of water. Strecker (1931) noted, however, that *Q. houstonensis* from the Elm Fork near Lewisville was "rather inflated and seems peculiar to this branch of the Trinity." Examination of

**Table 1.** Occurrence of bivalves of Lake Lewisville for each collecting locality.

| | Area 1 | | | Area II | | | | | | Area III | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total | % | Rank | No. of sites |
| *Corbicula fluminea* | — | * | — | — | — | 2 | 2 | 1 | — | — | 1 | — | 6 | 0.4 | 13 (T) | 5 |
| *Anodonta grandis* | 1 | 13 | 2 | 5 | 2 | 14 | 12 | 14 | 3 | 21 | 7 | 12 | 106 | 6.5 | 4 | 12 |
| *Anodonta imbecilis* | 1 | 3 | — | — | — | 3 | * | 2 | 2 | 3 | 2 | 2 | 18 | 1.1 | 10 | 9 |
| *Arcidens confragosus* | 2 | * | 2 | — | — | 1 | — | 1 | — | 4 | 4 | 2 | 16 | 1.0 | 11 | 8 |
| *Amblema plicata* | 41 | 33 | 54 | 33 | 21 | 89 | 37 | 89 | 32 | 144 | 21 | 30 | 624 | 38.5 | 1 | 12 |
| *Quadrula mortoni* | 2 | * | 1 | 1 | — | — | 2 | 4 | 1 | 1 | — | 1 | 13 | 0.8 | 12 | 9 |
| *Quadrula apiculata* | 21 | 25 | 37 | 1 | 4 | 37 | 29 | 40 | 5 | 54 | 11 | 17 | 281 | 17.3 | 2 | 12 |
| *Tritogonia verrucosa* | — | * | — | — | — | — | — | — | — | — | — | — | * | — | * | 1 |
| *Lampsilis hydiana* | 3 | 9 | 1 | 10 | 7 | 70 | 14 | 18 | 5 | 58 | 11 | 8 | 214 | 13.2 | 3 | 12 |
| *Lampsilis satura* | — | — | — | — | — | — | * | — | — | — | — | — | * | — | * | 1 |
| *Lampsilis teres* | 5 | * | 1 | 2 | 1 | 27 | 2 | 13 | 5 | 15 | 4 | 1 | 76 | 4.7 | 6 | 12 |
| *Leptodea fragilis* | 1 | 2 | * | 5 | 1 | 16 | 1 | 13 | 1 | 4 | 11 | 8 | 63 | 3.9 | 8 | 12 |
| *Potamilus amphichaenus* | 2 | 1 | * | 3 | — | — | 2 | 10 | 1 | 8 | 6 | 7 | 40 | 2.5 | 9 | 10 |
| *Potamilus purpuratus* | 8 | 12 | 6 | 4 | 1 | 14 | 3 | 14 | 7 | 5 | 6 | 8 | 88 | 5.4 | 5 | 12 |
| *Toxolasma parvus* | — | * | — | 2 | 1 | 3 | — | — | — | — | — | * | 6 | 0.4 | 13 (T) | 5 |
| *Truncilla truncata* | 4 | 2 | 4 | 2 | 3 | — | 6 | 18 | 8 | 11 | 1 | 10 | 69 | 4.3 | 7 | 11 |
| Species | 12 | 15 | 11 | 11 | 9 | 11 | 13 | 13 | 11 | 12 | 12 | 13 | 16 | | | |
| Individuals** | 91 (12) | 100 (9) | 108 (9) | 68 (11) | 41 (9) | 276 (11) | 110 (11) | 237 (13) | 70 (11) | 328 (12) | 85 (12) | 106 (12) | 1,620 | 100.0 | — | 12 |

* Species present, but not found in transect.
** Number in parentheses is number of species present in transect.
(T) = Tie for ranking position.

