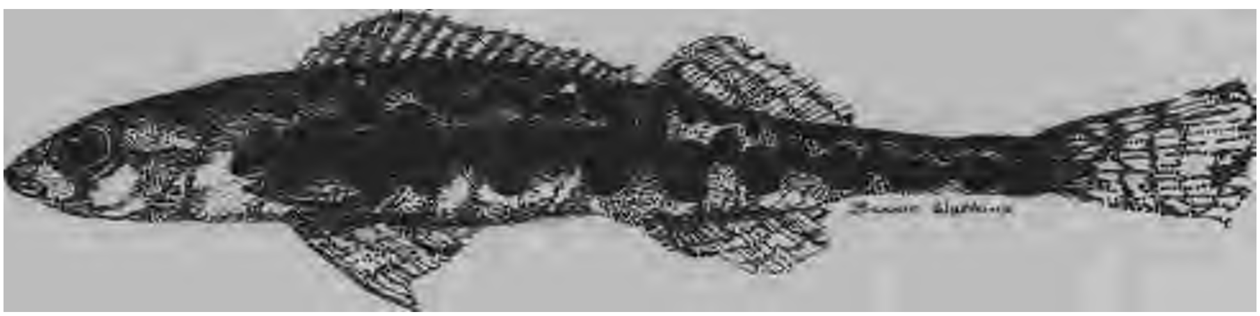
STATUS of the LEOPARD DARTER

in

OKLAHOMA and ARKANSAS



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ENDANGERED SPECIES REPORT 12

THE LEOPARD DARTER, PERCINA PANTHERINA: STATUS OF POPULATIONS IN GLOVER CREEK, McCURTAIN COUNTY, OKLAHOMA

and

COSSATOT RIVER, ARKANSAS

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EXECUTIVE SUMMARY

This report contains the results of a 2-year research project designed to obtain current information on the status of leopard darter populations (Percina pantherina) in Glover Creek, McCurtain County, Oklahoma. A one-summer study on leopard darters in the Cossatot River in Arkansas and data collected on leopard darters during a 2-year instream flow project on Glover Creek by Orth (1980) are included also.

A total of 139 leopard darters were collected in Glover Creek from August 1977 to July 1980 and 19 on the Cossatot River. Average density per 100 m. of stream was 3.64 on the Glover and 3.44 on the Cossatot. The maximum density recorded at any site on the Glover was 27 leopard darters per 100 m. of stream (.017/m) and 8 on the Cossatot (obtained by extrapolation from 100 ft. sections sampled). The total number of leopard darters in Glover Creek was estimated to be 2,827. In comparison to published density estimates of other darter species, leopard darter densities were very low. However, densities of all darter species in Glover Creek were consistently low.

Leopard darters inhabited the entire area designated as critical habitat in Glover Creek, and several locations outside the designated area. Leopard darters also were collected at several locations both inside and outside the area designated critical habitat where the species had not been captured previously. Distribution within the study area was clumped, not random. Comparison of our data with those of previous workers (1884-1972) indicated leopard darter populations are stable in Glover Creek (Robinson 1978, Taylor and Wade 1972).

Leopard darters preferred pool habitats in all seasons. Specifically, depths from 20 to 79 cm, water velocities from 0 to 19 cm/s, and substrates of rubble, rubble/boulder mixed, and boulder were the most preferred habitats.

Total lengths ranged from 45 to 92 mm with a mean and a standard deviation of 70.2 and 9.0, respectively. Based on these data and limited scale analyses, ages were assigned as follows: < mm = 0+; 51 to 71 mm = 1+; 72 to 87 mm = II+; and ≥ 88 mm = III+. Contribution to total catch by each age group was: 0+ = 1.5%; I+ = 63.5%; II+ = 32%; and III+ = 3.0%. The low number of 0+ individuals captured was unexplained.

The darter community in Glover Creek was dominated by the orangebelly darter and was composed of six additional species. The leopard darter, channel darter and logperch were the only other species, besides the orangebelly darter, that contributed significantly to the darter community.

Several methods were used to capture and/or to observe leopard darters. D.C. electrofishing equipment was used exclusively on Glover Creek, but Robison evaluated seining, underwater capture and enclosures on the river (Jones et al. 1979). Robison concluded that capture with dipnets while snorkeling was the most effective method in shallow clear sections of the Cossatot, but this method did not have general application. Therefore, since D. C. electrofishing was extremely effective for collecting leopard darters, it was used in all subsequent studies.

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CHAPTER I

INTRODUCTION

On January 27, 1978, the U.S. Fish and Wildlife Service (1978) determined the leopard darter, Percina pantherina (Plate 1), to be threatened, giving it full protection under the 1973 Endangered Species Act. At that time, several areas within the Little River system were designated as critical habitat for the leopard darter, and the U.S. Fish and Wildlife Service was given responsibility for monitoring leopard darter populations. The U.S. Fish and Wildlife Service, in cooperation with the Oklahoma Cooperative Fishery Research Unit and Oklahoma State University, fulfilled this responsibility by studying leopard darter populations from 1978 to 1980. The overall objectives of this project were to provide current information on the status of leopard darter populations and to collect data on the biology and ecology of the species.

The leopard darter is endemic to the Little River system in southeastern Oklahoma and southwestern Arkansas (Miller and Robison 1973), but previous collections indicate that the largest populations reside in Glover Creek, McCurtain County, Oklahoma (Robison 1978). Therefore, Glover Creek was selected as the principal study area (Figure 1) with an additional study area on the Cossatot River in Howard County, Arkansas (Figure 2). The following objectives were used for the Glover Creek study: 1) describe the preferred habitat, 2) estimate leopard darter numbers and densities, 3) determine the distribution of leopard darters, 4) estimate leopard darter abundance in relation to other darter species in Glover Creek, and 5) examine leopard darter population composition. The objectives for the Cossatot River study were: 1) obtain data on abundance of leopard darters, 2) examine preferred habitat of leopard darters, and 3) compare the effectiveness of several techniques for capturing and/or observing leopard darters.

From August 1977 to September 1979, Dr. Donald J. Orth,* formerly with the Oklahoma Cooperative Fishery Research Unit, estimated numbers, calculated densities and measured total lengths and habitat for fishes in Glover Creek at 74100 m.s. (m.s. designated main sites where population estimates were made and the numbers designate specific Weyerhauser access roads) and 61200 m.s. (Figure 3). Orth's data for 20 leopard darters are included in this report.

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*Dr. Donald J. Orth is presently an Assistant Professor of Fisheries in the Department of Fisheries and Wildlife Sciences at Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

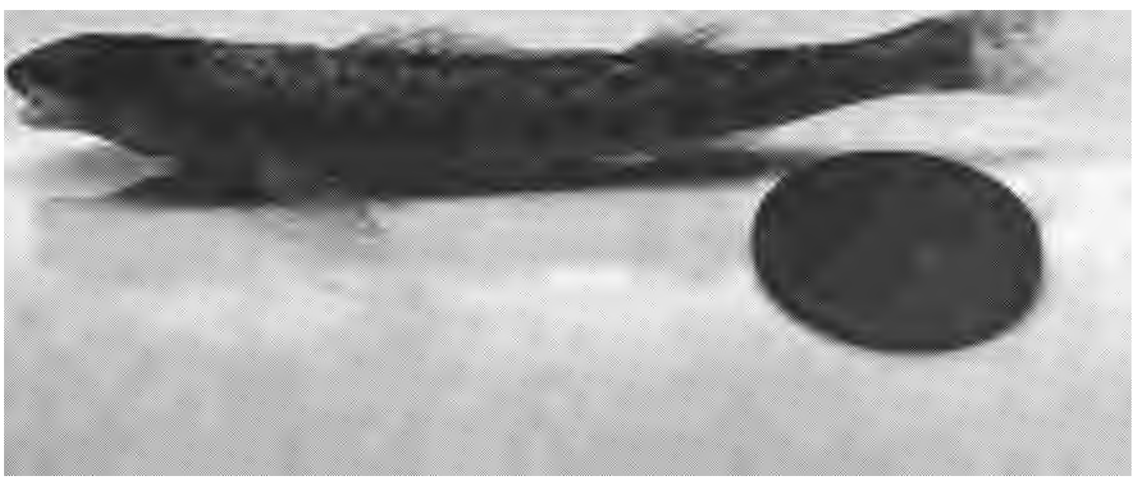

PLATE 1. Leopard darter, <u>Percina pantherina.</u> Specimen from the Oklahoma State University Museum collected from Glover Creek, Oklahoma.

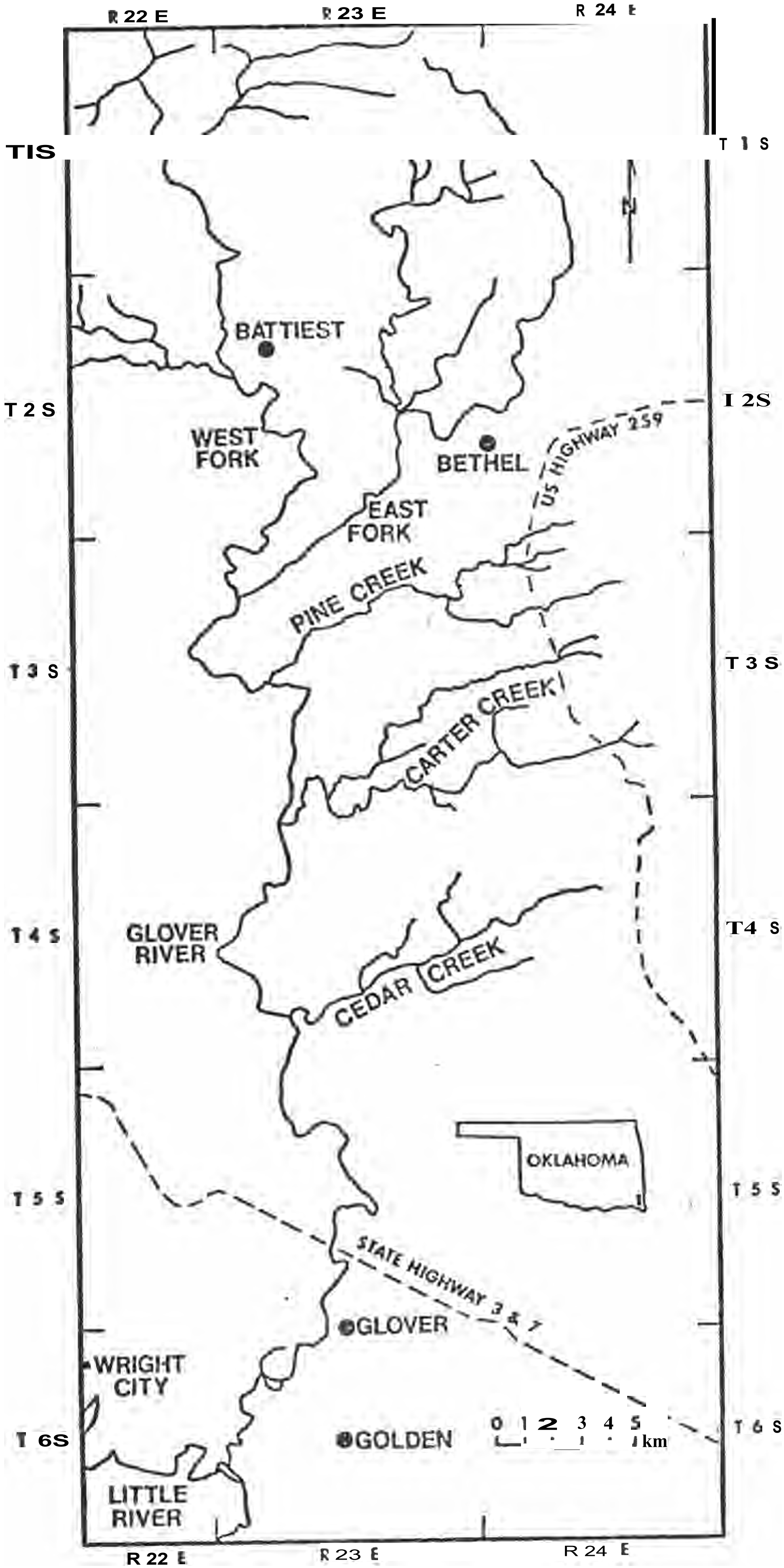

Figure 1. Glover Creek, McCurtain County, Oklahoma.

