FINAL REPORT

As Required by

THE ENDANGERED SPECIES ACT, SECTION 6

TEXAS
Project No: E-1-4

ENDANGERED AND THREATENED SPECIES CONSERVATION

Job No. 2.5

Conservation of the Upper San Marcos and Comal Ecosystems

Project Coordinator: Lee Ann Johnson Linam

Principal Investigators: Gordon W. Linam
Kevin Mayes
Kenneth Saunders
Lee Ann Johnson Linam
David R. Hernandez

Larry D. McKinney, Ph.D.
Director
Resource Protection Division

Andrew Sansom
Executive Director
TX Parks and Wildlife Department

March 12, 1993

FINAL REPORT

STATE: Texas **PROJECT NO.:** E-1-4

PROJECT TITLE: Endangered and Threatened Species Conservation.

PERIOD COVERED: September 1, 1991 - August 31, 1992

JOB NUMBER: 2.5

JOB TITLE: Conservation of the Upper San Marcos and Comal Ecosystems

JOB OBJECTIVE: Conserve the habitats of the Texas wild-rice and the fountain darter in the San Marcos River. Study the population dynamics of Texas wild-rice and the fountain darter. Use instream flow incremental methodology for characterizing stream habitats. Monitor the river system monthly to determine that new activities do not further deteriorate the habitat.

ACCOMPLISHMENTS

See attached reports.

SIGNIFICANT DEVIATIONS

Due to pressures on the Comal River system, fountain darter studies focused on that system, to produce a population estimate and evaluate habitat preferences. IFIM methodology was not utilized; however, distribution, habitat preference, and population status of the fountain darter in the San Marcos River was examined.

PREPARED BY: Lee Ann Johnson Linam 3-12-93
Date

Coord., End. Sp. Program
Title

APPROVED BY: [signature] 3-12-93
Larry D. McKinney, Ph.D. **Date**
Director, Resource Protection Division

HABITAT UTILIZATION AND POPULATION SIZE ESTIMATE OF FOUNTAIN DARTERS, *Etheostoma fonticola*, IN THE COMAL RIVER, TEXAS

Gordon W. Linam, Kevin B. Mayes, and Kenneth S. Saunders

Resource Protection Division
Texas Parks and Wildlife Department
P.O. Box 947
San Marcos, TX 78667

ABSTRACT--Fountain darters (*Etheostoma fonticola*) were sampled in the Comal River, Texas, to determine their habitat utilization and population size. Sampling grids were established along transects to characterize the vegetation community and depth regimes. Fountain darters, collected within these grids, were found in greatest densities in filamentous algae. The mean population estimate was 168,078 with 95% confidence limits of 114,178 and 254,110.

Listed as endangered by the U.S. Fish and Wildlife Service (USFWS) (35 FR 16047; October 13, 1970) fountain darters (*Etheostoma fonticola*: Percidae) are endemic to the Comal and San Marcos rivers (USFWS, 1984). Both rivers originate from springs fed by the Edwards Aquifer.

Reduced spring flows have impacted the fountain darter population at Comal Springs in the past and are a continual threat to the species' viability. A severe drought from 1950-1956 greatly reduced the aquifer level and spring discharges. During 1956, Comal Springs ceased to flow for five months (Buckner and Shelby, 1990) as total well pumping increased to 321,100 acre-feet, while recharge decreased to 43,700 acre-feet (U.S. Geological Survey [USGS], 1991). A less severe drought in 1984 resulted in minimum daily spring flows of 24 cfs (0.7 m^3/s; Buckner et al., 1986). Annual recharge in 1984 was 197,900 acre-feet and total well discharge was 529,800 acre-feet (USGS, 1991). Several years later, another drought reduced minimum daily spring flows to 46 cfs (1.3 m^3/s) in 1990, compared to a mean spring flow discharge (1933-1990) of 293 cfs (8.3 m^3/s; Buckner and Shelby, 1990).

Since 1970, well withdrawal has averaged 422,000 acre-feet per year (USGS, 1991). Given the relationship between aquifer recharge and precipitation and the increasing trend in well pumpage, Comal Springs is likely to cease flowing again (Guyton and Associates, 1979; USFWS, 1984; Edwards Aquifer Research and Data Center [EARDC] and Southwest Texas State University [SWTSU], 1988).

The 1950's drought and subsequent cessation of flows from the Comal Springs is presumed to have caused the Comal River fountain darter population to be extirpated (Schenck and Whiteside, 1976). This population had been impacted in the early drought during renovation efforts of Landa Lake in 1951 when the piscicide, rotenone, was applied to remove exotic Rio Grande cichlids (*Cichlasoma cyanoguttatum*) (Ball et al., 1952). Renovation efforts did not eliminate the fountain darter population, because individuals were seined and held in a protected area prior to the rotenone application (Ball et al., 1952; C. Hubbs, pers. comm.); however, it probably made the population more vulnerable to extirpation. The Comal River was restocked in 1975 and 1976 with 457 fountain darters taken from the San Marcos River (USFWS, 1984).

Schenck and Whiteside (1976) reported that fountain darters predominantly inhabit vegetated areas, and estimated the population at 102,966 individuals in the San Marcos River between Spring Lake Dam and the outfall of the San Marcos Wastewater Treatment Plant (river area of 102,633 m^2). Until now, no such work had been conducted in the Comal River. This study was designed to determine fountain darter habitat utilization, the amount of habitat available, and to estimate the number of fountain darters in the Comal River. Study results will assist future efforts to determine spring flow requirements necessary to protect the Comal River ecosystem.

STUDY AREA--The Comal River, Comal County, Texas, originates from numerous springs fed by the Edwards Aquifer and flows eastward for about 5 km before joining with the Guadalupe River (Figure 1). The headwaters of the river were dammed in the late 1880's (D. Whatley, pers. comm.), forming Landa Lake (approximately 84,280 m^2). Water exits the lake at two points, the "old" and "new" channels. Most of the water is diverted through the new channel, a channelized run formerly used for cooling an electrical power generating plant (Ottmers, 1987). The remainder flows through the old channel which rejoins the new channel about 2.5 km downstream of the lake.

The physical and chemical properties of the Comal River are relatively stable; water temperature remains near 25° C year-round and water clarity is high (Brune, 1981; Ottmers, 1987). The Comal River supports a large quantity and variety of aquatic macrophytes (Table 1), and is heavily utilized for contact and non-contact recreation by area residents and visitors.

MATERIALS AND METHODS--In August 1990, 30 cross-channel transects were systematically placed at 200 m intervals beginning at three random starting points - one in Landa Lake, one in the new channel, and one in the old channel (Figure 1). No transects were established below Torrey Mill Dam, as instream vegetation appeared patchy and few fountain darters were collected during reconnaissance sampling. Permanent markers were established at each transect. A row of 10 m^2 cells was placed along each side of the transect line to form a sampling grid.