**Table 2.** Relative counts and percentages of bivalves of Lake Lewisville and subdivisions.

| | I | | II | | III | | Total | |
|---|---|---|---|---|---|---|---|---|
| | n | %** | n | % | n | % | n | % |
| *Corbicula fluminea* | * | — | 5 | 0.6 | 1 | 0.2 | 6 | 0.4 |
| *Anodonta grandis* | 16 | 5.4 | 50 | 6.2 | 40 | 7.7 | 106 | 6.5 |
| *Anodonta imbecilis* | 4 | 1.3 | 7 | 0.9 | 7 | 1.3 | 18 | 1.1 |
| *Arcidens confragosus* | 4 | 1.3 | 2 | 0.2 | 10 | 1.9 | 16 | 1.0 |
| *Amblema plicata* | 128 | 42.8 | 301 | 37.5 | 195 | 37.6 | 624 | 38.5 |
| *Quadrula mortoni* | 3 | 1.0 | 8 | 1.0 | 2 | 0.4 | 13 | 0.8 |
| *Quarula apiculata* | 83 | 27.8 | 116 | 14.5 | 82 | 15.8 | 281 | 17.3 |
| *Tritogonia verrucosa* | * | — | — | — | — | — | * | — |
| *Lampsilis hydiana* | 13 | 4.3 | 124 | 15.5 | 77 | 14.8 | 214 | 13.2 |
| *Lampsilis satura* | — | — | * | — | — | — | * | — |
| *Lampsilis teres* | 6 | 2.0 | 50 | 6.2 | 20 | 3.9 | 76 | 4.7 |
| *Leptodea fragilis* | 3 | 1.0 | 37 | 4.6 | 23 | 4.4 | 63 | 3.9 |
| *Potamilus amphichaenus* | 3 | 1.0 | 16 | 2.0 | 21 | 4.0 | 40 | 2.5 |
| *Potamilus purpuratus* | 26 | 8.7 | 43 | 5.4 | 19 | 3.7 | 88 | 5.4 |
| *Toxolasma parvus* | * | — | 6 | 0.7 | * | — | 6 | 0.4 |
| *Truncilla truncata* | 10 | 3.3 | 37 | 4.6 | 22 | 4.2 | 69 | 4.3 |
| Species | 15 | — | 15 | — | 14 | — | 16 | — |
| Individuals*** | 299 (13) | — | 802 (14) | — | 519 (12) | — | 1,620 (14) | — |
| % of Total Sample | 18.5 | — | 49.5 | — | 32.0 | — | 100.0 | — |

* Present, but not recorded in transect.
** % of transect sample.
*** Number in parentheses is number of species present in transect.

shells at the Strecker Museum (SM) from the Elm Fork near Lewisville identified as *Q. houstonensis* by Strecker (SM 325–329) revealed shells of *Q. pustulosa* that are somewhat more quadrate than typical *Q. mortoni.* No such shells were found in the present survey. Examination of other shells referred to *Q. houstonensis* by Strecker revealed robust shells that appear to represent several species of *Quadrula.*

*Quadrula nodulata* (Rafinesque, 1820) has been reported from various portions of eastern Texas (Strecker, 1931). A single specimen that resembles *Q. nodulata* was found in Lake Lewisville in transect samples. Examination of specimens from Lake Lewisville that resemble *Q. nodulata* indicated that these shells were *Q. mortoni.* These Lake Lewisville specimens did not exhibit nodules on the posterior ridge as in typical *Q. nodulata*; nodules are restricted to the middle of the shell (below the umbo area).

Read (1954) reported *Quadrula metanevra* (Rafinesque, 1820) from adjacent Dallas County. These shells may have been these *nodulata*-like shells or an extremely angulate *Quadrula apiculata.*

*Quadrula apiculata* (Say, 1829) ranges from the Rio Grande through all Texas streams to the Alabama River (Neel, 1941). The southern maple-leaf mussel is the second-most abundant naiad species in Lake Lewisville; 281 individuals were taken at all 12 sites (table 1). Read (1954) reported two phenotypes in Dallas County including Elm Fork below the present Lake Lewisville: 1) "*speciosa* Lea, 1862" with pustules extending to the ventral margin, and 2) "*forsheyi* Lea, 1859" with pustules only on the more dorsal portions of the valves. Read (1954) reported that both forms prefer sand bottoms; "*speciosa*" tended to be found in shallow water while "*forsheyi*" tended to be found in fairly deep water. These morphological types represent genetic variation in the *Q. apiculata* population, but they may also be the result of reduced rates of pustule formation in older individuals. Neel (1941), who treated *apiculata* as a form of *Quadrula quadrula* (Rafinesque, 1820), presented a discussion of the forms of the *Q. quadrula* group.