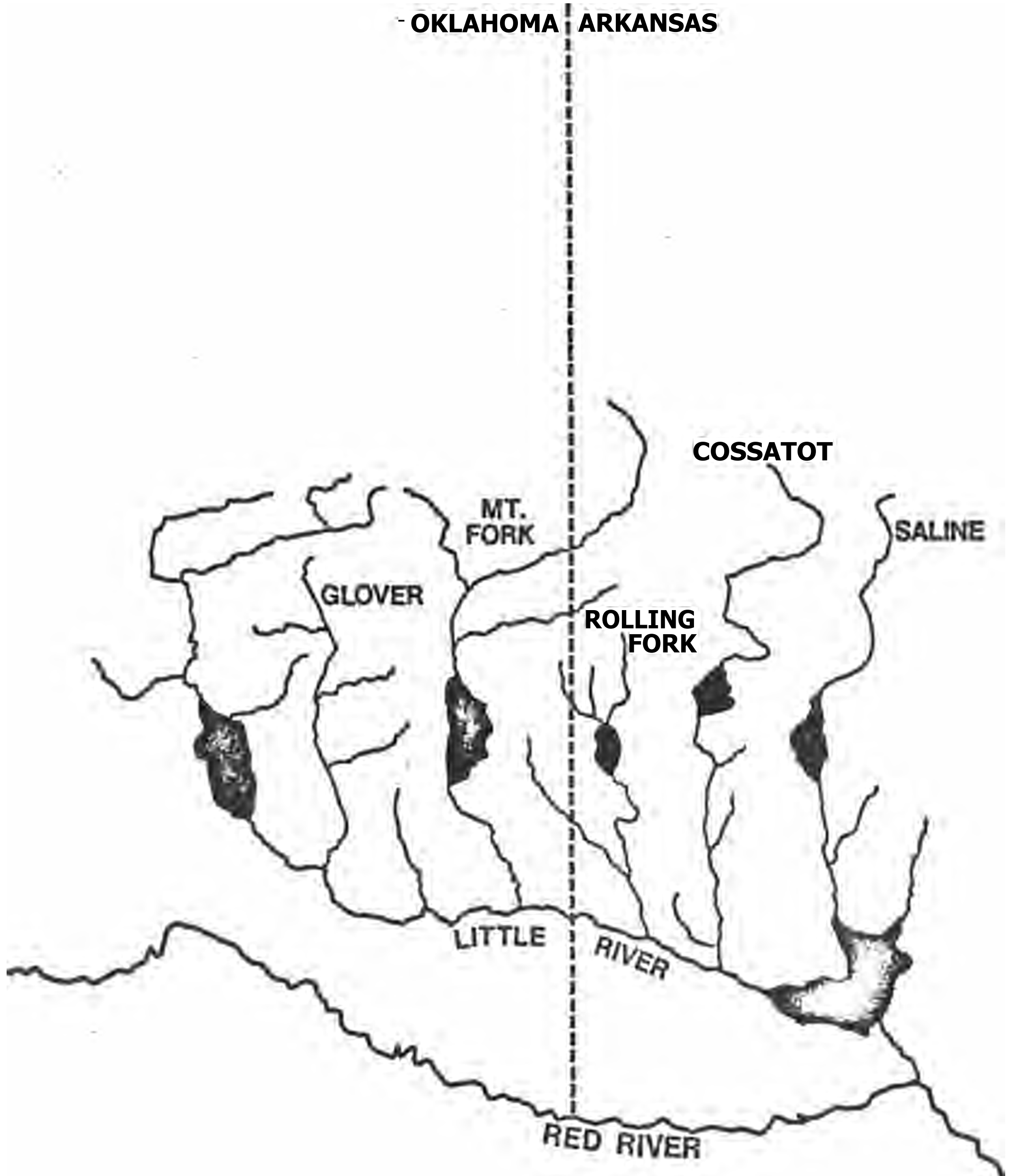

Figure 2. Little River System, Oklahoma and Arkansas.

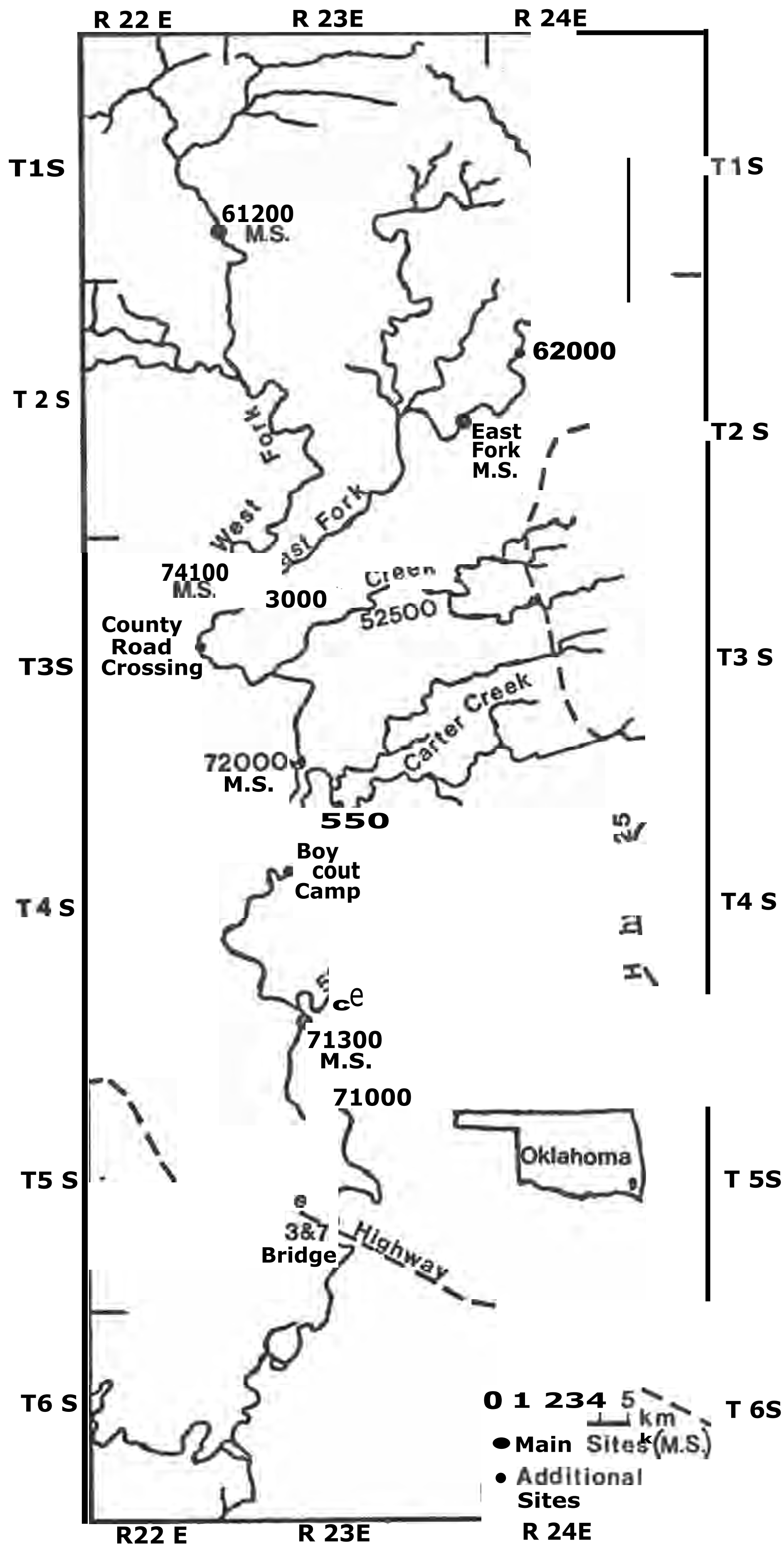

Figure 3. Glover Creek study area with sampling site locations.

CHAPTER II

DESCRIPTION OF STUDY AREAS

Glover Creek, a tributary of the Little River in McCurtain County, southeastern Oklahoma, originates in the Beaver Bend Hills subsection of the Ouachita Mountains in the vicinity of the McCurtain-LeFlore County line. The drainage basin of Glover Crgek is 56.3 km long and 32.2 km wide, an area of approximately 876 km^2. The mainstem Glover Creek, from its mouth to the confluence of the East and West Forks, is 53 km long. The lengths of the East and West Forks are 35 km and 33 km, respectively. Elevations range from 103 m, mean sea level, at the mouth to 610 m, mean sea level, in the upper reaches. The average slope is 2.3 m/km, varing from 19 m/km in the upper reaches to 1 m/km at the mouth. Other major tributaries that drain the eastern portion of the Glover Creek watershed are Pine, Carter and Cedar Creeks.

The upper reaches of Glover Creek are characterized by mountainous ridges with steep slopes heavily forested with oak and pine; only a small portion is cultivated. Commercial timber harvesting is the principal economic activity. Lower reaches of the stream are surrounded by low, fertile flatlands that enter the flood plains of the Gulf Coastal Plain. This area is devoted to livestock grazing with most of the former woodlands converted to improved pasture.

Glover Creek is the last unimpounded tributary of the Little River. Basin characteristics and annual precipitation patterns cause the lower flood plains to flood an average of three times each year (Taylor and Wade 1972). Estimated annual flood damage to agricultural development and rural structures averages $1,083,900 (Taylor and Wade 1972). Consequently, the Army Corp of Engineers, Tulsa District, proposed construction of Lukfata Lake dam for flood control and water supply. The proposed dam site was 19.3 km northwest of Broken Bow, Oklahoma, on river kilometer 39.4 of Glover Creek (Taylor and Wade 1972). However, funds were not appropriated for Lukfata Lake and the recent designation of Glover Creek as critical habitat for the leopard darter makes construction of the reservoir unlikely.

The study area for the portion of the project on Glover Creek was defined as the section designated as critical habitat for the leopard darter (Figure 4), although other areas within the drainage were sampled also. A preliminary survey of the study area was conducted in November 1978 and 15 sites were selected (Figure 3): five main sites* for estimating population sizes and densities and 10 additional sites to aid in evaluating leopard darter distribution and relative abundance.

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*Two of these main sites, located on the West Fork of Glover Creek, are study sites used by Dr. Donald J. Orth. Main sites are designated by m.s. on Figure 3.

Three criteria were used in selecting sites: 1) a uniform distribution of sites throughout the study area, 2) roads providing all-weather access, and 3) wide variability in available habitat types at each site. The legal location and a description of each site was given by Jones et al. (1979). Limited work was accomplished on the Cossatot River, and therefore only an abbreviated description of the study site is presented.

The Cossatot River study area is located in Howard County, above the fall line separating the Gulf Coastal Plain from the Ouachita Mountains. The site is a large shallow pool (110 m long, 15-18 m wide, and 0.7 m deep, plus an upstream riffle bounded downstream by a low-water bridge. The substrate varies from sand to rocks and is covered by a heavy aufwuchs community. Water willow is the predominant vegetation.

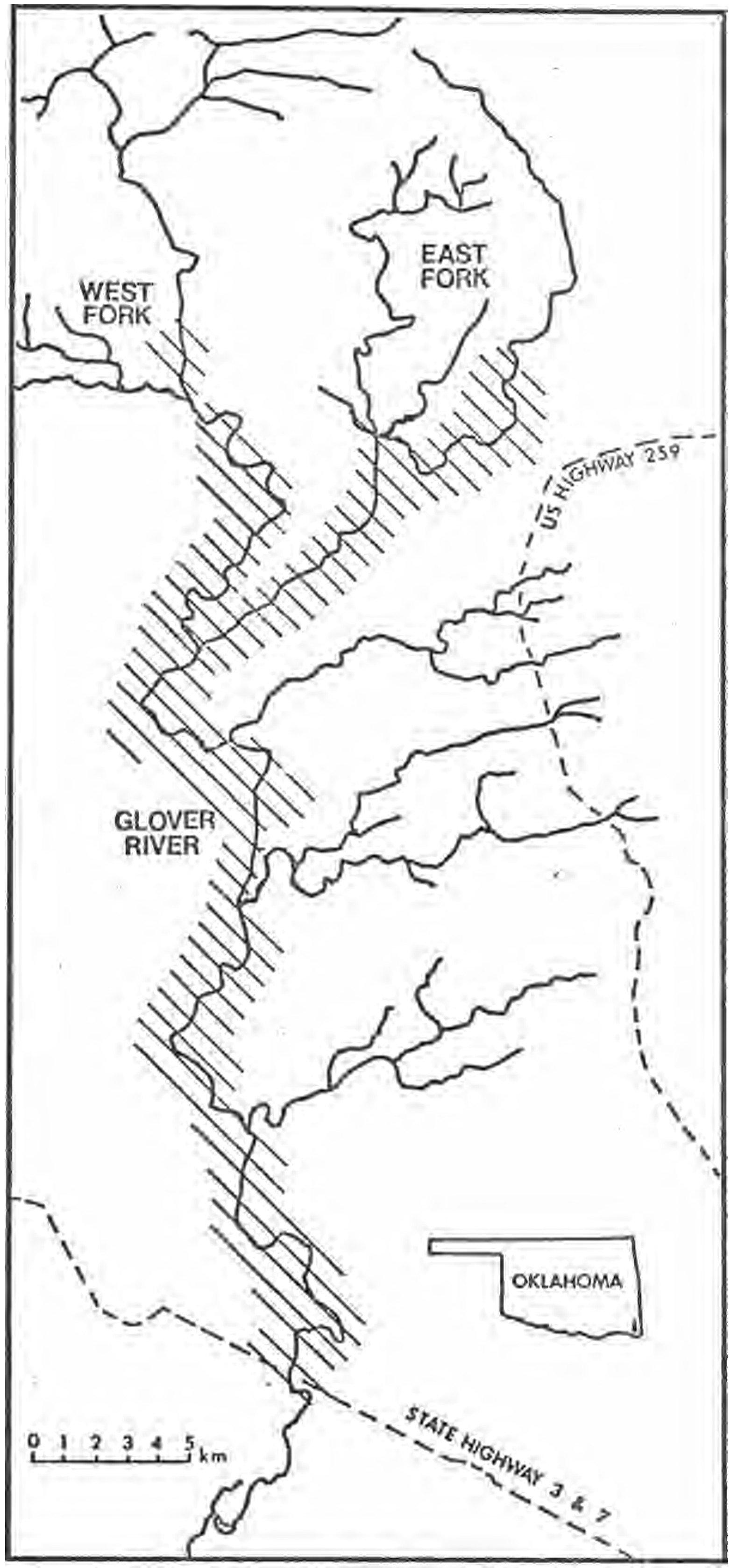

Figure 4. Designated critical habitat for the leopard darter on Glover Creek.