Habitat types within each cell were identified (Correll and Correll, 1975; Tarver et al., 1986) and classified into a series of cover classes, where class one represented 0-5% cover, two (5-25%), three (25-50%), four (50-75%), five (75-95%), and six (95-100%). To estimate area covered by each habitat type over the entire system, the midpoint of each cover class (i.e. 15% for cover class two) for each habitat type within each cell was multiplied by the cell area. Values for the habitat types were summed and divided by the total area sampled. These values were then multiplied by the

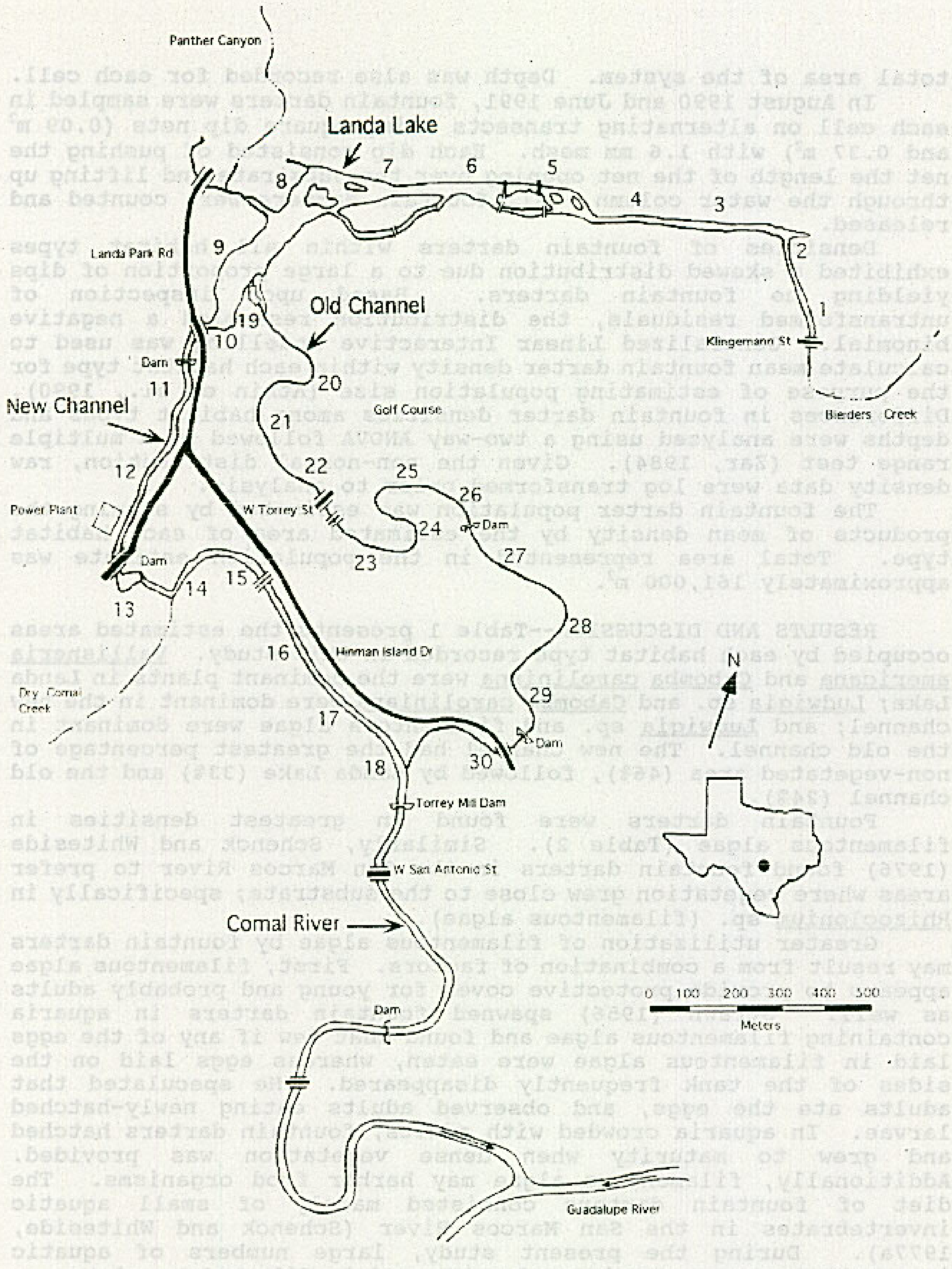

Figure 1. Map of the Comal River illustrating the transect locations. Modified from Brune (1981).

total area of the system. Depth was also recorded for each cell.

In August 1990 and June 1991, fountain darters were sampled in each cell on alternating transects using square dip nets (0.09 m^2 and 0.37 m^2) with 1.6 mm mesh. Each dip consisted of pushing the net the length of the net opening over the substrate and lifting up through the water column. All fountain darters were counted and released.

Densities of fountain darters within all habitat types exhibited a skewed distribution due to a large proportion of dips yielding no fountain darters. Based upon inspection of untransformed residuals, the distribution resembled a negative binomial. Generalized Linear Interactive Modelling was used to calculate mean fountain darter density within each habitat type for the purpose of estimating population size (Atkin et al., 1990). Differences in fountain darter densities among habitat types and depths were analyzed using a two-way ANOVA followed by a multiple range test (Zar, 1984). Given the non-normal distribution, raw density data were log transformed prior to analysis.

The fountain darter population was estimated by summing the products of mean density by the estimated area of each habitat type. Total area represented in the population estimate was approximately 161,000 m^2.

RESULTS AND DISCUSSION--Table 1 presents the estimated areas occupied by each habitat type recorded in this study. *Vallisneria americana* and *Cabomba caroliniana* were the dominant plants in Landa Lake; *Ludwigia* sp. and *Cabomba caroliniana* were dominant in the new channel; and *Ludwigia* sp. and filamentous algae were dominant in the old channel. The new channel had the greatest percentage of non-vegetated area (46%), followed by Landa Lake (33%) and the old channel (24%).

Fountain darters were found in greatest densities in filamentous algae (Table 2). Similarly, Schenck and Whiteside (1976) found fountain darters in the San Marcos River to prefer areas where vegetation grew close to the substrate; specifically in *Rhizoclonium* sp. (filamentous algae).