*Tritogonia verrucosa* (Rafinesque, 1820) has a wide distribution throughout the Mississippi drainage and other Gulf coastal drainages from Georgia to Texas (Valentine & Stansbery, 1971). In Dallas County, Read (1954) found it only in Elm Fork, where it was "perhaps the most abundant species," on hard gravel or sand in fairly deep water in swift current. This species most often has white nacre; pink and purple nacres become more common in the southern part of its range according to Valentine and Stansbery (1971), who found few specimens in Lake Texoma (all of which had white nacre). All specimens located in this study have white nacre. This species is extremely uncommon in Lake Lewisville; no specimens were encountered in the transect censuses (only one specimen was found, at Graveyard Slough, which is near an incoming creek, which would "freshen" the water quality). The rarity of *T. verrucosa* in Lake Lewisville is the result of its requirement for a rapid current of water.

*Lampsilis hydiana* (Lea, 1838) ranges from eastern Texas and Oklahoma eastward to Arkansas and Alabama

(Burch, 1973:20). *L. hydiana* was reported rare in Dallas County by Read (1954), who found it only in Elm Fork. *L. hydiana* is the third most abundant mussel in Lake Lewisville (but is not common in Area I); a total of 213 individuals were counted in 12 transects (tables 1, 2). Shells exhibit phenotypic variation in details of structure of the pseudocardinal teeth, but this variation tends to be ontogenetic (changing with age). Rays are absent, present on the entire shell, or restricted to the posterior half. Rays may be single and narrow (about 0.1 mm wide) or may coalesce into stripes (whose widths approach 3 mm). Spacing between rays varies such that 80% of the periostracum may be greenish in contrast to the yellowish horn color of the background. Variation in shell morphology may reflect genetic influence by *Lampsilis luteola* (Lamarck, 1819), a species that ranges throughout all of the Mississippi River and southern Canada east of the Rocky Mountains (Burch, 1973:21); *luteola* intergrades with *hydiana* in Louisiana and southern Arkansas (Stansbery, 1983).

*Lampsilis satura* (Lea, 1852), the southernmost species of the *Lampsilis ovata* (Say, 1817) group, is restricted to westernmost Louisiana and eastern Texas (D. H. Stansbery, personal communication). A single shell was found in Lake Lewisville at station 7 (table 1). This specimen is small (47.6 mm, shell length) and had been dead for several years before recovery. The umbo is somewhat higher than those of most *L. satura* from eastern Texas. The recovered specimen probably represents a remnant population (possibly now extirpated) adapted to a free-flowing stream. Read (1954) reported *Lampsilis ventricosa* (Barnes, 1823) as rare in Dallas County; this record probably refers to *L. satura*.

*Lampsilis teres* (Rafinesque, 1820) was reported by Read (1954) as being not very abundant in Dallas County on soft mud substrate, but found in the side of a tight mud bank. *Lampsilis fallaciosa* Smith, 1899, has been utilized to refer to a smaller form with greenish rays (not found in Lake Lewisville but found in Elm Fork below Lewisville Dam during this study). Valentine and Stansbery (1971) suggested that *Lampsilis fallaciosa* may have been replaced by *L. teres* in Oklahoma during the twentieth century after they compared their contemporary collections with those of Isely (1924). White and White (1977) reported the two forms from Lake Texoma in similar habitats but in different arms of the reservoir. *L. teres* was found at every locality sampled in this study; a total of 76 individuals were counted in 11 transects (table 1).