CHAPTER III

METHODS AND MATERIALS

Samples were collected quarterly from November 1978 to July 1980 (Appendices II, III, and IV) for Glover Creek and May-September 1979 for the Cossatot River. Although field trips were scheduled for the same time each year, high water levels caused occasional delays, especially during spring.

Population estimates were made using the depletion method (Carle and Maughan 1980) and maximum likelihood estimator (Carle and Strubb 1978). Sampling sites were enclosed completely with 30 m blocknets of 1/4-in. mesh. Darters were collected with a boatmounted, D.C. pulse, electrofishing unit equipped with two remote, handheld electrodes (Plate 2). The electrodes were used to disturb the substrate, while water currents swept stunned darters into dipnets. A unit-of-effort was one complete pass through the site, and successive passes were made to obtain a depletion. During periods of low flow, Smith-Root Type VII* backpack electrofishing units (Plate 3) were used in place of the boatmounted unit. Each of the large areas of 61200 m.s. and 74100 m.s., as used by Orth (1980), were subdivided into a pool and riffle area. Each subarea was considered distinct, and data from each subarea were analyzed separately.

Densities for each darter species were obtained by dividing the estimated number of each species by the total length of the site. Densities also were calculated at each site by dividing the estimated number of each darter species by the total surface area. The total number of leopard darters in Glover Creek was estimated by multiplying the total stream length of designated critical habitat by the average number of leopard darters per 100 m of stream.

Ten additional sites on the Glover were also sampled to aid in evaluating distribution and relative abundance. Seven sites were located within the area of critical habitat and three sites were located outside the area; one each on Pine, Carter and Cedar Creeks. These sites were not enclosed with nets during sampling and were electrofished with Smith-Root Type VII backpack units. As much area as possible was sampled within 1 to 2 hours and each habitat type was sampled in proportion to its relative abundance. The procedure consisted of shocking and disturbing the substrate in an area of 1 to 2 m while water currents swept stunned darters into dipnets held immediately downstream. The shocking unit recorded the total number of seconds that electrical current was produced and these data were used to calculate the catch per unit-of-effort for each species. Catch per unit-of-effort and percent of total catch of each species were used as indices of relative abundance. The uniformity of leopard darter distribution

*Does not constitute an endorsement.

PLATE 2. Boatmounted, D.C. pulse, electrofishing unit equipped with two remote, handheld electrodes.

PLATE 3. Smith-Root Type VII, battery powered, D.C. pulse, backpack electrofishing unit.

in Glover Creek was calculated by tabulating the total catch for each site and comparing this distribution to a uniform distribution using a chi-square goodness-of-fit test (Conover 1971). Expected catches were adjusted for differences in sampling effort between sites by multiplying the total catch times the percentage of total effort at each site.

The preferred habitat of leopard darters was determiend by quantitative methods similar to those described by Bovee and Cochnauer (1977) for the development of probability-of-use curves. According to these authors, "...biological criteria are primarily aimed at those parameters affecting fish distribution which are most directly related to stream flow, i.e., water depth, water velocity, and substrate type." (Bovee and Cochnauer 1977:1). This approach assumes that, given a range of values for each parameter, individuals of a species tend to select those areas within a stream that provide the most favorable hydraulic conditions. Once these measurements of use are obtained, the probability of encountering the species can be predicted. Data for calculating preferred habitat were obtaind by measuring the water depth, water velocity, and substrate type at each location where a leopard darter was captured. Water depth was measured with a metric wading rod; water velocity was measured at 0.6 of the depth with a Pygmy-Gurley current meter (Plate 4). Substrates were classified according to the modified Wentworth partical size scale (Appendix I) and given a numerical code from 1 to 8 (Bovee and Cochnauer 1977). Mixtures of adjacent substrate categories were given intermediate code values.

Frequency distributions of water depth, water velocity and substrate types were tabulated. The null hypothesis that leopard darters utilized each habitat parameter in proportion to its availability was tested using a chi-square goodness-of-fit test (Conover 1971:185-187). If the null hypothesis is true, occurrence will have no relationship to habitat variables and the expected frequencies should be similar to the actual observed frequencies. The relative availability of each habitat parameter was estimated by measuring the water depth, water velocity and substrate type at 1 m intervals along established transects at each main site during each sampling period. However, hydraulic simulation programs, described by Orth (1980) and Main (1978a, 1978b), were used to predict the relative availability of each habitat parameter during seasons when excessively high flows precluded actual measurements. A significance level of .10 was used to reject the null hypothesis for data which combined seasonal and annual variations. If the null hypothesis was rejected, probability-of-use curves were developed as follows: optimum range was determined by comparing actual and expected catches for each interval of the parameter (Plate 5). For intervals where actual catches exceeded expected catches, the intervals with highest relative densities were defined as the optimum. The optimum range was assigned a preference factor of 1 and preference factors for other intervals were obtained by dividing the density in the interval by the mean density in the optimum range (Orth 1980). Probability-

PLATE 4. Metric wading rod and Pygmy-Gurley current meter for measuring water depth and water velocity.

PLATE 5. Typical leopard darter habitat. Shallow, boulder-bedrock-bottomed pool located at 61200 M.S. on the West Fork of Glover Creek.

of—use curves were then drawn to fit the preference factor data. If the null hypothesis was not rejected, indicating no significant deviation from a uniform distribution, a preference factor of one was given over the entire range of the parameter used.

Initially, all leopard darters were measured (total length) to the nearest millimeter and weighed to the nearest gram. However, early in the study, weighing was discontinued because of difficulty in obtaining accurate field measurements of these small fish and to avoid prolonged handling stress. Although scales were not removed for the same reasons, 6 to 15 scales were removed from each of 14 specimens in the Oklahoma State University Museum. Scales were taken from the left side of the body, below the lateral line, just posterior to the pectoral fin as it was extended along the side of the body. Scales were mounted dry between glass slides and examined at 100x using a compound microscope. The number of annuli were counted and, in conjunction with a length frequency distribution, were used to estimate ages of leopard darters of various lengths.

Comparisons of vulnerability to sampling gear were accomplished on Glover Creek (D.C. electrofishing) and Cossatot River (underwater counts, captures and seining). Each area was seined thoroughly or darters counted or captured along measured transects on the Cossatot. Procedures on the Glover were described previously.

CHAPTER IV

RESULTS

Habitat

Water Depth

Leopard darters were captured at depths ranging from 8 to 122 cm but were most frequently present at depths from 20 to 79 cm (Table 1). Frequencies of capture among 20 cm depth intervals were significantly different ($P<.0001$) from a uniform distribution (Table 2), suggesting that leopard darters prefer certain depths. Observed frequencies were less than expected for shallow areas (0 to 19 cm) and deep areas (> 80 cm) but greater than expected for moderate depths (20 to 79 cm) (Table 2). Since relative densities between preferred depth intervals were similar (Table 1), the range of depths from 20 to 79 cm was given a preference factor of 1 (Figure 5), and other depth intervals were assigned preference factors by dividing the density in the interval by the mean density in the optimum interval (Orth 1980).

Water Velocity

Leopard darters were captured at water velocities ranging from 0 to 96 cm/s, but were present most frequently from 0 to 19 cm/s (Table 1). The frequency of capture among 20 cm/s intervals was significantly different ($P<.10$) from a uniform distribution (Table 2), and indicates that leopard darters select for a particular range of velocities. Observed frequencies were higher than expected in areas of little or no velocity (0 to 19 cm/s) and less than expected for higher velocities (> 20 cm/s) (Table 2). Therefore, a preference factor of 1 was assigned to velocities ranging from 0 to 19 cm/s (Figure 6), and other velocity intervals were assigned preference factors according to the methods of Orth (1980).

Substrate Types

Leopard darters were captured over substrates ranging from gravel/rubble (5.5) to bedrock (8.0), but were captured most frequently over rubble/boulder (6.5) (Table 1). The frequency of capture among various substrate types and mixtures was significantly different ($P<.10$) from a uniform distribution (Table 2), which shows that leopard darters select for particular substrate types. Observed frequencies were higher than expected for rubble (6.0), rubble/boulder (6.5), and boulder (7.0). Relative densities among these substrates were similar and a preference factor of 1 was assigned to these categories (Figure 5). Other substrates were assigned preference factors according to the methods of Orth (1980). Note that although no captures were made over areas having a significant proportion (> 50%) of smaller particles, small gravels and sands were frequently present in the interstices of larger substrates at capture locations.

TABLE 1. Amount of available area, frequency of capture and density of leopard darters at various depths, velocities, and substrates.

Variable and Interval	Available Area	Frequency of Capture	Relative Density
Depth (cm)			
0-19	9,133.252	9	.00098
20-39	9,582.625	48	.00501
40-59	5,925.735	34	.00573
60-79	3,467.110	26	.00750
> 80	3,540.890	14	.00395
	31,649.612	131	
	T = 37.00 (4 d.f.) P<.0001		
Velocity (cm/s)			
0-19	25,416.066	116	.00456
20-39	3,442.520	10	.00290
40-59	1,602.170	3	.00187
60-79	830.490	0	.00000
> 80	347.150	1	.00288
	31,638.396	130	
	T = 7.96 (4 d.f.) P<.10		
Substrate Type			
4.0	398.695	0	.00000
4.5	275.310	0	.00000
5.0	407.690	0	.00000
5.5	6,641.190	20	.00301
6.0	4,591.960	25	.00544
6.5	10,123.249	47	.00464
7.0	5,127.825	29	.00565
7.5	1,553.052	6	.00321
8.0	2,531.153	5	.00197
	31,650.124	131	
	T = 14.61 (8 d.f.) P<.10		

TABLE 2. Observed and expected frequencies of leopard darters over all depth, velocity and substrate intervals.

	Depth interval (cm)				
	0-19	20-39	40-59	60-79	> 80
Observed frequency	9	48	34	26	14
Expected frequency	37.8	39.6	24.5	14.3	14.6

T = 37.00 (4 d.f.) P<.0001

	Water velocity intervals (cm/s)				
	0-19	20-39	40-59	60-79	> 80
Observed frequency	116	10	3	0	1
Expected frequency	104.4	14.1	6.6	3.4	1.4

T = 7.96 (4 d.f.) P<.10

	Substrate types								
	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0
Observed frequency	0	0	0	20	25	47	29	6	5
Expected frequency	1.6	1.1	1.7	27.4	19.0	41.9	21.2	6.4	10.4

T = 14.61 (8 d.f.) P<.10

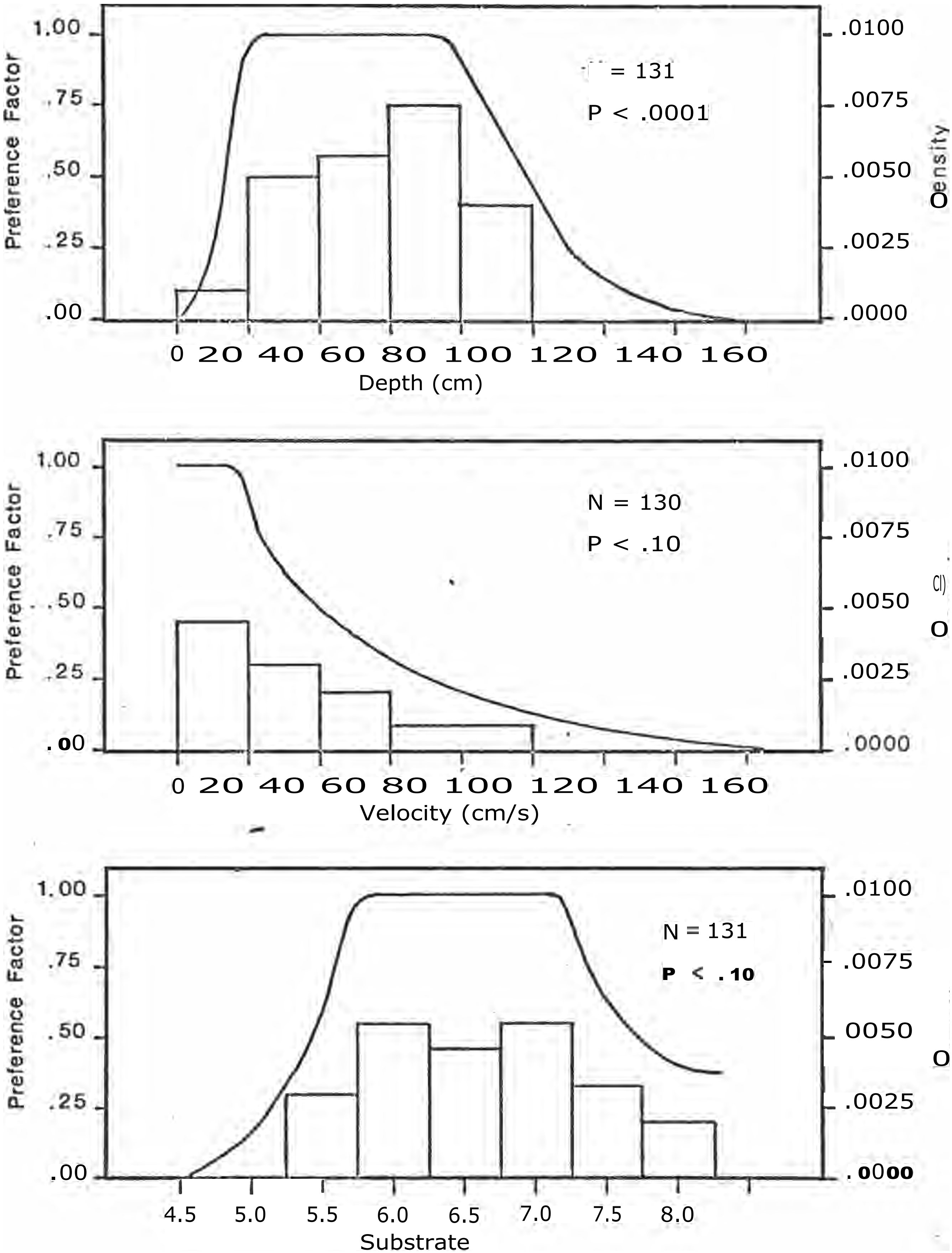

Figure 5. Relative densities of leopard darters and probability-of - use- curves for water depth, water velocity, and substrate types in Glover Creek, Oklahoma.