Greater utilization of filamentous algae by fountain darters may result from a combination of factors. First, filamentous algae appears to provide protective cover for young and probably adults as well. Strawn (1956) spawned fountain darters in aquaria containing filamentous algae and found that few if any of the eggs laid in filamentous algae were eaten, whereas eggs laid on the sides of the tank frequently disappeared. He speculated that adults ate the eggs, and observed adults eating newly-hatched larvae. In aquaria crowded with adults, fountain darters hatched and grew to maturity when dense vegetation was provided. Additionally, filamentous algae may harbor food organisms. The diet of fountain darters consisted mainly of small aquatic invertebrates in the San Marcos River (Schenck and Whiteside, 1977a). During the present study, large numbers of aquatic invertebrates were consistently observed in filamentous algae.

A statistically significant difference ($P<0.0001$) was observed between fountain darter densities at nine feet and all other

Table 1. Estimated area (m^2) for each habitat type in the Comal River during the summer of 1990 (number of cells sampled in parenthesis).

Vegetation	Landa Lake (268)	Old Channel (135)	New Channel (105)	Total (508)
Amblistegium sp.	28	0	0	28
Bryophyta	669	0	358	1027
Cabomba caroliniana	16,606	69	3927	20,602
Ceratopteris thalictroides	121	244	66	431
Chara sp.	1497	68	0	1565
Egeria densa	0	9	0	9
Filamentous algae	1381	14,636	372	16,389
Hydrilla verticillata	0	0	19	19
Hydrocotyle sp.	0	9	0	9
Justicia americana	1060	1189	9	2258
Ludwigia sp.	7787	17,025	8824	33,636
Ludwigia sp./filamentous algae	0	44	2127	2171
Myriophyllum sp.	0	44	0	44
Nuphar luteum	1103	154	0	1257
Potamogeton illinoensis	949	0	1851	2800
Riccia sp.	38	0	0	38
Sagittaria sp.	0	18	0	18
Typha latifolia	0	95	0	95
Utricularia sp.	25	0	0	25
Vallisneria americana	25,138	8	182	25,328
No vegetation	27,878	10,637	15,058	53,573
	84,280	44,249	32,793	161,322

Table 2. Mean fountain darter densities (fish/m^2) calculated for various habitat types in the Comal River during the summers of 1990 and 1991 (sample size in parenthesis). Significant differences ($P<0.05$) in density are followed by different letters. Densities reported for the San Marcos River (Schenck 1975) are included for comparison.

Vegetation	Comal	San Marcos
Filamentous algae	4.99 (28) a	4.68
Chara sp.	2.15 (10) b	-
Ludwigia sp./filamentous algae	1.74 (31) b	-
Cabomba sp.	1.44 (84) b	0.69-3.15
Ludwigia sp.	0.88 (209) b	0.00-2.58
Ceratopteris sp.	0.54 (5) b	-
No vegetation	0.26 (126) b	0.00-0.90
Vallisneria sp.	0.21 (65) b	0.71
Justicia sp.	0.18 (15) b	-
Nuphar sp.	0.00 (4) b	-
Potamogeton sp.	0.00 (12) b	1.36

depths. Significant depth by plant species interaction was also observed ($P<0.0001$); however, only two observations were associated with that depth in a single plant type (Cabomba caroliniana). Consequently, it was concluded that the differences were not biologically meaningful.

The mean population estimate was 168,078 with 95% confidence limits of 114,178 and 254,110. This seems reasonable given the fountain darter's fecundity and spawning characteristics, and the population size estimated for the San Marcos River by Schenck and Whiteside (1976). The population estimate indicates that the reintroduction effort was successful. Reproductive success was noted a few months after reintroduction when offspring were collected in the vicinity where adult fountain darters had been released (USFWS, 1984). Fountain darters appear to spawn throughout the year (Strawn, 1956; Schenck and Whiteside, 1977b). Schenck and Whiteside (1977b) collected females with mature ovum throughout the year in the San Marcos River and reported two major spawning periods annually, one in August and the other in late winter to early spring. In regards to fecundity, Brandt et al. (in press) reported a daily mean of 19.3 eggs released per female on days when eggs were released, and a maximum of 60 eggs released over a 24 hour period. Over a 54 day period, the mean number of days an individual deposited eggs was 13.5 (25%), and ranged from five (9%) to 27 (50%). Taking a conservative approach with their data in assuming eggs are released on nine percent of the days each year, and on each of these days a mean of 19 eggs are released per female, a total of 624 eggs would be released each year per female. Assuming the 457 fountain darters reintroduced to the Comal River had a male to female ratio of 1.39:1 (Schenck and Whiteside, 1977b), the 191 restocked females would have released 119,184 eggs the first year. Fountain darters reach sexual maturity at a relatively early age. Eggs were collected from fish about six months of age during laboratory spawning, and mature ova were found in fountain darters estimated at 3.5 months of age from the San Marcos River (Brandt et al., in press; Schenck and Whiteside, 1977b).

Despite the successful reintroduction effort, other factors might preclude it being replicated should the springs cease to flow again. During the 1950's drought when Comal Springs ceased to flow for five months, enduring pools sustained some segment of the aquatic plant community, providing a base for reestablishment. Should another drought cause cessation of spring flow, the assumption enduring pools will once again provide a source of aquatic plants is no longer valid. Since the introduction of giant rams-horn snails (Marisa cornuarietis) around 1983, plants in many areas of Landa Lake have been denuded of leaves or even grazed to the bottom (Horne et al., 1992). The snail population significantly increased during the low flows associated with the 1988-90 drought, leading researchers to conclude that spring flow may influence their numbers (T. Arsuffi, pers. comm.). If this is the case, low flow conditions may allow grazing by giant rams-horn snails to more severely impact or even eliminate the fountain darter habitat.

If another severe drought occurs, given present groundwater pumping rates, Comal Springs will again stop flowing, but for a longer period than in 1956 (Guyton and Associates, 1979). They also state that if pumpage from wells continues to increase, Comal Springs will go dry even without a major drought, since average withdrawals are slowly approaching average recharge. Lowering the water levels of the aquifer below the historic lows of 1956 could also result in intrusion of water with high dissolved solids from formations adjacent to the southern or down slope boundaries of the aquifer (Guyton and Associates, 1979; EARDC and SWTSU, 1988). An extended period without spring flow, the possibility of a shift in water quality, and the presence of giant rams-horn snails makes the likelihood of another successful reintroduction of fountain darters unlikely.

Funding for this project was provided through a cooperative agreement between the USFWS and the Texas Parks and Wildlife Department (TPWD) under Section 6 of the Endangered Species Act. Field assistance was provided by J. Bowling, L. Linam, R. Noches, K. Quinonez, D. Sager (TPWD), and M. Skalberg (Southwest Texas State University). P. Chai, A. Green, A. Miller, and A. Morgan (TPWD) provided statistical help. D. Diamond (TPWD) assisted in study design. L. Kleinsasser and R. Moss (TPWD) assisted in study design and manuscript review. Special thanks to D. Whatley (City of New Braunfels Parks and Recreation Department) for his cooperation and lending of boats, and to the landowners and businesses along the Comal River for providing access and allowing permanent markers to be placed on their property.