*Leptodea fragilis* (Rafinesque, 1820) occurs throughout most of the eastern United States (Valentine & Stansbery, 1971). Read (1954) found *L. fragilis* widely distributed in Dallas County in soft sand and muck. *L. fragilis* was found at all 12 of my sample sites although only 63 individuals were found in eleven transects (table 1). This species was more abundant on sand than on clay substrates, although I found *L. fragilis* in mud at the base of a terrace cutbank in moving water in the Elm Fork above Lake Lewisville.

*Potamilus amphichaenus* (Frierson, 1898), is known from the Brazos, Trinity and Sabine Rivers of Texas and westernmost Louisiana (Strecker, 1931). Despite Frierson's (1898) statement that *P. amphichaenus* was "one of the most distinct and remarkable Unios," this taxon is little known today. Specimens of *P. amphichaenus* from Lake Lewisville can be separated from specimens of *Potamilus ohiensis* (Rafinesque, 1820) from the Red River to the north by the following characters of *P. amphichaenus*: 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.

*Potamilus purpuratus* (Lamarck, 1819) occurs in streams from western Tennessee to Kansas, southward to Louisiana, where it is more common in downstream sites (Valentine & Stansbery, 1971). Read (1954) found it abundant in Elm Fork on gravel, hard clay, mud, and sand. *P. purpuratus* is the fifth most common naiad in Lake Lewisville; 88 specimens were counted in 12 transects, and presence was noted in two additional sites.

*Toxolasma parvus* (Barnes, 1823) is the smallest unionid found in this area. *T. parvus* is found in streams from New York to the Dakotas, southward to Texas and Alabama (Valentine & Stansbery, 1971). Live specimens from Lake Texoma were found on silt or soft mud in areas protected from wind disturbance (White and White, 1977). Read (1954) found *T. parvus* widely distributed in Dallas County on mud bottoms in shallow ponds and sluggish streams. The largest *T. parvus* that I have seen from Lake Lewisville were 24.9 mm in length. Only six individuals were found at three transects; additional specimens were found at three other sites. *T. parvus* is a monomorphic (presumably monoeicious) species in comparison to the larger, dimorphic (presumably dioecious) *Toxolasma texasensis* (I. Lea, 1857), a species not known from Lake Lewisville.

*Truncilla truncata* Rafinesque, 1820, is known from the Mississippi River drainage and westward into eastern Texas (Strecker, 1931; Burch, 1973). *T. truncata* was reported from Elm Fork on soft mud, but occasionally in gravel and sand (Read, 1954). Color of periostracum of Lake Lewisville specimens varies from yellowish brown to dark brown; a few specimens have narrow, faint rays. Sixty-nine individuals were collected from 11 transects.

The bivalve fauna of Lake Lewisville as recorded in this survey consists of 16 species (one corbiculid and 15 unionid species). *Amblema plicata* is the most numerous species at all 12 sampling localities and includes well over one-third of the individuals counted. The seven most abundant species in the transects comprise 89.9% of the sample. The seven least common species comprise the remaining 10.1% of the sample. Seven species were found at all 12 sampling sites; 11 species, 9 or more sites. Except for the two species found at only a single locality, all species were found at five or more sites. No site contained all species, but all sites had at least nine.

## DISCUSSION

### Zoogeography

The unionid fauna present in Lake Lewisville is typical of the West Gulf Province (Roback *et al.*, 1980; Neck, 1982a), which includes the area drained by rivers west and south of the Mississippi River from the Sabine system through the Rio Grande System. The Trinity River drainage abuts the Mississippi drainage just north of Lake Lewisville, where the Red and Trinity Rivers are separated by a low divide. Little or no recent faunal exchange has occurred because of the very limited number of mussel species in the Red River. Along the Coastal Plain the drainages of the Trinity and the Red are separated by the Sabine/Neches system.

The species present in Lake Lewisville represent the "upland" component of those species present in the Trinity River. Strecker (1931) recorded several species in the lower Trinity (but not the Elm Fork) that are not present in Lake Lewisville, because the pre-impoundment conditions of the Elm Fork were not suitable for such large-stream or sand-substrate forms. Species included are *Strophitis undulatus* (Say, 1817), *Fusconaia cerina* (Conrad, 1838), *Megalonaias nervosa* (Rafinesque, 1820), *Plectomerus dombeyanus* (Valenciennes, 1827), *Truncilla donaciformis* (I. Lea, 1828), and *Truncilla macrodon* (I. Lea, 1859).