General Habitat

Of 139 total captures, 108 were in pools, 19 in riffles, and 11 in runs (Table 3). Of 19 captures made in riffles, 13 occurred during spring, 5 during winter, and 1 during fall. Of 11 captures made in runs, 8 were made during winter, 2 during spring, and 1 during fall. Pools were the only major habitat type occupied by leopard darters during summer, although absence of other habitats during this season severely limited availability of other habitat types. However, leopard darters were captured in pools (Plate 5) most often (64 to 89%) regardless of season or availability of other habitat types.

Seasonal Variation

The range of depths utilized by leopard darters varied somewhat between seasons (Table 4). During winter and spring, leopard darters occupied a wider range of depths than during summer and fall. Relative densities during winter were higher in moderately deep areas (60 to 89 cm). In spring, however, frequency of capture and relative densities formed a distinct bimodal distribution with peaks occurring in moderately shallow areas (10 to 39 cm) and moderately deep areas (60 to 89 cm). During summer, leopard darters inhabited shallow areas (0 to 29 cm) less than during spring and used deeper areas (60 to 89 cm) less than during winter. During fall, leopard darters utilized a narrower range of depths than during other seasons and tended to avoid deeper areas (> 70 cm) more than in summer, despite similar availability in depths during fall and summer. However, these data clearly indicate that seasonal differences in depth utilization do not constitute a major deviation (except for spring) from the curve developed for combined data.

Utilization of water velocity also varied somewhat between seasons (Table 5). During summer and fall, leopard darters utilize only those areas with little or no measureable velocity (0 to 19 cm/s), although areas with higher velocities were available, especially in fall. These observations closely agree with preference factors for combined data. On the other hand, relative densities were much higher in areas with greater velocity (> 20 cm/s) during winter and spring than from combined data. However, areas with higher velocities were more available during these seasons.

Utilization of substrate by leopard darters differed slightly between seasons (Table 6). Relative densities tended to be higher over smaller substrates (5.5 to 6.5) during spring and winter and higher over larger substrates (6.5 to 7.5) during summer and fall. However, these data again constitute only a minor deviation from the combined results.

Yearly Variation

Fluctuations in leopard darter abundance occurred during the 3 years of sampling. Total seasonal catch was relatively low, but constant, from August 1977 through June 1979, increased dramatically from August 1979 to

TABLE 3. Number of leopard darters captured in each general habitat type during each season (summarized from Appendix II).

Season	Frequency of capture: Pool	Riffle	Run	Total
Fall	16	1	1	18
Winter	37	5	8	50
Spring	27	13	2	42
Summer	29	0		29
Total	109	19	11	139

TABLE 4. Relative densities of leopard darters in each 10 cm depth interval for each season.

Depth interval (cm)	Area (m^2)	Frequency of capture	Relative density (n/m^2)
	FALL		
0-9	947.783	1	.00105
10-19	1,053.147	1	.00094
20-29	812.050	4	.00492
30-39	745.260	4	.00536
40-49	597.850	2	.00334
50-59	477.270	1	.00209
60-69	315.370	2	.00634
70-79	298.570	0	.00000
80-89	151.780	0	.00000
90-99+	126.280	0	.00000
	5,524.93		
	WINTER		
0-9	768.555	0	.00000
10-19	1,018.425	1	.00098
20-29	1,428.230	3	.00210
30-39	1,716.350	9	.00524
40-49	1,073.315	10	.00931
50-59	781.960	5	.00639
60-69	432.520	6	.01387
70-79	505.880	4	.00790
80-89	565.780	4	.00706
90-99+	1,070.870	4	.00373
	9,364.23		

TABLE 4. Cont.

Depth interval (cm)	Area (m^2)	Frequency of capture	Relative density (n/m^2)
	SPRING		
0-9	721.905	1	.00138
10-19	1,385.315	5	.00361
20-29	1,636.925	10	.00611
30-39	1,677.170	9	.00536
40-49	1,054.980	1	.00095
50-59	895.380	3	.00335
60-69	489.140	4	.00818
70-79	544.490	5	.00918
80-89	560.490	3	.00535
90-99+	823.940	0	.00000
	9,789.74		
	SUMMER		
0-9	1,921.028	0	.00000
10-19	1,317.098	0	.00000
20-29	944.490	4	.00423
30-39	622.150	5	.00803
40-49	482.740	10	.02071
50-59	562.240	2	.00355
60-69	501.790	4	.00797
70-79	377.350	1	.00265
80-89	180.150	0	.00000
90-99+	61.600	3	.04870
	6,970.69		

TABLE 5. Relative densities of leopard darters in each 10 cm/s water velocity interval for each season.

Velocity intervals (cm/s)	Area (m^2)		Relative density (n/m^2)
	FALL		
0-9	4,631.916	14	.00302
10-19	363.240	1	.00275
20-29	124.950	0	.00000
30-39	129.650	0	.00000
40-49	64.390	0	.00000
50-59	34.520	0	.00000
60-69	87.790	0	.00000
70-79	31.350	0	.00000
80-89	25.350	0	.00000
90-99+	33.680	0	.00000
	5,524.93		

TABLE 5. Cont.

Velocity intervals (cm/s)	Area (m^2)		Relative density (n/m^2)
	WINTER		
0-9	4,968.690	31	.00623
10-19	1,725,555	7	.00669
20-29	1,045.550	4	.00382
30-39	454.110	2	.00440
40-49	351.540	2	.00568
50-59	235.210	0	.00000
60-69	171.030	0	.00000
70-79	180.450	0	.00000
80-89	145.730	0	.00000
90-99+	79.000	0	.00000
	9,364.23		
	SPRING		
0-9	5,341.405	29	.00543
10-19	1,706.730	6	.00351
20-29	828.050	2	.00241
30-39	656.100	2	.00305
40-49	397.380	0	.00000
50-59	444.150	1	.00225
60-69	254.310	0	.00000
70-79	105.560	0	.00000
80-89	37.730	0	.00000
90-99+	14.590	1	.06854
	9,789.74		
	SUMMER		
0-9	6,323.940	28	.00440
10-19	354.590	0	.00000
20-29	204.110	0	.00000
30-39	63.800	0	.00000
40-49	11.200	0	.00000
50-59	0.000	0	.00000
60-69	0.000	0	.00000
70-79	0.000	0	.00000
80-89	0.000	0	.00000
90-99+	13.070	0	.00000
	6,970.69		

TABLE 6. Relative density of leopard darters in each substrate type for each season.

Substrate	Area	C	Relative density (n/m^2)
	FALL		
4.0	51.870	0	.00000
4.5	72.220	0	.00000
5.0	19.510	0	.00000
5.5	1,648.950	3	.00181
6.0	824.550	1	.00121
6.5	1,526.415	9	.00589
7.0	578.210	0	.00000
7.5	252.867	2	.00790
8.0	551.260	0	.00000
	5,524.93		
	WINTER		
4.0	126.250	0	.00000
4.5	88.450	0	.00000
5.0	174.050	0	.00000
5.5	1,954.920	7	.00358
6.0	1,451.645	9	.00619
6.5	3,013.990	20	.00663
7.0	1,311.295	8	.00610
7.5	568.360	0	.00000
8.0	675.905	2	.00296
	9,364.23		
	SPRING		
4.0	175.115	0	.00000
4.5	96.520	0	.00000
5.0	179.180	0	.00000
5.5	1,958.190	6	.00306
6.0	1,420.915	11	.00774
6.5	3,017.710	8	.00265
7.0	1,886.315	11	.00583
7.5	377.315	2	.00530
8.0	677.285	3	.00443
	9,789.74		

TABLE 6. Cont.

Substrate	Area		Relative density (n/m²)
	SUMMER		
4.0	45.460	0	.00000
4.5	18.120	0	.00000
5.0	34.950	0	.00000
5.5	1,079.130	4	.00370
6.0	894.850	3	.00335
6.5	2,565.134	10	.00340
7.0	1,352.005	10	.00739
7.5	354.690	2	.00564
8.0	626.703	0	.00000
	6,970.69		

TABLE 7. Total catch of leopard darters at main sites for each season from November 1977 to July 1980 (summarized from Table 9).

Season	Total catch				Total
	1977	1978	1979	1980	
Winter		4	5	17	26
Spring		5	2	18	25
Summer		5	13	3	21
Fall	3	2	7		12
Total	3	16	27	38	84

TABLE 8. Total catch of leopard darters at additional sites for each season from November 1978 to July 1980 (summarized from Appendix III).

Season	Total catch			Total
	1978	1979	1980	
Winter		3	21	24
Spring		1	16	17
Summer		1	4	5
Fall	2	4		6
Total	2	9	41	52

Table 9. Population estimates and densities of leopard darters during November 1977 to July 1980.

Sampling period/ date	Site	C	N	95% C.I.	Std. error	Area of site (m^2)	Length of site (m)	Density (m^{-2})	Density (Ha)	Density (N/100 m)
*Fall 1977										
15 Nov.	61200 m.s.(P)	0	–	–	–	631	45.3	–	–	
16 Nov.	74100 m.s.(P)	2	2	2.4- 4.1	1.05	892	44.5	.0022	22	4.50
10 Dec.	71300 m.s.	1	1	1.0- 1.0	0.00	450	41.3	.0022	22	2.42
10 Dec.	74100 m.s.(R)	0	–	–	–	580	42.3	–		
*Winter 1978										
10 Jan.	74100 m.s.(P)	4	4	4.0- 6.9	1.48	884	44.5	.0045	45	9.00
11 Jan.	74100 m.s.(R)	0				545	42.3			
12 Jan.	71300 m.s.	0				344	41.3			
*Spring 1978										
9 Apr.	61200 m.s.(P)	0	–	–	–	664	45.3	–	–	–
10 Apr.	74100 m.s.(P)	2	2	2.0- 2.8	0.38	941	44.5	.0021	21	4.50
16 Apr.	74100 m.s.(R)	3	3	3.0- 5.5	1.27	707	42.3	.0042	42	7.00
17 Apr.	61200 m.s.(R)	0	–	–	–	429	41.0	–		
*Summer 1978										
12 July	61200 m.s.(R)	0	–	–	–	97	41.0	–		
13 July	74100 m.s.(R)	0	–	–	–	269	42.3	–		
20 July	74100 m.s.(P)	0	–	–	–	787	44.5	–		
21 July	61200 m.s.(P)	5	5	5.0- 5.3	0.16	620	45.3	.0080	80	11.00
*Fall 1978										
**15 Oct.	74100 m.s.(P)	2	2	2.0- 2.8	0.38	615	44.5	.0032	32	4.50
**16 Oct.	61200 m.s.(P)	0	–	–	–	620	45.3	–		
**21 Oct.	74100 m.s.(R)	0	–	–	–	185	42.3	–		
**23 Oct.	61200 m.s.(R)	0	–	–	–	97	41.0	–		

Table 9. Continued.