LITERATURE CITED

Atkin, M., D. Anderson, B. Francis, J. Hinde (editors). 1990. Statistical modelling in GLIM. Oxford University Press, New York. 374 pp.

Ball, J., W. Brown, and R. Kuehne. 1952. Landa Park Lake is renovated. Texas Game and Fish 10(5): 8-9,32.

Brandt, T.M., K.G. Graves, C.S. Berkhouse, T.P. Simon, and B.G. Whiteside. In press. Laboratory spawning and rearing of the endangered fountain darter. Prog. Fish-Cult.

Brune, G. 1981. Springs of Texas. Volume I. Branch-Smith, Inc., Fort Worth, Texas. 566 pp.

Buckner, H.D., E.R. Carrillo, and H.J. Davidson. 1986. Water resources data for Texas, water year 1985, volume 3: Colorado River Basin, Lavaca River Basin, Guadalupe River Basin, Nueces River Basin, Rio Grande Basin, and intervening coastal basins. Water-data report TX-85-3. U.S. Geological Survey, Austin, Texas. 447 pp.

Buckner, H.D. and W.J. Shelby. 1990. Water resources data for Texas, water year 1990, volume 3: Colorado River Basin, Lavaca River Basin, Guadalupe River Basin, Nueces River Basin, Rio Grande Basin, and intervening coastal basins. Water-data report TX-90-3. U.S. Geological Survey, Austin, Texas. 443 pp.

Correll, D.S. and H.B. Correll. 1975. Aquatic and wetland plants of Southwestern United States. Stanford University Press, Stanford, California. 1792 pp.

Edwards Aquifer Research and Data Center and Southwest Texas State University. 1988. Proceedings of the San Marcos and Comal springs symposium. Guadalupe-Blanco River Authority, Edwards Aquifer Research and Data Center, Southwest Texas State University, San Marcos, Texas. 74 pp.

Guyton, W.F. and Associates. 1979. Geohydrology of Comal, San Marcos, and Hueco springs. Report 234. Texas Department of Water Resources, Austin, Texas. 85 pp.

Horne, F.R., T.L. Arsuffi, and R.W. Neck. 1992. Recent introduction and potential botanical impact of the giant ramshorn snail, <u>Marisa cornuarietis</u> (Pilidae), in the Comal Springs Ecosystem of Central Texas. Southwest Nat. 37: 194-214.

Ottmers, D.D. 1987. Intensive survey of the Comal River segment 1811. Report IS 87-08. Texas Water Commission, Austin, Texas. 19 + A-17 pp.

Schenck, J.R. 1975. Ecology of the fountain darter, _Etheostoma fonticola_ (Osteichthyes: Percidae). Master's thesis, Southwest Texas State University, San Marcos, Texas. 100 pp.

Schenck, J.R. and B.G. Whiteside. 1976. Distribution, habitat preference and population size estimate of _Etheostoma fonticola_. Copeia 1976: 697-703.

Schenck, J.R. and B.G. Whiteside. 1977a. Food habits and feeding behavior of the fountain darter, _Etheostoma fonticola_ (Osteichthyes: Percidae). Southwest Nat. 21: 487-492.

Schenck, J.R. and B.G. Whiteside. 1977b. Reproduction, fecundity, sexual dimorphism and sex ratio of _Etheostoma fonticola_ (Osteichthyes: Percidae). Amer. Midland Nat. 98: 365-375.

Strawn, K. 1956. A method of breeding and raising three Texas darters, Part II. Aquarium Journal 27: 12-14,17,31.

Tarver, D.P., J.A. Rodgers, M.J. Mahler, and R.L. Lazor. 1986. Aquatic and wetland plants of Florida. Florida Department of Natural Resources, Tallahassee, Florida. 127 pp.

U.S. Fish and Wildlife Service. 1984. San Marcos River recovery plan. U.S. Fish and Wildlife Service, Albuquerque, New Mexico. 109 pp.

U.S. Geological Survey. 1991. Compilation of hydrologic data for the Edwards Aquifer, San Antonio Area, Texas, 1991, with 1934-91 summary. Bulletin 51. Edwards Underground Water District, San Antonio, Texas.

Zar, J.H. 1984. Biostatistical analysis, second edition. Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 718 pp.

A REASSESSMENT OF THE DISTRIBUTION, HABITAT PREFERENCE, AND POPULATION SIZE ESTIMATE OF THE FOUNTAIN DARTER (ETHEOSTOMA FONTICOLA) IN THE SAN MARCOS RIVER, TEXAS

Lee Ann Johnson Linam

INTRODUCTION

Located approximately 24 km north of the Comal River, the San Marcos River also finds its source in the Edward's Aquifer on the eastern edge of the Edward's Plateau. One of the largest and most culturally significant spring systems in the state (Brune 1981), the San Marcos River is home to four endangered or threatened species, including the fountain darter (*Etheostoma fonticola*), San Marcos gambusia (*Gambusia georgei*), San Marcos salamander (*Eurycea nana*), and Texas wild-rice (*Zizania texana*). Although San Marcos Springs originate lower in the aquifer table than Comal Springs (174 m above mean sea level compared to 187 m), the San Marcos ecosystem is subject to the same concerns about Edward's Aquifer water quality and quantity as the Comal ecosystem.

Schenck (1975) conducted the first study of the status and habitat of the fountain darter in the San Marcos River, estimating approximately 103,000 in the upper 4.8 km of the river. Although the type specimen was collected in 1886 approximately 6.4 km downstream (Burr 1980), surveys by Schenck and Whiteside (1976) in 1973-74 failed to collect any fountain darters downstream of the San Marcos sewage treatment plant (4.8 km downstream) (Figure 1). Extensive sampling efforts by U.S. Fish and Wildlife Service personnel in 1992 collected only one fountain darter within the 1.6 km reach downstream of the plant (Casey Berkhouse, pers. comm.). In 1991 Janet Nelson conducted scuba-aided surveys in Spring Lake and estimated at least 16,000 fountain darters at the spring openings and another 15,000 in the green algae habitat (Longley 1991).

Unregulated withdrawal from the Edward's Aquifer and other anthropogenic pertubations continue to raise concerns for the San Marcos ecosystem. This study was initiated to evaluate the current status of the fountain darter in the San Marcos River. Specifically, the study set out to reassess the distribution, habitat preference, and population size estimate of the fountain darter in the upper San Marcos River.