### Intra-reservoir Distributions

Lake Lewisville can be divided into three major subdivisions, which are based upon natural and artificial environmental factors (figure 2). Area I consists of the original Lake Dallas; this area is underlain by the Woodbine Formation. The substrate presently consists of silty clays which have been deposited over the past 50 years. This area receives sewage outfall from the city of Denton (1980 population—48,063) and probably several small towns farther upstream. Area II consists of the larger part of the new reservoir portion of Lake Lewisville which is underlain by thin silty clay terraces that mantle the Eagle Ford Formation (shale). Area III is the Hickory Creek Arm of the new lake portion, which is underlain by the Woodbine Formation. Substantial portions of this area maintain sandy substrates although the upper reaches are covered by recently deposited sediments.

The Denton County soil survey provides information concerning soils now covered by Lake Lewisville (Ford & Pauls, 1980). Soil types presently inundated by the original Lake Dallas (area I) include Callisburg fine sandy loam, Gowen clay loam, and Navo clay loam. Soils presently under area II include Altoga silty clay, Ferris-Heiden clays, and Heiden clay. Area III inundates Bastrop fine sandy loam, Birome-Rayex-Aubrey complex (sands), Callisburg fine sandy loam, and Crockett fine sandy loam.

Examination of the data concerning relative percentages of species in the three major subdivisions of Lake Lewisville indicates that areas II and III are more similar to each other than either is to area I (table 2). This relationship indicates that, as a factor in this lake's distribution, similar period of impoundment (II and III) is more important than similar geological substrate (I and III). Also important is unrestricted water and organism movement between II and III whereas an old dam structure with a narrow breach exists between I and II; no direct connection exists between I and III. Shallower water depths and decreased water quality in area I may be additional factors.

Except the stream species that are found only near creek entrances and probably do not reproduce within the reservoir (*Lampsilis satura* and *Tritogonia verrucosa*), no species are restricted to only one of these three subgroups. However, as indicated above, area I stands well apart from the other two in terms of faunal composition. For example, the two most common unionids in Lake Lewisville (*Amblema plicata* and *Quadrula apiculata*) together comprise 55.8% of the entire fauna, and the corresponding values for areas II and III are comparable (53.0% and 53.4%, respectively), but in area I these two species comprise 70.6% of the fauna. Area I supports the least diverse fauna and is the area most dominated by species that are tolerant of environmental disturbance by humans.

In contrast to dominance by abundant taxa, the third most common species, *Lampsilis hydiana*, is distinctly least common in area I. The other species that are least abundant in area I are *Anodonta grandis*, *Lampsilis teres*, *Leptodea fragilis*, *Potamilus amphichaenus* and *Truncilla truncata*. *Potamilus purpuratus* is distinctly most common in area I. *Arcidens confragosus* is more common in areas I and III than in area II; this distribution pattern indicates a preference for sandy substrates, possibly in inflowing streams. Rare in all areas are *Quadrula mortoni*, *Anodonta imbecilis*, *Toxolasma parvus*, and *Corbicula fluminea*.

More individuals and more species occurred in areas with clay rather than sand substrates in Lake Lewisville, although a few species are more abundant on sand substrates (*Leptodea fragilis*, *Quadrula mortoni*, *Arcidens confragosus*, and *Tritogonia verrucosa*). Domination of the fauna by one or two species was frequent in clay substrates and rare in sand substrates. Such relative abundance relationships were also observed at several sites in area II where well-developed sand bars overlay shale bedrock. Within areas of clay substrate, unionids were more common on sites with exposure to wave action. Small sloughs in these areas seldom supported more than a few bivalves.