Sampling period/ date	Site			95% C.I.	Std. error	site (m^2)	site (m)	Density (m^2)	(Ha)	(N/100 m)
Winter 1979										
** 4 Jan.	61200 m.s.(R)	0	–	–	–	488	41.0	–		
7 Jan.	East Fork m.s.	2	2	2.0- 2.0	0.00	322	31.02	.0062	62	6.44
** 9 Jan.	74100 m.s.(P)	0	–	–	–	947	44.5	–	–	–
**10 Jan.	74100 m.s.(R)	1	1	1.0- 2.4	0.73	748	42.3	.0013	13	2.36
**12 Jan.	61200 m.s.(P)	2	2	2.0- 6.6	2.32	669	45.3	.0030	30	4.40
Spring 1979										
**28 Apr.	61200 m.s.(R)	1	1	1.0- 2.4	0.73	488	41.0	.0020	20	2.43
**29 Apr.	61200 m.s.(P)	1	1	1.0- 3.3	1.16	667	45.3	.0015	15	2.20
**12 Jun.	74100 m.s.(P)	0	–	–	–	931	44.5	–		
**13 Jun.	74100 m.s.(R)	0	–	–	–	693	42.3	–		
15 Jun.	East Fork m.s.	0	–	–	–	265	31.02	–		
Summer 1979										
18 Jul.	East Fork m.s.	0	–	–	–	210	31.02	–	–	–
20 Aug.	71300 m.s.	0	–	–	–	301	41.30	–	–	–
21 Aug.	72000 m.s.	1	1	1.0- 1.0	0.00	743	34.6	.0013	13	2.90
**22-23 Aug.	74100 m.s.(R)	0	–	–	–	533	42.3	–	–	
**24 Aug.	61200 m.s.(R)	0	–	–	–	275	41.0	–	–	
** 1 Sept.	61200 m.s.(P)	1	1	1.0- 3.3	1.16	648	45.3	.0015	15	2.20
** 2 Sept.	74100 m.s.(P)	11	12	11.0-17.4	2.73	896	44.5	.0134	134	26.96
Fall 1979										
20 Oct.	72000 m.s.	2	2	2.0- 5.2	1.64	828	34.6	.0024	24	5.80
21 Oct.	71300 m.s.	0	–	–			41.3	–		
22 Oct.	74100 m.s.(P)	5	5	5.0- 5.9	0.44	825	44.5	.0060	60	11.23
27 Oct.	61200 m.s.(R)	0	–	–	–	233	41.0	–	–	–
28 Oct.	61200 m.s.(P)	0	–	–	–	654	45.3	–	–	–
10 Nov.	East Fork m.s.	0	–	–	–	205	31.02	–		

Table 9. Continued.

Sampling period/ date	Site	C	N	95% C.I.	Std. error	site (m^2)	site (m)	Density		
									(Ha)	(N/100 m)
Winter 1980										
4 Jan.	East Fork m.s.	2	2	2.0- 4.0	1.03	280	31.02	.0071	71	6.44
5 Jan.	61200 m.s.(P)	11	11	11.0-12.1	0.57	663	45.3	.0165	165	24.30
23 Feb.	61200 m.s.(R)	4	4	4.0- 4.0	0.00	351	41.0	.0113	113	9.75
24 Feb.	74100 m.s.(P)	0	-	-	-	931	44.4			
Spring 1980										
8 Mar.	East Fork m.s.	1	1	1.0- 5.3	2.10	234	31.02	.0043	43	3.22
9 Mar.	61200 m.s.(R)	6	6	6.0- 6.7	0.37	352	41.0	.0170	170	14.63
10 Mar.	61200 m.s.(P)	5	7	5.0-22.0	7.65	677	45.3	.0103	103	15.45
11 Mar.	74100 m.s.(P)	6	6	6.0- 6.7	0.37	928	44.5	.0064	64	13.48
Summer 1980										
15 Jul.	61200 m.s.(P)	3	3	3.0- 3.0	0.00	654	45.3	.0045	45	6.62
16 Jul.	61200 m.s.(R)	0	-	-	-	205	41.0			
17 Jul.	East Fork m.s.	0	-	-	-	149	31.02			
18 Jul.	71300 m.s.	0	-	-	-	202	41.3			
19 Jul.	74100 m.s.	0	-	-	-	725	44.5			
20 Jul.	72000 m.s.	0	-	-	-	155	34.6			

*Population estimates conducted by Orth (1980).

**Population estimates conducted in conjunction with Orth.

March 1980, and decreased to former levels in July 1980 (Tables 7 and 8). Seventy-one percent of leopard darters captured from August 1977 to July 1980 were taken during four consecutive samples from August 1979 to March 1980.

Population Estimates and Densities

A total of 56 population estimates were made from November 1977 to July 1980: 41 at main sites on the West Fork, 7 on the East Fork, and 8 at main sites on the mainstem. A total of 84 leopard darters were captured during population estimates and 25 of the estimates (44.6%) were greater than 0. The maximum estimate for any site was 12. Densities ranged from 0 to 27 leopard darters per 100 m of stream. (0 to .0170/m) (Table 9) on the Glover and up to 8 leopard darters per 100 m of stream on the Cossatot (Table 10). Mean densities for the East Fork, West Fork and mainstem were estimated to be 805, 1,254 and 786, respectively, or 2,827 total.

Distribution

From August 1977 to July 1980, a total of 139 leopard darters were captured in Glover Creek (Appendix II) and 19 were observed on the Cossatot from May-September 1970. The only site where leopard darters were not captured was Cedar Creek (Figure 6). The distributions of leopard darters among main sites (Table 11) and among the additional sites (Table 12) were both significantly different from a uniform distribution ($P<.025$ and $P<.0001$, respectively). Comparison of actual and expected catches (based on the assumption of uniform distribution) showed concentrations of leopard darters at sites 61200 and 74100 (Table 11) and sites 71300, 71000, and 72000 (Table 12).

Population Composition

A total of 139 leopard darters were captured from August 1977 to July 1980 and 137 were measured for total length (Appendix II). Total lengths ranged from 45 to 92 mm with a mean and standard deviation of 70.2 and 9.0, respectively (Figure 7). Evaluation of museum specimens from previous studies showed that these fish were 1 or 2 years old. Leopard darters determined to be 1 year old ranged from 53 to 74 mm (TL) and those determined to be 2 years old ranged from 74 to 80 mm (TL) (Table 13). Based on these results and comparisons with the length frequency distribution (Figure 7), ages were assigned to the following length groups: < 50 mm = 0+, 51 to 71 mm = 1+, 72 to 87 mm = 2+, and < 88 mm = 3+. The percentages of the total catch contributed by each age groupwere as follows: 0+ = 1.5%, 1+ = 63.5%, 2+ = 32%, and 3+ = 3.0%.

Relative Abundance

Total catches of darters at the main sites (Appendix IV) and those at additional sites (Appendix III) were used to evaluate the abundance of leopard darters in relation to other darter species in Glover Creek. Results are presented separately because of differences in techniques and effort.

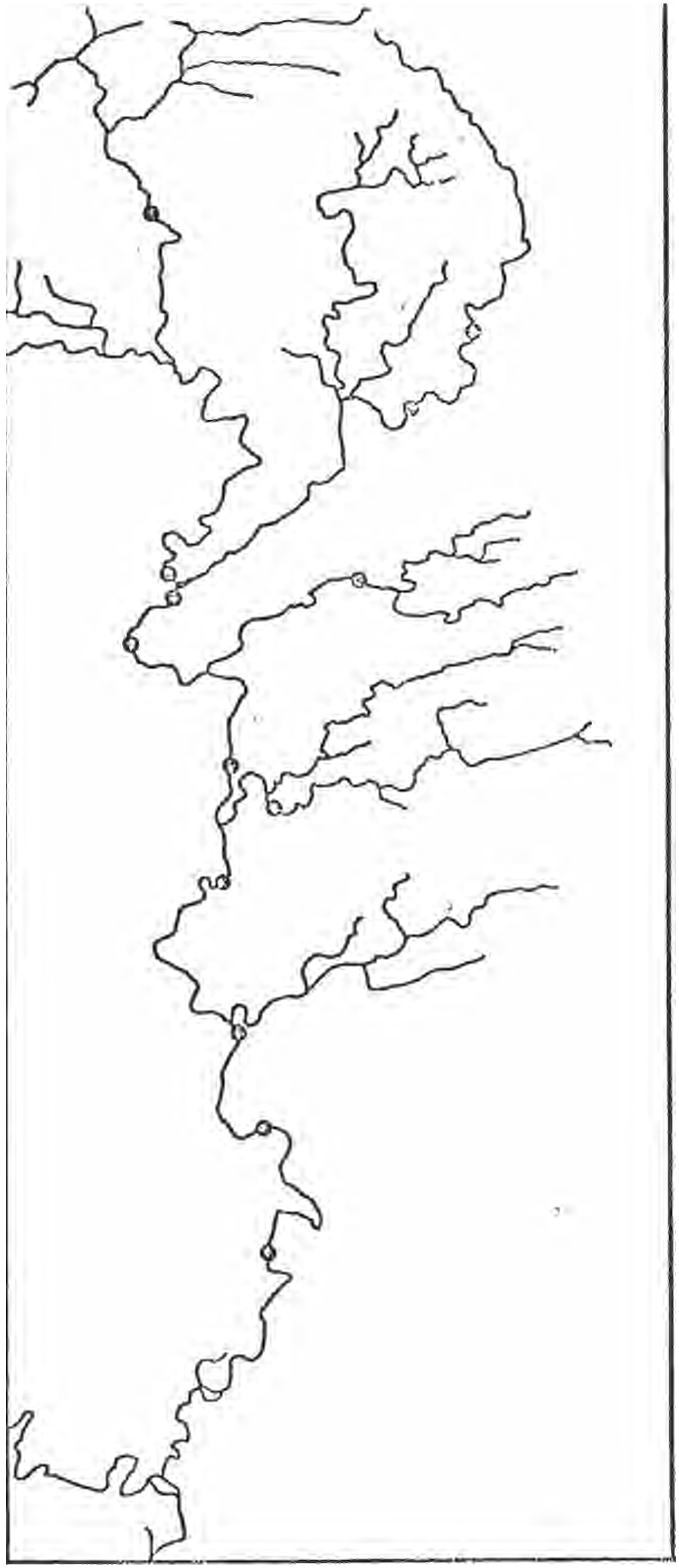

Figure 6. Leopard darter capture locations in Glover Creek from November 1977 to July 1980.

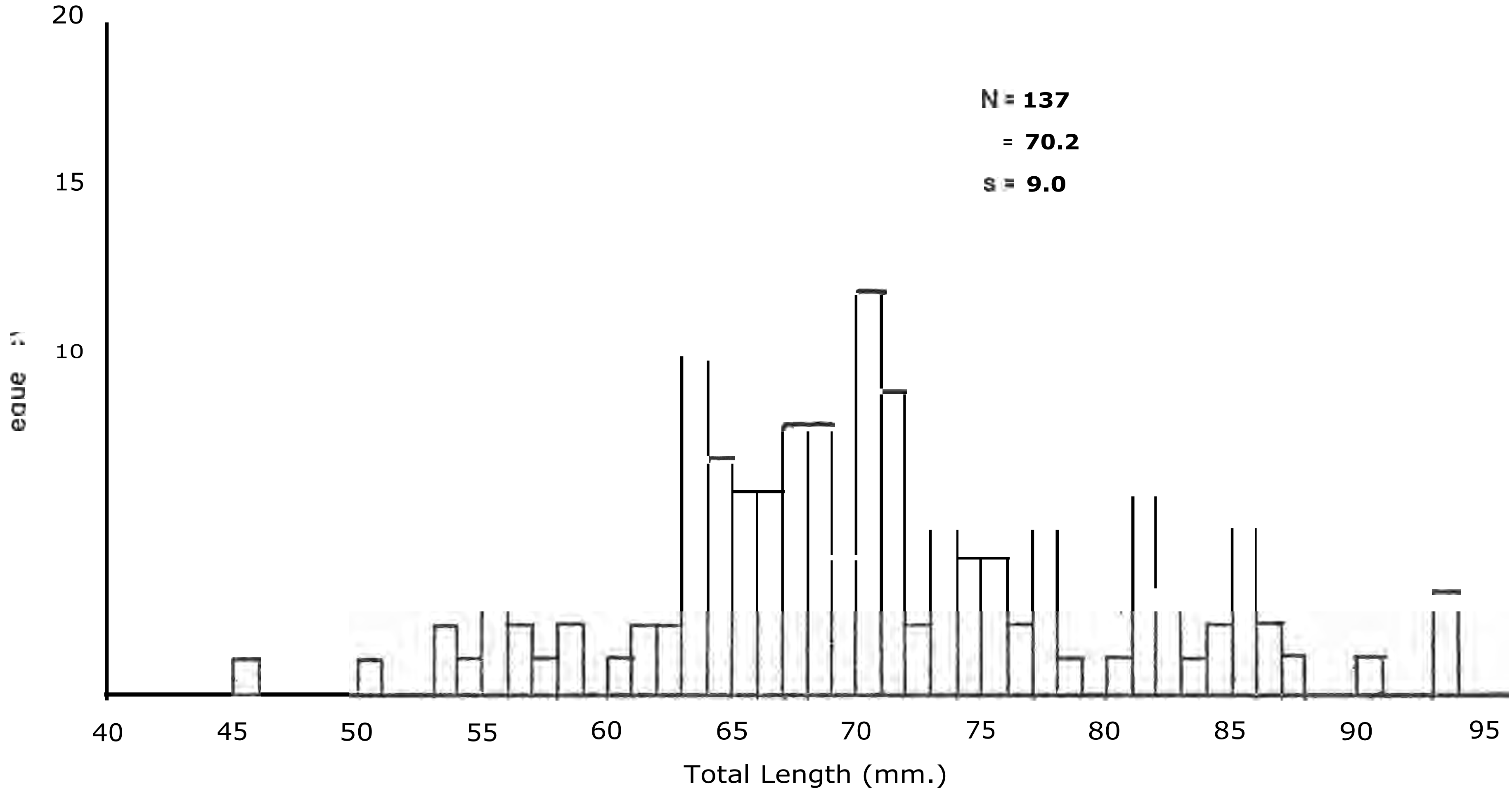

Figure 7. Length frequency distribution of leopard darters in Glover Creek, Oklahoma.