STUDY AREA

The study was conducted in the upper 5.0 km of the San Marcos River from just downstream of Spring Lake Dam to the San Marcos sewage treatment plant. The study area was described in detail by Schenck and Whiteside (1976). The San Marcos River ecosystem has been heavily modified by human activity. The headwaters and upper reaches of the river are located within the City of San Marcos. A dam constructed at the headwaters of the river in 1865 created Spring Lake, while three other dams were constructed in the early 1900's, including one about 6.4 km downstream at the approximate collection location for the type specimen. Hydrology within the river watershed has been influenced by impervious cover associated with urbanization and by the construction of flood-control check-dams by the Soil Conservation Service in the early 1970's. Non-native plant, fish, and invertebrate species are common in the river, likely a result of aquaria activities. The river is also popularly utilized for both contact and non-contact recreation. Finally, several new management proposals, such as dredging of gravel bars to increase channel depth and rerouting of utilities in the river bed have been proposed (Longley 1991).

METHODS

In September, 1991, 53 sample points were established at 91 m intervals beginning at a randomly located point just downstream of Spring Lake Dam. At each sample point a rope was stretched across the river to create a belt transect of contiguous 10 m^2 (3.3 m. x 3.3 m.) grids. Each grid was then sampled utilizing square dip nets (0.09 m^2 and 0.37 m^2) with 1.6 mm mesh according to techniques described for the Comal River. Five dips totalling 1.85 m^2 or 10 dips totalling 0.93 m^2 were performed in each grid, depending upon the net size used. Substrate, vegetation type, and depth class were recorded for each dip. Dips were distributed among habitat variables in approximate proportion to their occurrence in the grid.

Density was calculated for each dip. Examination of the data indicated a non-normal distribution due to an excessive proportion of zero values; therefore, a Kruskal-Wallis test was used to detect differences in density attributable to substrate, vegetation type, depth, and segment of the river. Where differences were detected a Tukey-type multiple comparison was used to sort different classes of variables from each other (Zar 1984). An overall density and population estimate was derived, based upon an estimated study area size of 102,000 m^2.

RESULTS AND DISCUSSION

Distribution - A total of 1812 sampling dips covering 389 m^2 resulted in capture of 140 fountain darters. Fountain darters were collected in 31 of the first 38 transects (Table 1). No darters were collected downstream of transect 38, located just upstream of River Road and the terminus of Thompson's Island (Appendix I).

Comparison of mean densities within segments defined by Schenck (1975; Figure 2) and by Poole (1991; Figure 1) during recent studies of the Texas wild-rice did not reveal any significant differences in densities between upstream and downstream segments of the river; however, sampling efforts do seem to reveal that greatest fountain darter densities are encountered in the upper 3-4 km of the river, perhaps with greatest densities in the section between Cheatham Street and Thompson's Island. Several factors may explain the impression of higher densities in this area, although an examination of causes is beyond the scope of this study. This section of the river lies within and downstream of a riparian greenbelt, has not received extensive channel modification, probably receives less recreational use than upstream areas, and is upstream of the discharges of the A.E. Wood State Fish Hatchery and the San Marcos sewage treatment plant. This section contains the Interstate 35 crossing, a potential source of pollution.

This study seemed to support the impressions of Schenck (1976) and the more recent findings by U.S. Fish and Wildlife Service personnel (Berkhouse, pers. comm.) that fountain darters are relatively rarer further downstream. River physiognomy shifts in downstream reaches to a relatively deeper and narrower channel, perhaps resulting in reduced habitat suitability. In addition, in a rapid bioassessment of the river conducted by Murray Owen in 1991, composition of the invertebrate fauna indicated that water quality may be degraded below Thompson's Island (Longley 1991).

Habitat Preference

Seventeen of 39 vegetation classes sampled contained fountain darters; however, many of the vegetation groups with no darters were relatively rare and therefore infrequently sampled (Table 4). Clumping of vegetation classes by dominant vegetation species allowed a better comparison of densities within vegetation types (Table 5). Fountain darters were found to occur in Rhizoclonium in significantly greater densities than in all other vegetation types. Fountain darters were significantly less likely to be found in non-vegetated areas than in vegetated areas. Preference for other vegetation classes could not be distinguished.

Schenck and Whiteside (1976) and the recently completed study in the Comal River also confirmed the preference of fountain darters for habitat containing Rhizoclonium and avoidance of non-vegetated habitat (Table 6). Although statistical comparison is not possible, fountain darters in all three studies were found relatively more densely in some species (e.g. Ludwigia sp.) and relatively less densely in others (e.g. Potamogeton sp. and Vallisneria). Schenck and Whiteside (1976) proposed that darters select vegetation with a growth form that provides cover close to the substrate; however, comparison of growth form types in this study could not separate low-growing forms from less-dense, long-leaved forms (Table 7). Several introduced species (e.g. Egeria and Hydrilla) had moderate densities of fountain darters in this study.

Darter densities were also determined within different depth classes and over different substrate types. Although densities were highest in 1-2 m. depths and over sand or silt substrates, no significant differences between depth and substrate classes could be detected (Tables 8 and 9).

Population Estimate

Overall density of fountain darters was determined by averaging mean densities in each segment defined by Poole (1991). Overall density was thus determined to be $0.45/m^2$ (stdev=0.34). Based upon an estimated study area size of 102,000 m^2, the population estimate for the upper 5.0 km of the San Marcos River (excluding Spring Lake) is estimated to be 45,900. Confidence intervals (90%) range from -15,900 to 107,700. Schenck and Whiteside (1976) estimated 103,000 fountain darters in the same study area, but offered no confidence intervals.

CONCLUSIONS

One habitat need is obvious from each of the field studies conducted on the fountain darter. Darter density is highest in filamentous green algae. Little information is available in the literature concerning habitat needs of Rhizoclonium species in fresh water. Chapman (1968) noted that in studies in Europe the genus grew best in slow-moving water, but that Rhizoclonium was outcompeted by other species in low-aeration conditions. It seems intuitive that for fountain darter habitat, the species would require light penetration to the riverbed, implying that water clarity and quality may be important. In vegetative transects of the San Marcos River conducted during 1990-91, Beth Staton noted that coverage of Rhizoclonium varied greatly during different sampling periods, ranging from 1691 m^2 in spring-summer to 43,100 m^2 in winter-spring (Longley 1991). More information on the habitat requirements of Rhizoclonium, including effects of flow, and information on important alternative fountain darter habitat during seasonal fluctions of filamentous green algae is needed.

