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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 vegetative community and depth regimes. Fountain darters, collected within these grids, were found in greatest densities in filamentous algae. The mean population estimate for the Comal River upstream of Torrey Mill Dam was 168,078 with 95% confidence limits of 114,178 and 254,110. Key words: Etheostoma fonticola; fountain darter; Comal River; Edwards Aquifer; endangered fishes.

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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 cubic feet per second (cfs; 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 in 1990, compared to a mean spring flow discharge (1933-1990) of 292 cfs (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.sup.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 five kilometers before joining with the Guadalupe River (Fig. 1). The headwaters of the river were dammed in the late 1880's (D. Whatley, pers. comm.), forming Landa Lake (about 84,280 [m.sup.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 kilometers downstream of the lake.

The physical and chemical properties of the Comal River are relatively stable; water temperature remains near 25[degrees] 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 meter intervals beginning at three random starting points--one in Landa Lake, one in the new channel, and one in the old channel (Fig. 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. Two rows of 10 [m.sup.2] cells constructed of nylon rope were stretched across the water at each transect (one on each side of the transect line) to form a sampling grid.

[FIGURE 1 OMITTED]

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

Fountain darters were sampled in each cell of transects 6, 8, 10, 11, 13, 15, and 17 in August 1990, and in each cell of transects 2, 4, 20, 22, 24, 26, 28, and 30 in June 1991 using square dip nets (0.09 [m.sup.2] and 0.37 [m.sup.2]) with 1.6 millimeter 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 estimating population size (Atkin et al., 1990). Differences in fountain darter densities among habitat types and depths were analyzed using a two-way analysis of variance 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.sup.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 preferred 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 2.7 meters and all other depths. Significant depth by plant species interaction was also observed ($P<0.0001$); but, only two observations were associated with that depth in a single plant type (Cabomba caroliniana). Consequently, we concluded that the differences were not biologicially meaningful.

The mean population estimate for the Comal River upstream of Torrey Mill Dam 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 ova throughout the year in the San Marcos River and reported two major spawning periods annually, one in August and another 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.

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TABLE 1. Estimated area ([m.sup.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	3,927	20,602
Ceratopteris thalictroides	121	244	66	431
Chara sp.	1,497	68	0	1,565
Egeria densa	0	9	0	9
Filamentous algae	1,381	14,636	372	16,389
Hydrilla verticillata	0	0	19	19
Hydrocotyle sp.	0	9	0	9
Justicia americana	1,060	1,189	9	2,258
Ludwigia sp.	7,787	17,025	8,824	33,636
Ludwigia sp./filamentous algae	0	44	2,127	2,171
Myriophyllum sp.	0	44	0	44
Nuphar luteum	1,103	154	0	1,257
Potamogeton illinoensis	949	0	1,851	2,800
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.sup.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