TABLE 10. Number of leopard darters observed per 100 ft. of stream and per hour of observation at the Highway 4 Cossatot River site.

Location and date	# observed	#/100 ft.	#/hour
Cossatot River			
5/18/79	4	0.67	1.00
8/11/79	14	2.33	3.50
9/1/79	1	0.17	0.33
Total and average	19	1.05	1.90

TABLE 11. Number and frequency of population estimates, actual total catch of leopard darters and expected total catch of leopard darters (assuming a uniform distribution) for each main site sampled from November 1977 to July 1980 (summarized from Appendix IV).

Site	estimates	f(estimates)	Total catch	Total e(catch)
East Fork m.s.	7	.125	5	10.5
61200 m.s.	21	.375	39	31.5
74100 m.s.	20	.357	36	29.98
72000 m.s.	3	.053	3	4.45
71300 m.s.	5	.089	1	7.47

X^2 = 11.95 T<.025

TABLE 12. Total catch of leopard darters, total sampling effort, frequency of sampling effort and expected total catch of leopard darters (assuming a uniform distribution) for sites sampled from November 1978 to July 1980 using backpack shocker (summarized from Appendix III).

Site	Effort(hrs)	f(effort)	Catch	E(Catch)
Cedar Creek	3.287	.088	0	4.57
3+7 Bridge	4.109	.111	3	5.77
East Fork 62000	3.126	.084	5	4.37
County Rd. Crsg.	3.478	.094	3	4.88
71300	3.531	.095	10	4.94
71000	3.197	.086	8	4.47
53300	4.771	.130	3	6.76
Carter Creek	3.132	.084	3	4.37
Pine Creek	3.104	.084	1	4.37
Boy Scout Camp	3.607	.097	2	5.04
72000	1.650	.045	14	2.34

X^2 = 79.74 T<.0001

Main Sites

A total of 4,614 orangebelly darters (Etheostoma radiosum), 1 johnny darter (E. nigrum), 73 logperch (Percina caprodes), 65 channel darters (P. copelandi), and 84 leopard darters were captured at main sites from November 1977 to July 1980 (Table 14). Orangebelly darters, logperch and leopard darters were captured at every main site, channel darters were taken at sites on the West Fork and East Fork and the johnny darter was taken on the West Fork (Figure 3). Orangebelly darters comprised approximately 95% of the total catch and leopard darters were the second most frequently captured species. Overall, total catch and frequency of capture for leopard darters, logperch and channel darters were similar (Table 14). However, total catch and frequency of capture between years varied considerably for these three species. Logperch were most abundant the first year, channel darters the second year and leopard darters the third year.

Additional Sites

A total of 3,622 orangebelly darters, 13 johnny darters, 28 orangethroat darters (E. spectabile), 21 logperch, 40 channel darters, 9 dusky darters (P. sciera) and 52 leopard darters were collected from November 1978 to July 1980 (Table 15 and Appendix III). Orangebelly darters were captured at every site, leopard darters at every site except Cedar Creek, logperch and channel darters at six sites, johnny darters at three sites and orangethroat and dusky darters at one site.

The orangebelly darter was most abundant overall, comprising about 95% of the total catch and leopard darters were captured the next most frequently overall. However, total catch and frequency of catch of species other than orangebelly darters varied between years (Table 15). Channel darters were most abundant the first year while leopard darters and logperch were second most abundant. Conversely, leopard darters were most abundant the second year while abundance of orangethroat, channel and logperch darters followed in descending order (Table 15).

Absolute catch and total effort also varied from year to year. Total effort was higher the second year than the first year, probably because lower water levels during the fall, winter and spring allowed us to electrofish a larger area. Total catch was also higher the second year. The increase in total catch reflected either a real population increase or increased sampling efficiency because catch per unit effort and frequency of catch also increased.

TABLE 13. Ages at various lengths for leopard darters examined from the Oklahoma State University Museum.

Date	Total length (mm)	Age (number annuli)
June 1972	62	1+
	66	1+
	70	1+
	70	1+
	71	1+
	74	1+
	74	2+
	78	2+
	80	2+
April 1979	53	1+
	78	2+
September 1979	62	1+
March 1980	68	1+
	80	2+

TABLE 14. Total number and frequency of capture of each darter species collected at main sites from November 1977 to July 1980 (summarized from Appendix IV).

	1977-1978		1978-1979		1979-1980		Total	
Species	Catch	Freq.	Catch	Freq.	Catch	Freq.	Catch	Freq.
E. radiosum	350	.866	2,405	.969	1,859	.959	4,614	.954
E. nigrum	1	.002	0	.000	0	.000	1	.001
P. caprodes	22	.054	22	.008	25	.013	73	.015
P. copelandi	14	.034	33	.013	9	.004	65	.013
P. pantherina	17	.042	22	.008	45	.023	84	.017

TABLE 15. Total catch, total effort, catch per unit-of-effort and relative frequency for darter species collected at additional sites from November 1978 to July 1980 (summarized from Appendix III).

Sampling period	Species	c(n)	f(hrs)	c/f(n/hr)	Rel. freq.
Fall 1978 - Summer 1979					
	E. radiosum	892	13.852	64.40	.960
	E. nigrum	2	16.915	.12	.002
	E. spectabile	3	16.915	.18	.003
	P. caprodes	7	16.915	.41	.007
	P. copelandi	17	16.915	1.00	.018
	P. pantherina	7	16.915	.41	.007
	P. sciera	1	16.915	.06	.001
Fall 1979- Summer 1980					
	E. radiosum	2,730	18.712	145.90	.956
	E. nigrum	11	19.820	.55	.005
	E. spectabile	25	19.820	1.26	.009
	P. caprodes	14	19.820	.71	.005
	P. copelandi	23	19.820	1.16	.008
	P. pantherina	45	19.820	2.27	.015
	P. sciera	8	19.820	.40	.003
Totals					
	E. radiosum	3,622	32.564	111.20	.956
	E. nigrum	13	36.735	.35	.003
	E. spectabile	28	36.735	.76	.007
	P. caprodes	21	36.735	.57	.005
	P. copelandi	40	36.735	1.10	.010
	P. pantherina	52	36.735	1.42	.013
	P. sciera	9	36.735	.24	.002

CHAPTER V

DISCUSSION

Sampling Techniques

The absence or reduction of the swim bladder in darters has led some authors to conclude that shocking is not an effective method of capture (Lachner et al. 1950). Consequently, most authors have evaluated populations with intensive seining (Page and Smith 1970, 1971; Page 1974, 1975; Burr and Page 1978). Intensive seining may be effective in riffle habitat where the substrate can be kicked and water currents carry darters into the net, but did not prove effective in pool areas where larger, boulder substrates predominated and there was no effective water current. In 1979, Robison evaluated the effectiveness of seines (3.1 m mesh of lengths 3.04 m, 4.56 m and 6.08 m), underwater observations and counts and underwater capture with dipnets. No leopard darters were captured with seines, probably because of net avoidance over rocky substrate. Underwater capture was the most effective of the other two methods because this technique eliminated the possibility of counting a darter more than once. However, the technique was limited to periods of low flow and in locations with high water clarity. Such conditions are not present during many seasons and locations where leopard darters may occur. During 1977 and 1979, the Oklahoma Unit sampled leopard darters with D.C. electrofishing equipment. This technique allowed sampling over a broader range of environmental conditions than snorkeling and did not reveal significantly different population levels. Therefore, because of the limitations of underwater techniques we employed only D.C. electrofishing combined with substrate disturbance for most of the study. Although our technique was effective in riffle habitats, several difficulties were encountered in pools. Slow water currents did not move stunned darters and capture required that darters be seen as they rolled over on the substrate. However, leopard darters occasionally showed a tendency to swim up to the electrodes in response to the electrical field. Also, efficiency in pools was affected by reduced visibility during periods of increased turbidity after hard rains, or increased surface turbulence on windy days. In addition, areas deeper than 120 cm and moderately deep areas (> 80 cm) with fast current (> 200 cm/s) were difficult to negotiate. We could not eliminate totally these biases.

Based on these evaluations, snorkeling and D.C. electrofishing appeared to be the most effective methods for capturing and/or observing leopard darters. Snorkeling may be effective at greater depth than electrofishing but is restricted to periods when water is low and clear. D.C. electrofishing is also affected by high water levels and excessive turbidity, but can be used during all seasons. A combination of these two methods would probably give optimum results.

Habitat

Quantitative methods, such as the development of probability-of-use curves (Bovee and Cochnauer 1977), are necessary to adequately assess the impact of stream flow changes on the aquatic habitat required by fish populations. Curves are developed from field data and define optimum habitat conditions for the particular parameters most important to the species. Ideally, seasonal curves are developed for eggs, fry, juveniles, adults and spawning adults.

Our objective was to develop seasonal curves for each major life history stage of the leopard darter, but there were not enough data to allow us to meet this objective. Therefore, a single curve for each habitat parameter was developed for the adult stage based on data pooled over all seasons and all years. This procedure introduced potential biases into the curves, since seasonal and annual variations were not accounted for. In spite of these biases, these curves are good general indication of habitat requirements.

Results of this study appear to conflict with the previous description of leopard darter habitat. Moore and Reeves (1955) described leopard darter habitat as swift, gravelly riffles. The Oklahoma Biological Survey (1972) stated that leopard darters preferred riffles with moderate flow and small to medium gravel. Miller and Robison (1973) reported that leopard darters occur in the swift, clear, upper reaches of the Little and Mountain Fork rivers and their tributaries, preferentially inhabiting areas of intermixed gravel and sand. Cloutman and Olmsted (1974) reported the capture of two leopard darters in the Cossatot River, Arkansas, from a patch of Potamogeton sp. in an area that had moderate current, about 6 inches deep, with a gravel bottom. Eley et al. (1975) stated that leopard darters were caught in relatively clear, turbulent water less than 1 meter deep and hypothesized that, although leopard darters occasionally frequented pools, they were unlikely to occur there in significant numbers except during drought.

Most previous descriptions of leopard darter habitat are qualitative and it is often difficult to interpret terms like "swift or moderate flow," "small to medium gravel" and "shallow or moderate depth." However, it is clear that these descriptions of leopard darter habitat refer to riffle-type areas (Robison 1978). In contrast, our data show that leopard darters prefer pools during all seasons. These preferred pools range from 20 to 79 cm deep, with water velocities from 0 to 19 cm/s, and with larger substrates such as rubble (64 mm to 254 mm), boulder (> 256 mm) and mixtures of these two. In addition, all leopard darters captured from the Cossatot River ***were*** caught in pools. We conclude that, although habitat utilization appears to vary somewhat between seasons, leopard darters inhabit pools all year, even during winter and spring when riffles and runs are most available.

Population Estimates and Densities

Leopard darter densities in Glover Creek are exceptionally low compared to estimates published for other darter species (Table 16). The highRst density of leopard darters in Glover Creek was estimated to be $.017/m^2$. Although exceedingly low, our estimates are similar to those of Thomas (1970) for P. phoxocephala, and those of Starnes (1977) for P. tansi. An average of 3.64 and 3.44 leopard darters per 100 m of stream for the Glover and Cossatot, respectively, are also similar to densities calculated by Pflieger (1978) for E. nianguae and E. blennoides.

Low densities appear to be characteristic for all darter species in Glover Creek (Appendix IV). Even orangebelly darter (the most abundant species) densities are quite low in comparison to estimates of density published for other darters. Although interspecific interactions may be occurring and may possibly contribute to the significant difference in abundance between E. radiosum and the other darter species, the low density of the darter community, as a whole, more likely is related to the net productivity and carrying capacity of streams in the Little River System.

One factor that may influence the ability of Glover Creek to support larger numbers of darters is extreme variations in seasonal discharge (Plates 6 and 7). Heavy rains in the late fall and during spring result in very high discharges and occasional flooding, while low discharges and little or no surface flow is typical of summer and early fall. Periodic flooding in the spring may interfere with spawning while low flows may limit habitat availability.

We plotted mean monthly discharges for Glover Creek vs. total seasonal catch of leopard darters from August 1977 to July 1980 to determine if physical habitat changes might explain the increased populations during 1979-80 (Figure 8). Seventy percent of the leopard darters captured during the latter part of 1979 and early part of 1980 were 1+-year old individuals. Those fish were spawned the previous year when spring flows were relatively high and may have favored successful spawning. During the following summer, flows reached low levels but did not remain low for an extended period. It is possible that these conditions could have resulted in increased survival. The abrupt decrease in leopard darter abundance in July 1980 might be attributable to drought conditions and record high temperatures during May and June.

Distribution

Leopard darters were captured near all the locations on Glover Creek where the species have been collected previously but were also captured at new locations; 71000, the 3+7 State Highway bridge, Pine Creek and Dierk's Boy Scout Camp. Captures at 61200 m.s., 51750 on Carter Creek, areas below the 3+7 bridge and 52500 Pine Creek are significant because these locations are outside designated critical habitat.

TABLE 16. Species and location of density estimates published for other darter species.