### Faunal Change

Several species reported from the Elm Fork by Read (1954) were not found in Lake Lewisville. *Obliquaria reflexa* Rafinesque, 1820, is a species that requires hard substrates and moderate to fast currents. *Obliquaria reflexa* was reported from Lake Texoma (White & White, 1977) only in riprap gravel substrate and substantial wind-generated water movement; this was the only riverine species found in Lake Texoma. I have found *O. reflexa* in the Elm Fork, below Lewisville Dam; isolated individuals could survive in locally favorable micro-habitats within Lake Lewisville, but periodic drought conditions reduce reservoir elevation and feeder creek flows to such low levels that survival of *O. reflexa* is unlikely

Only two unionid taxa reported by Strecker (1931) from the Elm Fork at Lewisville were not found during this survey. His *Quadrula houstonensis* apparently represented shells referred to *Quadrula mortoni* in this study (see previous discussion). Read (1954) reported Strecker's *Fusconaia flava undata* to be rare in Dallas County, and found only in the southeastern section. Several other species were reported by Read (1954) in Dallas County, *i.e.*, *Lasmigona costata* (Rafinesque, 1820), *Obovaria subrotunda* (Rafinesque, 1820), *Pleurobema cordatum* (Rafinesque, 1820), *Quadrula metanevra* (Rafinesque, 1820) and *Quadrula petrina* (Gould, 1855). These species are not known to have occurred anywhere in the Trinity River; these records appear to represent misidentifications.

Two species not recorded for the Trinity River at Lewisville by Strecker (1931) have established populations in Lake Lewisville. These species are *Anodonta grandis* and *Anodonta imbecillis*; the former has become the fourth most common bivalve in Lake Lewisville. Increase in abundance of these *Anodonta* has been reported by Murray (1982). Causes of this expansion are not understood but probably involve employing a large number of fish species as hosts during the glochidial stage of the unionid life cycle (Trdan & Hoeh, 1982). Read (1954) suggested that fish stocking activities "probably contributed some species . . . since Strecker," but offered no supporting evidence. Changes in the bivalve fauna of this reservoir are similar to those faunal alterations observed in Lake Springfield, Illinois (Parmalee, 1955; Klippel & Parmalee, 1979).

### Human Utilization of Fauna

An additional human impact upon the unionid fauna of Lake Lewisville was observed during this survey. Unionid valve material is being utilized in the cultured pearl industry. The high-purity calcium carbonate of unionid shells (Nelson *et al.*, 1966) is formed into spheres to provide large "seeds" for cultured pearls (Peach, 1983). In August 1978 individual shell collectors were being paid twenty cents a pound (total wet weight of shell and animal) for shells of *Amblema plicata* and *Quadrula apiculata*. At least one collector sold 500 kilograms (1,100 pounds) in a single day. The preferred species was *A. plicata*, which had to measure about 125 mm in length and could not exhibit worn periostracum on the ridges.

Only *Amblema plicata* from the "new lake" (areas II and III in discussion below) were acceptable as shells from the "old lake" (area I) had thin layers with black or purple coloration. *Amblema plicata* from the "old lake" possessed thinner shells than those from other portions of Lake Lewisville, shell material was often heavily suffused with purple, and shells with white nacre did not possess the bright white nacre seen elsewhere in the reservoir. Stansbery (1971) found that young *A. plicata* on fine substrates (similar to silted portions of the "old lake" bed) grew more slowly than *A. plicata* on coarse substrates.

Individual collectors were experiencing the effects of resource depletion as suitable unionids were "becoming hard to find." Unionids in some isolated coves were reasonably safe from collection, but some collectors used boats to get to these sites. Most collectors gathered unionids in water that was less than two meters deep. Unionids were located visually or tactilely (with hands or feet). In deeper water, diving equipment was used. Neck (1982b) reported amounts of shell removed from various Texas reservoirs, including Lake Lewisville. The 500 kilograms of *A. plicata* reported above consist of approximately 1,430 animals with an average weight of 350 grams.

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## LITERATURE CITED

Burch, J. B. 1973. Freshwater unionacean clams (Mollusca: Pelecypoda) of North America. Biota of Freshwater Ecosystems, Identi. Man. 11, U.S. Envi. Pro. Agency, 176 p.