Staton also noted several other qualitative changes when contrasting vegetative composition in 1990-91 to surveys done in the mid-1970's. She noted that the exotic species Egeria densa, Hydrilla verticillata, and Colocasia esculata were the dominant species within her transects. While moderate fountain darter densities were associated with Egeria and Hydrilla, nothing is known of their competitive interactions with native species, some of which (e.g. Ludwigia) may have higher value for fountain darters. In addition, Colocasia, which now dominates streamside vegetation, is presumed to have low value for fountain darters.

Our population estimate may indicate some need for concern, since it indicates a decline of over 50% since Schenck and Whiteside's work in the 1970's; however, interpretation is confounded by the high standard error associated with the sampling method and by possible seasonal sampling effects. Schenck (1975) found seasonal variation in densities of up to 400% at selected sampling stations. Fountain darter densities may fluctuate seasonally as habitat conditions, especially the availability of Rhizoclonium, change.

Human-induced pertubations of the San Marcos River outlined above continue to increase. More rigorous statistical analysis of available data, along with more efficient sampling techniques, are desirable in order to be able to monitor meaningful trends in the fountain darter population in the San Marcos River. In addition, other habitat features, such as sedimentation and water quality, which may play a role in the health of the San Marcos River fountain darter population should be examined.

ACKNOWLEDGEMENTS

Funding for this project was provided through a cooperative agreement between the U.S. Fish and Wildlife Service and the Texas Parks and Wildlife Department under Section 6 of the Endangered Species Act. Appreciation is expressed to D. Hernandez, G. Linam, K. Quinonez, W. Berquist, and R. Murphy for field assistance. P. Chai, A. Morgan, G. Linam, and D. Hernandez graciously provided assistance in statistical analysis. Thanks to Southwest Texas State University and TPWD River Studies Program for the use of equipment to make the project possible.

LITERATURE CITED

Burr, B.M. 1980. Etheostoma fonticola (Jordan and Gilbert), Fountain darter. Page 648 in D.S. Lee, C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer, Jr., eds. Atlas of North American Freshwater Fishes. N.C. State Mus. Nat. Hist., Raleigh, i-x + 854 pp.

Brune, G. 1981. Springs of Texas. Volume I. Branch-Smith, Inc., Fort Worth, TX. 566 pp.

Chapman, V.J. 1968. The Algae. MacMillan, London, Eng. 472 pp.

Correll, D.S. and H.B. Correll. 1975. Aquatic and Wetland Plants of the Southwestern United States. Stanford Univ. Press, Stanford, CA. 1792 pp.

Longley, G. 1991. San Marcos River management plan--Phase II. TPWD Endangered Species Act Section 6 report. 143 pp.

Poole, J.M. 1991. Conservation of the upper San Marcos River system. TPWD Endangered Species Act Section 6 report. 66 pp.

Schenck, J.R. 1975. Ecology of the fountain darter, Etheostoma fonticola (Osteichthyes: Percidae). Master's thesis, Southwest Texas State Univ., San Marcos, TX. 100 pp.

Schenck, J.R. and B.G. Whiteside. 1976. Distribution, habitat preference and population size estimate of Etheostoma fonticola. Copeia 1976: 697-703.

Zar, J.H. 1984. Biostatistical Analysis, Second Ed. Prentice-Hall, Inc., Englewood Cliffs, NJ. 718 pp.

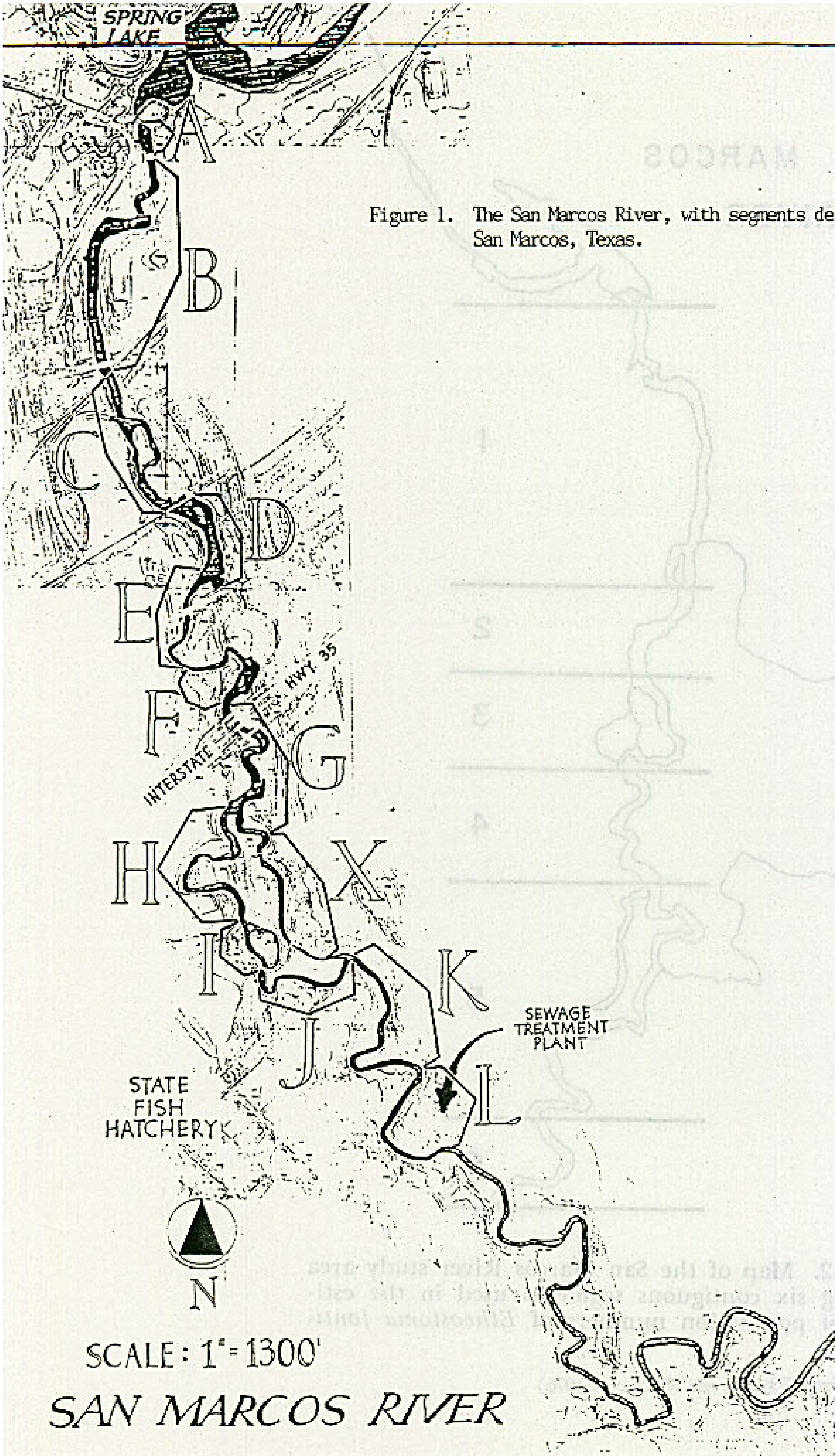

Figure 1. The San Marcos River, with segments delineated by Poole (1991), San Marcos, Texas.