Species	Location	Density	Author(s)
Etheostoma blennoides	French Creek, Pa.	$1.19/m^2$ (total)	Lachner et al. 1950
E. zonale			
E. variatum			
E. maculatum			
E. flabellare			
E. camurum			
E. tippecanoe			
E. nigrum			
Percina maculata			
P. caprodes			
E. caeruleum	Deckart Run, Little Sugar Creek, and Conneaut Creek, Pa.	$3.2/m^2$ (total)	Reed 1968
E. blennoides			
E. flabellare			
E. zonale			
E. variatum			
E. nigrum			
E. maculatum			
P. maculata			
E. radiosum	Blue River, Okla.	$2.6/m^2$	Scalet 1973
E. squamiceps	Big Creek, Ill.		
	Ferguson Creek, Ky.	$9.6/m^2$	Page 1974
E. kennicotti	Big Creek, Ill.	$6.5/m^2$	Page 1975
E. proeliare	Max Creek, Ill.	$5.5/m^2$	Burr and Page 1978
P. sciera	Embarras River, Ill.	$.19/m^2$	Page and Smith 1970
P. phoxocephala	Embarras River, Ill.	$.03/m^2$	Page and Smith 1971
P. phoxocephala	Kaskaskia River, Ill.	$.05/m^2$	Thomas 1970
E. nianguae	Osage River Basin, Mo.	1.15/100 m	Pflieger 1978
E. blennoides	Osage River Basin, Mo.	7.28/100 m	

PLATE 6. Low flow at location 72000 M.S. on the mainstem of Glover Creek in early November 1978.

PLATE 7. High flow at location 72000 M.S. on the mainstem of Glover Creek in late November 1978.

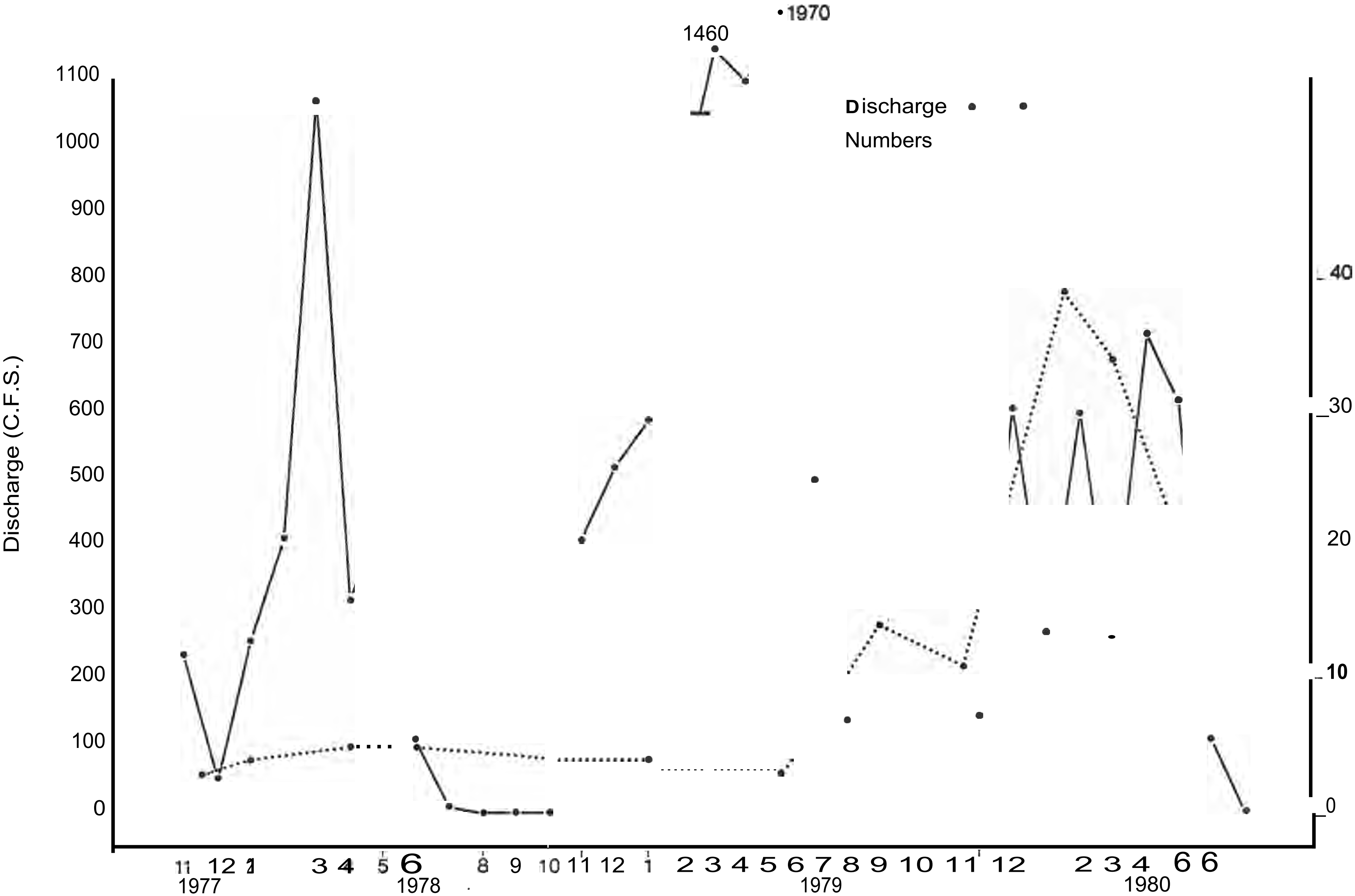

Figure 8. Mean monthly discharge vrs. total seasonal catch of leopard darters in Glover Creek from November 1977 to July 1980.

Although we failed to capture leopard darters in Cedar Creek, several kilometers downstream from where Taylor and Wade (1972) captured a single leopard darter, the species inhabits several smaller tributaries of Glover Creek and have also been found in several smaller tributaries of the Mountain Fork River (James Randolph, pers. comm.). Robison (1978) concluded that leopard darters are not typically inhabitats of headwater tributaries but prefer the larger, more riverine situations. Our data generally agree with Robison's conclusions since most of the leopard darters we captured were taken from the main stem of Glover and its two primary tributaries, the West Fork and East Fork.

Although contagious distributions are typical of many organisms, the reasons for the clumped distribution of leopard darters are unclear. While many darter species are solitary and show territoriality as individuals, some show gregarious behavior and at least one species, the logperch, forms loose spawning schools (Winn 1958a). Pflieger (1978) found that E. nianguae also had a clumped distribution and attributed this distribution, in part, to the possibility that individuals of the species had an affinity for one another. However, it was more common to capture single individuals at a site during our sampling. Therefore, we concluded that leopard darters are typically solitary and that clumped distributions occur because of optimal factors. Darters are usually more dense in areas of more favorable habitat (Starnes 1977; Burr and Page 1978; Braasch and Smith 1967; Page 1974, 1975). Although we do not have the data to correlate leopard darter density with habitat availabilty, there were several general characteristics common to sites where leopard darters were most abundant. These sites contained large deep pools throughout the year and extensive riffles and runs during winter and spring. Large, deep pools may be important for survival of leopard darters during low flows in summer and fall, while riffles and runs may provide spawning areas. However, if this evaluation is correct, it is unclear why we failed to capture leopard darters in greater numbers at additional sites that seemed to contain an abundance of these general habitat characteristics. Most likely, those areas that appeared to provide excellent leopard darter habitat have limited populations due to factors we did not detect or did not attempt to measure. Interspecific interactions, inadequate food supplies, limiting spawning habitat, physical or chemical parameters or combinations of these factors may be some of the factors limiting leopard darter populations in areas that otherwise appear favorable.

Population Composition

Ages at various lengths could be determined only for 14 leopard darters specimens. Previously, only one leopard darter, a 3+ year-old female measuring 76.8 mm (SL), had been aged (Robison 1978). Therefore, we used the length frequency distribution, based on fish caught during all three years, to aid us in assigning ages at various lengths. Although these groups probably overlap, our determinations are not unrealistic for the Genus Percina (Page and Smith 1970; Starnes 1977).

The individuals measuring 92 mm (TL) captured during this study are the largest leopard darters reported. The largest specimen reported by Robison (1978) was 76.8 mm (SL), collected from Glover Creek. The smallest specimen ever collected was 22 mm (SL) (Moore and Reeves 1955), but the smallest captured during our study was 45 mm (TL).

The 0+ age group apparently comprises a small percentage of the total catch in Glover Creek, even though it is usually the most abundant age group elsewhere (Starnes 1977, Page and Smith 1970, 1971; Thomas 1970). Although we could not determine mortality rates, some 0+ individuals obviously survive each year since older age groups are represented. Therefore, either the 0+ age group was not collected in proportion to its actual abundance, or our age determinations are not completely accurate. Since we did not collect significant numbers of smaller leopard darters (< 50 mm) at any time during the study, we attributed the discrepancy in the 0+ age group to sampling bias. The explanation of this bias is not clear since our sampling technique effectively captured smaller [18 mm to 50 mm (TL)] E. radiosum, E. nigrum, E. spectabile and P. copelandi. One possible explanation is that leopard darters grow very rapidly and are quickly recruited into longer length groups, as does E. nianguae (Pflieger 1979). However, small leopard darters should still be present in late spring and early summer before any such growth occurs. A more probable explanation is that during early life leopard darters inhabit areas that are inaccessible with our sampling techniques, such as deep pools. If this is true, then movement into adult habitat after good growth would explain why only larger leopard darters are captured.

Relative Abundance and General Community Structure

Data on total catch and frequency of catch, at main sites and additional sites, show a community structure dominated by the orangebelly darter. The species was abundant at every location sampled in Glover Creek. Orangebelly darters predominately inhabit the riffle areas, but also inhabit most other habitats, except deeper pools. Although leopard darters were captured more frequently than any other darter species, except orangebelly darters, the relative abundances of leopard darter, channel darters and logperch were similar. However, leopard darters were captured at more sites than the other two species and apparently have a wider distribution in Glover Creek. Johnny darters, orangethroat darters and dusky darters were the least abundant and all three species had distributions that were restricted to the lower portion of Glover Creek.

In the literature, it is reported that leopard darters have been captured with the dusky darter, the channel darter, the slenderhead darter (P. phoxocephala), the orangebelly darter, the johnny darter (Moore and Reeves 1955), the logperch, the orangethroat darter, the slough darter (E. gracile) and the mud darter (E. asprigene) (Eley et al. 1975; Robison 1978). Except for the slenderhead darter, the mud darter and slough darter, we collected all of the above species with leopard darters.

Our failure to capture the slough darter and mud darter is not surprising because both species are usually associated with lowland rivers, sloughs, oxbows and backwaters which provide quiet pools with silty, soft, clay bottoms covered with organic debris and vegetation (Miller and Robison 1973, Braasch and Smith 1967; Smith 1979). This habitat type is virtually nonexistent in the upper portion of Glover Creek, but the lower Glover has many areas that would provide excellent habitat for these two species near the confluence with the Little River. However, leopard darters rarely should be taken with either of these species because of marked differences in preferred habitat.

Although the slenderhead darter prefers moderate to fast currents in areas of gravel and sand substrates (Page and Smith 1971), this species is usually associated with larger streams and rivers and is typically not found in headwater areas and smaller streams (Smith 1979). Although the upper Glover has relatively high gradients and extensive riffles, most of the substrate is larger gravel and rubble with scattered boulder and bedrock. On the other hand, the slenderhead darter is abundant in the lower Glover (James Randolph, pers. comm.) where smaller substrates are more common and probably co-exists with leopard darters on occasion.

Where present in our study area, the dusky darter and orangethroat darter were common, but johnny darters were rare. Reasons for low abundance of johnny darters in the upper Glover are unclear. This darter is generally common and inhabits pools, areas with slow current and occasionally in riffles (Spearse 1960; Pflieger 1975; Smith 1979). These types of habitats are common throughout the upper Glover. The dusky darter prefers areas 30 to 40 cm deep with fast currents and gravel bottoms and is never found in quiet pools or areas with substrates other than gravel (Page and Smith 1970). Spawning occurs in shallow riffles over gravel with swift current (Smith 1979). The species also has been associated with cover in aquatic vegetation and accumulations of branches and leaves in the gravel. The lack of smaller gravel substrates and aquatic vegetation in the upper reaches of Glover Creek probably limits the distribution of the dusky darter to the lower Glover.

The orangethroat darter prefers riffle habitat with gravel bottoms in small streams (Distler 1968, Miller and Robison 1973), spawns in the same habitat, and is tolerant of fluctuating water levels (Cross 1967). Although the orangebelly darter is the only "riffle" darter in Glover Creek, it occurs sympatrically with the orangethroat darter and hybridizes with it in other Oklahoma streams (Echelle et al. 1975; Linder 1959, 1955; Branson and Campbell 1969). However, sympatric populations of these species tend to segregate (Echelle et al. 1974) with the orangebelly darter occupying the main channels and the orangethroat darter predominating in the smaller tributaries. Except for the lack of gravel substrates, reasons are unclear for the absence of the orangethroat darter in many of the smaller tributaries of Glover Creek.

On the basis of distribution and total numbers collected, leopard darters, channel darters and logperch were similar in relative abundance and were captured frequently together. This similarity is reasonable since both channel darters and logperch prefer habitat similar to habitat preferences we determined for leopard darters (Trautman 1957; Cross 1967; Thomas 1970; Pflieger 1974; Smith 1979).