Burch, J. B. 1975. Freshwater unionacean clams (Mollusca: Pelecypoda) of North America, revised ed. Malacological Publications, Hamburg, Michigan, 204 p.

Dowell, C. L. and S. D. Breeding. 1967. Dams and reservoirs in Texas. Texas Water Development Board Report 48, 267 p.

Flook, J. M. and J. E. Ubelaker. 1972. A survey of metazoan parasites in unionid bivalves of Garza-Little Elm Reservoir, Denton County, Texas. Texas Journal of Science 23: 381–392.

Ford, A. and E. Pauls. 1980. Soil survey of Denton County, Texas. U.S. Department of Agriculture, Soil Conservation Service and Texas Agricultural Experiment Station, Washington, D.C., 160 p.

Frierson, L. S. 1898. *Unio* (*Lampsilis*) *amphichaenus*, n. sp. The Nautilus 11:109–110.

Harris, B. B. and J. K. G. Silvey. 1940. Limnological investigation on Texas reservoir lakes. Ecological Monographs 10:111–143.

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

Isely, F. B. 1924. The freshwater mussel fauna of eastern Oklahoma. Proceedings of the Oklahoma Academy of Science 4:43–118.

Klippel, W. E. and P. E. Parmalee. 1979. The naiad fauna of Lake Springfield, Illinois: an assessment after two decades. The Nautilus 94:189–197.

Mauldin, V. L. 1972. The bivalve mollusca of selected Tarrant County, Texas reservoirs. Master's thesis, Texas Christian University, Ft. Worth, 83 p.

Murray, H. D. 1972. Fresh water mussels of Lake LBJ, Texas. Bulletin of the American Malacological Union 1972:36–37.

Murray, H. D. 1978. Freshwater mussels of Lake Corpus Christi, Texas. Bulletin of the American Malacological Union 1978:5–6.

Murray, H. D. 1982. Unionids from Indian sites in McMullen and Live Oak counties, Texas. Bulletin of the American Malacological Union 1981:10–11.

Murray, H. D. and A. B. Leonard. 1962. Handbook of unionid mussels in Kansas. University of Kansas Museum of Natural History Miscellaneous Publication 28, 184 p.

Neck, R. W. 1982a. Preliminary analysis of the ecological zoogeography of the freshwater mussels of Texas. *In:* Davis, J. R. (ed.). Proceedings of the symposium on recent benthological investigations in Texas and adjacent states. Texas Academy of Science, Austin, p. 33–42.

Neck, R. W. 1982b. A review of interactions between humans and freshwater mussels in Texas. *In:* Davis, J. R. (ed.). Proceedings of the symposium on recent benthological investigations in Texas and adjacent states. Texas Academy of Science, Austin, p. 169–182.

Neck, R. W. 1986. Freshwater bivalves of Lake Tawakoni, Sabine River, Texas. Texas Journal of Science 38:241–249.

Neck, R. W. 1987. Freshwater bivalves of the Baffin Bay drainage basin, southern Texas. Texas Journal of Science 39:177-182.

Neck, R. W. 1989a. Freshwater bivalves of Medina Lake, Texas: factors producing a low-diversity fauna. Texas Journal of Science 41:319–325.

Neck, R. W. 1989b. Freshwater bivalves of Lake Arrowhead, Texas: apparent lack of local extirpation. Texas Journal of Science 41:371–377.

Neck, R. W. and A. L. Metcalf. 1988. Freshwater bivalves of the lower Rio Grande, Texas. Texas Journal of Science 40:259–268.

Neel, J. K. 1941. A taxonomic study of *Quadrula quadrula* (Rafinesque). Occasional Papers of the Museum Zoology of the University of Michigan 448:1–8.

Nelson, D. J., T. C. Rains, and J. A. Norris. 1966. High-purity calcium carbonate in freshwater clam shell. Science 152: 1368–1370.

Parmalee, P. W. 1955. Some ecological aspects of the naiad fauna of Lake Springfield, Illinois. The Nautilus 69:28–34.

Peach, J. L. 1983. Comments on the commercial shell industry, past and present. *In:* Miller, A. L. (compiler). Report of freshwater mussels workshop; 26–27 October 1982. U.S. Army Engineer Experiment Station, Vicksburg, MS, p. 84–89.