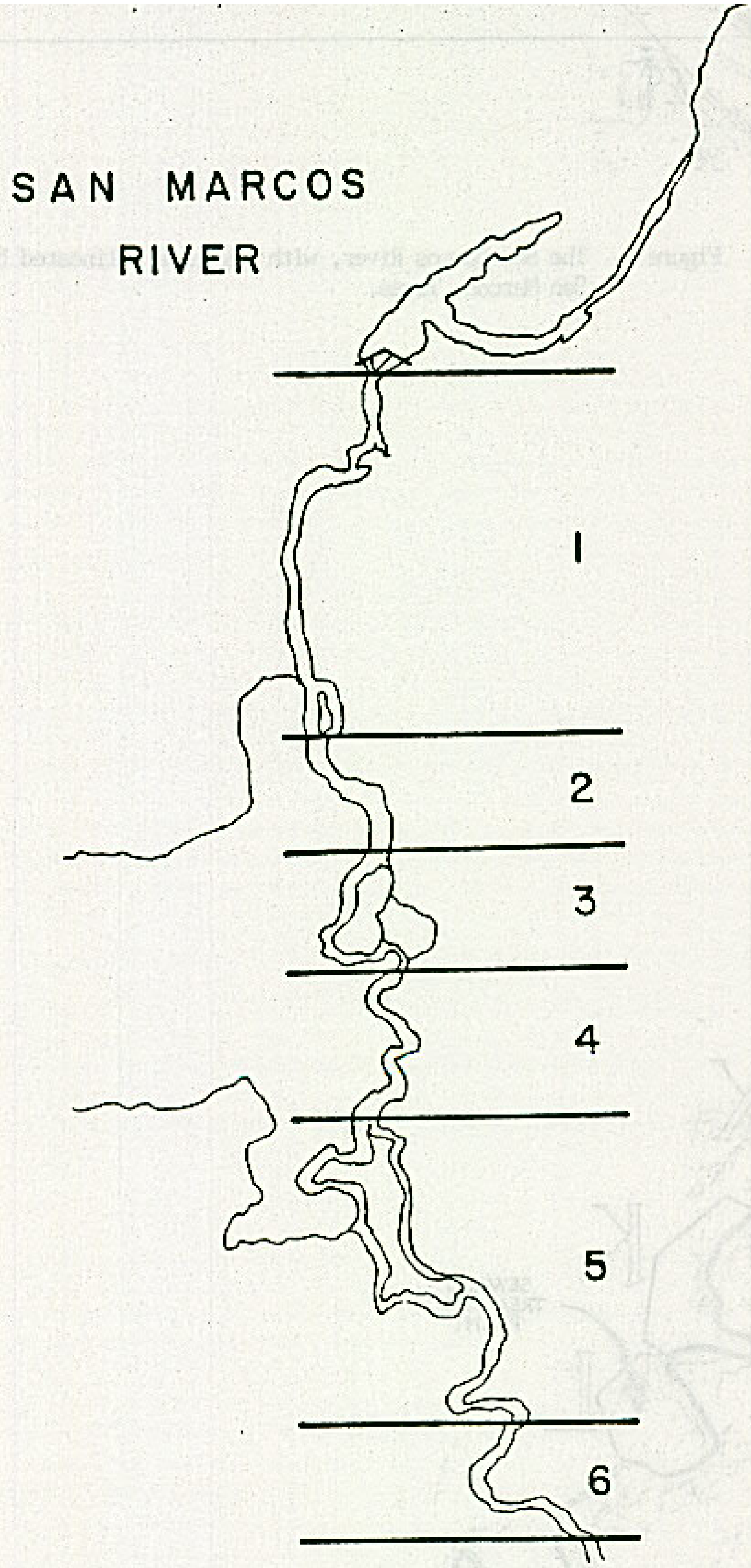

Fig. 2. Map of the San Marcos River study area showing six contiguous segments used in the estimate of population numbers of *Etheostoma fonticola*.

(Taken from Schenck and Whiteside 1976)

Table 1. Densities of fountain darters in 53 transects on the upper San Marcos River, Texas - 1991

SEG-MENT	TRAN-SECT	# DARTERS	AREA SAMPLED (SQ.M.)	DENSITY #/SQ.M.
A	1	11	18.55	0.592934
B	2	3	12.99	0.231011
B	3	5	7.42	0.673782
B	4	1	11.13	0.089838
B	5	9	22.26	0.404269
B	6	9	16.70	0.539025
B	7	3	12.99	0.231011
C	8	0	12.99	0
C	9	2	10.76	0.185871
C	10	1	4.17	0.239567
C	11	0	6.12	0
C	12	2	4.27	0.468718
C	13	2	14.10	0.141849
D	14	13	20.59	0.631291
D	15	6	9.28	0.646831
E	16	2	15.31	0.130673
E	17	0	5.57	0
E	18	8	3.71	2.156102
E	19	0	5.66	0
F	20	3	7.42	0.404269
F	21	3	3.80	0.788818
F	22	25	12.99	1.925091
G	23	1	2.78	0.35935
G	24	8	7.05	1.13479
G	25	1	2.23	0.449188
G	26	4	3.34	1.197834
X	27	1	3.71	0.269513
X	28	1	3.62	0.276423
X	29	1	2.78	0.35935
X	30	2	2.78	0.718701
X	31	0	1.86	0
X	32	6	1.67	3.593503
H	33	0	5.57	0
H	34	2	5.57	0.35935
H	35	0	5.57	0
H	36	2	2.32	0.862441
H	37	2	2.78	0.718701
I	38	1	2.78	0.35935
I	39	0	5.57	0
J	40	0	11.13	0
J	41	0	6.68	0
J	42	0	7.42	0
J	43	0	7.79	0
K	44	0	7.79	0
K	45	0	7.42	0
K	46	0	4.64	0
K	47	0	9.00	0
L	48	0	2.41	0
L	49	0	5.57	0
L	50	0	4.55	0
L	51	0	3.25	0
L	52	0	7.79	0
L	53	0	2.88	0
TOTALS		140	389.04	

Table 2. Densities of fountain darters in segments of the San Marcos River delineated by Schenck and Whiteside (1976) during September, 1991.

SCHENCK SEGMENT	1973-74 DENSITY #/SQ.M.	1991 DENSITY #/SQ.M.	STDEV	n
1	1.15	0.31	1.14	411
2	2.04	0.44	2.06	55
3	1.43	1.03	9.51	477
4	0.87	1.09	3.98	201
5	0.04	0.33	2.06	541
6	0.005	0.00	0.00	127

Table 3. Densities of fountain darters in segments of the San Marcos River delineated by Poole (1991) during September, 1991.

SEGMENT	DENSITY #/SQ.M.	STDEV	n
A	0.59	1.74	50
B	0.36	1.05	225
C	0.20	1.30	220
D	0.68	2.90	241
E	0.70	5.80	131
F	0.97	3.20	111
G	0.91	3.82	166
H	0.48	2.18	100
I	0.24	1.60	45
J	0.00	0.00	92
K	0.00	0.00	86
L	0.00	0.00	168
X	0.67	3.07	177

Table 4. Densities of fountain darters within complex vegetation groups in the San Marcos River, Texas - September, 1991.

	VEGETATION COMPLEX	DENSITY #/SQ.M.	STDEV	n	P<0.05 COMPARISON TEST
1	Rhizoclonium	8.61	9.01	5	a
2	Hydrilla\Rhizoclonium	2.21	8.27	72	bcd f
3	Complex*	2.15	4.81	5	abcde
4	Vallisneria\P. illinoensis	1.79	1.55	3	abcd
5	P. illinoensis\Egeria	1.08	1.47	5	abcde
6	Ludwigia	0.95	3.31	85	ef
7	Egeria	0.66	2.81	257	ef
8	Hydrilla	0.60	2.95	336	ef
9	Egeria\Hydrilla	0.51	2.35	21	ef
10	Debris	0.41	1.99	59	ef
11	Potamogeton illinoensis	0.35	1.04	61	ef
12	Sagittaria	0.28	1.23	19	ef
13	P. illinoensis\Vallisneria	0.28	0.83	29	ef
14	P. illinoensis\Ludwigia	0.26	0.95	112	ef
15	Hydrilla\Ludwigia	0.26	1.68	41	ef
16	Vallisneria	0.15	0.63	35	ef
17	None	0.10	1.01	561	e
18	Ceratophyllum	0.00	0.00	1	a ef
19	Colocasia	0.00	0.00	1	a ef
20	Egeria\Vallisneria	0.00	0.00	1	a ef
21	Hydrilla\Potamogeton	0.00	0.00	1	a ef
22	Hydrilla\Sagittaria	0.00	0.00	1	a ef
23	Hydrilla\UnknownA	0.00	0.00	1	a ef
24	P. illinoensis\Sagittaria	0.00	0.00	1	a ef
25	Sagittaria\Vallisneria	0.00	0.00	1	a ef
26	Vallisneria\Egeria	0.00	0.00	1	a ef
27	Vallisneria\Ludwigia	0.00	0.00	1	a ef
28	Zizania\P. illinoensis	0.00	0.00	1	a ef
29	Hydrilla\Egeria	0.00	0.00	2	a ef
30	Algalmat	0.00	0.00	3	a ef
31	Egeria\Cabomba	0.00	0.00	3	a ef
32	Hydrilla\Vallisneria	0.00	0.00	3	a ef
33	Ludwigia\Hydrilla	0.00	0.00	4	c ef
34	Ludwigia\Vallisneria	0.00	0.00	5	ef
35	Cabomba	0.00	0.00	6	ef
36	Vallisneria\Hydrilla	0.00	0.00	7	ef
37	Potamogeton nodosus	0.00	0.00	11	ef
38	Vallisneria\Sagittaria	0.00	0.00	15	ef
39	Zizania	0.00	0.00	36	ef

*mixture of Rhizoclonium with several other species

Plant names follow Correll and Correll (1975)

Table 5. Densities of fountain darters within dominant plant species in the San Marcos River, Texas – September, 1991.

P<0.05

VEGETATION	DENSITY #/SQ.M.	STDEV	n	COMPARISON TEST
Rhizoclonium sp.	8.61	9.01	5	a
Ludwigia repens	0.86	3.16	94	b
Hydrilla verticillata	0.81	4.20	457	b
Egeria densa	0.64	2.76	282	b
Potamogeton sp.	0.29	0.95	219	b
Other*	0.67	2.69	16	bc
Debris	0.41	1.99	59	bc
Sagittaria platyphylla	0.27	1.20	20	bc
Vallisneria americana	0.17	0.67	62	bc
Zizania texana	0.00	0.00	37	bc
None	0.10	1.01	561	c
			1812	

*includes Colocasia esculenta, Ceratophyllum demersum, Cabomba caroliniana, and unidentified complexes

Table 6. Comparative densities of fountain darters in selected plant species in the San Marcos River in 1991, the San Marcos River in 1973-74 (Schenck 1975), and in the Comal River in 1990-91.

	DARTER DENSITY (#/SQ.M.)		
	San Marcos 1991	San Marcos 1973-74	Comal 1990-91
filamentous algae	8.61	4.68	4.99
Ludwigia sp.	0.86	0.00-2.58	0.88
Hydrilla verticillata	0.81	–	–
Egeria densa	0.64	3.12*	–
Potamogeton sp.	0.29	1.36	0.00
Debris	0.41	–	–
Sagittaria platyphylla	0.27	–	–
Vallisneria americana	0.17	0.71	0.21
Zizania texana	0.00	0.00-0.15	–
None	0.10	0.00-0.90	0.26

*mixed with Rhizoclonium

Table 7. Densities of fountain darters within different vegetation growth forms in the San Marcos River, Texas - September, 1991.

VEGETATION TYPE	DENSITY #/SQ.M.	STDEV	n	P<0.05 COMPARISON TEST
green algae groups	2.50	7.82	85	a
low-growing submergents	0.57	2.51	887	b
long-leaved submergents	0.21	0.63	220	b
no vegetation	0.13	1.11	620	c

Table 8. Densities of fountain darters within different water depth classes in the San Marcos River, Texas - September, 1991.

DEPTH	DENSITY #/SQ.M.	STDEV	n
<1 meter	0.35	2.08	320
1-2 meters	0.64	2.88	630
>2 meters	0.48	4.08	337

Table 9. Densities of fountain darters collected over different substrates in the San Marcos River, Texas - September, 1991.

SUBSTRATE	DENSITY #/SQ.M.	STDEV	n
Sand	0.62	4.60	237
Silt	0.59	2.72	937
Gravel	0.32	1.60	474
Boulder	0.00	0.00	11
Clay	0.00	0.00	104
Cobble	0.00	0.00	54
Rubble	0.00	0.00	5