Read, L. B. 1954. The Pelecypoda of Dallas County, Texas. Field & Laboratory 22:35–52.

Read, L. B. and K. H. Oliver. 1953. Notes on the ecology of the freshwater mussels of Dallas County. Field & Laboratory 21:75–80.

Roback, S. S., D. J. Bereza, and M. F. Vidrine. 1980. Description of *Ablasbesmyia* (Diptera:Chironomidae:Tanypodinae) symbiont on unionid freshwater mussels (Mollusca:Bivalvia:Unionacea), with notes on its biology and zoogeography. Transactions of the American Entomological Society 105:577–619.

Simpson, C. T. 1914. A descriptive catalogue of the naiades or pearly freshwater mussels. Detroit, 1540 p.

Singley, J. A. 1893. A preliminary list of the land, freshwater, and marine Mollusca of Texas. Annual Report Geological Survey of Texas, 1892. 4:299–343.

Smith, J. A. 1973. Primary productivity and nutrient relationships in Garza-Little Elm Reservoir. Ph.D. dissertation, North Texas University, Denton, 118 p.

Stansbery, D. H. 1971. A study of the growth rate and longevity of the naiad *Amblema plicata* (Say, 1817) in Lake Erie (Bivalvia: Unionidae). Annual Report of the American Malacological Union. 1970:78–79.

Stansbery, D. H. 1983. Some sources of nomenclatorial and systematic problems in unionid mollusks. *In:* Miller, A. C. (compiler). Report of freshwater mussels workshop; 26–27 October 1982, U.S. Army Engin. Waterways Exp. Sta., Vicksburg, MS, p. 46–62.

Strecker, J. K. 1931. The distribution of the naiads or pearly freshwater mussels of Texas. Baylor University Museum Special Bulletin 2, 71 p.

Trdan, R. J. and W. R. Hoeh. 1982. Eurytopic host use for two congeneric species of freshwater mussel (Pelecypoda: Unionidae: *Anodonta*). American Midland Naturalist 108: 381–388.

Turgeon, D. D., A. E. Bogan, E. V. Coan, W. K. Emerson, W. G. Lyons, W. L. Pratt, C. F. E. Roper, A. Scheltema, F. G. Thompson, and J. D. Williams. 1988. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks. American Fisheries Society Special Publication 16:1–277.

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 42:1–40.

White, D. S. and S. J. White. 1977. Observations on the pelecypod fauna of Lake Texoma, Texas and Oklahoma, after more than 30 years impoundment. Southwestern Naturalist 22:235–254.

Winton, W. M. 1925. The geology of Denton County. University of Texas Bulletin 2544, 86 p.

## APPENDIX

Below is a list of collecting localities on Lake Lewisville, Denton County, Texas, that were used for this study. Numbers are keyed to those in figure 3.

1. Northeast end of "old" Garza Dam, west or "old" Lake Dallas side.
2. Graveyard Slough, 1.75 km south of Shady Shores community.
3. Willow Grove Park, 1.25 km east of center of city of Lake Dallas.
4. East Hill Park, 1.0 km north of spillway of Lewisville Dam.
5. Stewart Creek Park, 1.5 km north of spillway of Lewisville Dam.
6. Hackberry Park, east side of large cove in southeastern portion of Lake Lewisville State Park, 3.6 km west of FM 423.
7. Little Elm bridge on Farm-to-Market Road (FM) 720, southeast portion 1.5 km southwest of community of Little Elm.
8. Cottonwood Park, 1.8 km south-southeast of Little Elm bridge (FM 720).

9. Northeast end of "old" Garza Dam, east or "new" Lake Lewisville Side.
10. Oakland Park, 0.7 km northeast of Copperas Point (across Hickory Creek Arm).
11. Fish-O-Rama (private commercial development), just southeast of boundary of Hickory Creek Park, 0.85 km west of IH 35 E.
12. Sycamore Bend Park, 2.9 km west of Interstate Highway 35E.