CHAPTER VI

RECOMMENDATIONS

Presently, commercial timber harvesting is the principal economic activity throughout the Glover Creek watershed. Potential changes in flow regimes and increases in sediment transport and deposition associated with road building activities have unknown impacts on leopard darter populations. Other activities, such as periodic gravel removal for construction, may have immediate impacts on those individuals in the areas of gravel removal and unpredictable impacts downstream. Although still pending in the legislature, the Comprehensive Water Plan for Oklahoma also may impact leopard darter populations. To insure the future protection of leopard darters in Glover Creek, the following actions are suggested:

1. If protection of all significant populations encountered is desired, critical habitat for the leopard darter should be extended to include the West Fork of Glover Creek upstream to at least 61200 m.s. (Figure 3). Protection of all populations encountered would also require extending critical habitat to include the mainstem of Glover Creek from the State Highway 3+7 bridge downstream to some unknown extent; Pine Creek upstream to at least 52500 (Figure 3); and Carter Creek upstream to at least 51750 (Figure 3). However, our data show low population levels at Pine Creek and Carter Creek and the extent of accusation of the main stream below the 3+7 bridge is unknown.

2. Populations in Glover Creek should be monitored periodically (every other year) to determine changes in abundance or distribution.

Since leopard darters are found in extremely small numbers throughout their range, research will require considerable effort and time. However, if leopard darters are to be protected, management must be based on a clear understanding of the biological and ecological requirements of the species. Results of this study demonstrate the need for further research and suggest the following:

I. Variables other than depth, velocity and substrate should be related to the habitat preferences and requirements of leopard darters; i.e., temperature, oxygen, pH, alkalinity, turbidity, suspended solids, optimum flow requirements, etc.

2. Seasonal differences in habitat utilization should be more clearly defined.

3. Basic information is needed on leopard darter reproduction; i.e., spawning habitat, egg development and early life history.

4. Interactions between leopard darters and other darter species should be investigated. These interactions, or the lack of them, may have important effects on the dynamics of leopard darter populations.

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Appendix I. Modified Wentworth particle size scale (Bovee and Cochnauer 1977).

Substrate description	Size range	Numerical code value
Muck	Black, finely divided organic matter; completely decomposed	1
Detritus	Material recognizable as herbaceous or woody vegetation in various stages of decomposition	
Mud/clay	Compacted particles less than .004 m in diameter; smooth, slick feeling between fingers	2
Silt	Noncompacted particles .004 mm to .06 mm in diameter	3
Sand	Particles .06 mm to 2.0 mm in diameter; gritty texture between fingers	4
Gravel	Rocks 2.0 mm to 64 mm in diameter (.08 in. to 2.5 in.)	5
Rubble	Rocks 64 mm to 256 mm in diameter (2.5 in. to 10.0 in.)	6
Boulder	Rocks over 256 mm in diameter (>10.0 in.)	7
Bedrock	Large mass of solid rock	**8**

Appendix II. Capture locations, total lengths, water depth, water velocity, and substrate type for leopard darters.

Sampling period	Date	Site	Total length (mm)	Habitat data: Water depth (cm)	Water velocity (cm/s)	Substrate type	Habitat
*Summer 1977	13 Aug.	74100 m.s.		41		Rub.	Pool
*Fall 1977	16 Nov.	74100 m.s.(P)	73	–	–	–	Pool
			75	–	–	–	Pool
	10 Dec.	73100 m.s.	58	–		–	Riffle
*Winter 1978	10 Jan.	74100 m.s.(P)	74	–	–	–	Pool
			77	–	–	–	Pool
			75	–	–	–	Pool
			75	–	–	–	Pool
*Spring 1978	10 Apr.	74100 m.s.(P)	67	30	4.6	Rub. + Bld.	Pool
			70	–	–	–	Pool
	16 Apr.	74100 m.s.(R)	72	28	96.0	Bld.	Riffle
			70	24	38.9	Bld.	Riffle
			50	18	38.9	Rub.	Riffle
*Summer 1978	25 May	61200 m.s.	–	42	2.3	Rub.	Pool
	8 Jun.	74100 m.s.	92	61	0	Bld.	Pool
	21 Jul.	61200 m.s.(P)	78	68	0	Bld. + Bed Rk.	Pool
			77	49	0	Rub. + Bld.	Pool
			73	25	0	Rub. + Grav.	Pool
			45	48	0	Bld.	Pool
			70	52	0	Rub. + Bld.	Pool

Appendix II. Continued.

Sampling period	Date	Site	Total length (mm)	Habitat data: Water depth (cm)	Water velocity (cm/s)	Substrate type	Habitat
Fall 1978	**15 Oct.	74100 m.s.(P)	63	64	0	Bld. + Bed Rk.	Pool
			56	67	0	Bld. + Bed Rk.	Pool
	18 Nov.	71300	53	31	9.6	Rub. + Gray.	Run
	18 Nov.	53300	86	50	6.9	Rub. + Gray.	Pool
Winter 1979	29 Dec.	3+7 Highway Bridge	63	41	2.3	Rub. + Gray.	Pool
	2 Jan.	Carter Creek	71	83	0	Rub. + Gray.	Pool
	7 Jan.	East Fork m.s.	81	29	0	Rub. + Gray.	Pool
			54	50	22.8	Bed Rock (Rub.)	Run
	**10 Jan.	74100 m.s.(R)	70	32	25.2	Rub. + Gray.	Riffle
	**12 Jan.	61200 m.s.(P)	55	99	0	Rub. + Bld.	Pool
			55	108	0	Rub. + Bld.	Pool
	13 Jan.	County Road Crossing	70	48	36.6	Rub.	Run
Spring 1979	**28 Apr.	61200 m.s.(R)	53	31	27.4	Rub. + Gray.	Riffle
	**29 Apr.	61200 m.s.(P)	78	63	0	Bld. (Gr)	Pool
	13 Jun.	71000	69	38	0	Rub.	Pool
Summer 1979	18 Jul.	62000	73	40	0	Rub.	Pool
	21 Aug.	72000 m.s.	64	33	0	Bed Rk. + Bld.	Pool
	** 1 Sept.	61200 m.s.(P)	72	78	0	Rub. + Bld.	Pool
	** 2 Sept.	74100 m.s.(P)	67	20	0	Bld.	Pool
			64	48	0	Rub. + Bld.	Pool
			64	57	0	Rub. + Bld.	Pool
			63	36	0	Gray. + Rub.	Pool
			65	62	0	Gray. + Rub.	Pool

Appendix II. Continued.

Sampling period	Date	Site	Total length (mm)	Habitat data			
				Water depth (cm)	Water velocity (cm/s)	Substrate type	Habitat
Summer 1979 ** (Continued)	2 Sept.	74100 m.s.(P)	66	62	0	Grav. + Rub.	Pool
			71	26	0	Rub. + Bld.	Pool
			64	44	0	Bld.	Pool
			62	45	0	Bld.	Pool
			68	33	0	Rub. + Bld.	Pool
			70	29	0	Rub. + Bld.	Pool
Fall 1979	20 Oct.	72000 m.s.	68	46	0	Bld. + Rub.	Pool
			69	9	0	Bld. + Rub.	Pool
	21 Oct.	3+7 Highway Bridge	65	20	0	Rub. + Grav.	Pool
	22 Oct.	74100 m.s.(P)	73	28	0	Bld. + Rub.	Pool
			70	38	0	Bld. + Rub.	Pool
			71	25	0	Bld. + Rub.	Pool
			71	34	0	Bld. + Rub.	Pool
			67	37	0	Bld. + Rub.	Pool
	23 Oct.	71000	70	26	0	Rub. + Bld.	Pool
			67	18	0	Rub.	Pool
	10 Nov.	62000	92	46	0	Bld. + Rub.	Pool
Winter 1980	4 Jan.	East Fork m.s.	81	43	41	Bed Rock	Pool
			77	43	0	Rub. + Bld.	Pool
	5 Jan.	61200 m.s.(P)	68	74	4	Rub. + Bld.	Pool
			71	66	4	Gray. + Rub.	Pool
			82	60	6	Rub.	Pool
			81	80	1	Rub. + Bld.	Pool
			67	84	0	Rub. + Bld.	Pool
			81	84	0	Bld.	Pool

Appendix II. Continued.

				Habitat data			
Sampling period	Date	Site	Total length (mm)	Water depth (cm)	Water velocity (cm/s)	Substrate type	Habitat
Winter 1980 (Continued)	5 Jan.	51200 m.s.(P)	77	67	5	Rub. + Bld.	Pool
			63	70	0	Gray. + Rub.	Pool
			67	94	7	Rub. + Bld.	Pool
			66	78	0	Rub.	Pool
			84	100	11	Rub. + Bld.	Pool
	8 Jan.	72000	70	42	3	Rub. + Bld.	Pool
			69	34	7	Rub. + Gray.	Pool
			67	42	8	Rub. + Bld.	Pool
			74	42	8	Rub. + Bld.	Pool
			67	30	26	Rub. + Bld.	Pool
			76	48	0	Rub. + Bld.	Pool
			71	30	15	Rub. + Bld.	Pool
			75	55	5	Bld.	Pool
			69	54	5	Bld.	Pool
			68	44	4	Rub.	Pool
			70	55	7	Rub. + Bld.	Pool
	9 Jan.	71300	65	61	15	Rub.	Run
			63	49	18	Rub. + Bld.	Run
			61	54	5	Bld. (Gr.)	Run
			66	68	0	Gray. + Rub.	Run
		Carter Creek	81	38	7	Rub.	Pool
			68	70	0	Rub. + Bld.	Pool
	10 Jan.	71000	68	18	14	Rub. + Bld.	Run
			65	36	16	Rub.	Run
			63	20	9	Rub.	Pool
		Boy Scout Camp	64	60	5	Bld.	Pool
	23 Feb.	61200 m.s.(R)	81	25	41	Rub.	Riffle
			73	32	26	Bld.	Riffle
			85	39	14	Bld.	Riffle
			71	32	34	Bld.	Riffle

Appendix II. Continued.

Sampling period	Date	Site	Total length (mm)	Habitat data: Water depth (cm)	Water velocity (cm/s)	Substrate type	Habitat
Spring 1980	8 Mar.	East Fork m.s.	55	20	50	Rub.	Riffle
	9 Mar.	61200 m.s.(R)	76	20	1	Rub. + Bld.	Riffle
			82	22	19	Rub.	Riffle
			92	21	12	Rub. + Gray.	Riffle
			90	27	5	Bld. (Grav.)	Riffle
			82	18	9	Rub. + Gray.	Riffle
			86	32	4	Bld. + Rub,	Riffle
	10 Mar.	61200 m.s.(P)	85	78	2	Rub. + Bld.	Pool
			77	80	0	Bld.	Pool
			74	70	0	Bld.	Pool
			85	47	8	Rub.	Pool
			65	84	0	Bld.	Pool
	11 Mar.	74100 m.s.(P)	63	72	0	Bld.	Pool
			64	70	0	Bed Rk. + Bld.	Pool
			68	88	0	Bed Rock	Pool
			70	50	1	Bld.	Pool
			71	76	6	Bed Rock	Pool
			60	56	0	Bld.	Pool
	12 Mar.	72000	63	30	0	Bld. + Rub.	Pool
			74	18	25	Bld. + Rub.	Riffle
			70	60	7	Bld. + Rub.	Pool
		71300	61	60	15	Bld. + Rub.	Pool
			63	50	17	Rub.	Pool
			56	30	1	Rub.	Pool
			58	28	0	Rub. + Gray.	Run
			57	62	0	Rub. + Gray.	Pool
		Pine Creek	80	14	18	Bld. (Sand)	Riffle

Appendix II. Continued.

				Habitat data			
Sampling period	Date	Site	Total length (mm)	Water depth (cm)	Water velocity (cm/s)	Substrate type	Habitat
Spring 1980 (Continued)	13 Mar.	53300	65	36	0	Bed Rk.	Pool
			63	8	0	Rub.	Pool
		County Road Crs.	66	18	0	Rub.	Pool
			68	24	0	Rub. + Bld.	Pool
	14 Mar.	71000	64	28	0	Rub.	Pool
			62	30	18	Rub.	Run
		Boy Scout Camp	66	36	1	Rub. + Gray.	Pool
Summer 1980	15 Jul.	61200 m.s.(P)	84	122	0	Bld.	Pool
			83	110	0	Bld.	Pool
			87	120	0	Bld.	Pool
	16 Jul.	62000	85	35	0	Bld. (Gr.)	Pool
			66	43	0	Bld.	Pool
			85	38	0	Bld. + Rub.	Pool
	23 Jul.	3+7 Highway Bridge	71	43	0	Rub. + Bld.	Pool

*Conducted by Orth.

**Conducted in conjunction with Orth.

Appendix III. Season, sampling location, total effort, total catch, and catch per unit of effort for darter species collected from November 1978 to July 1980.

Season and year	Sampling location	Species	C	F(hrs)	c/f
Fall 1978	3+7 Highway Bridge	E. radiosum		.415	
		P. caprodes	1	.415	2.4
	71000	E. radiosum		.169	
		P. copelandi	2	.169	11.8
	71300	E. radiosum		.386	
		P. pantherina	1	.386	2.6
	Cedar Creek	E. radiosum		.341	
	Carter Creek	E. radiosum		.279	
	Pine Creek	E. radiosum		.211	
	County Rd. Crossing	E. Radiosum		.288	
	53300	E. radiosum	34	.192	177.0
		P. pantherina	1	.192	5.2
	East Fk. 62000	E. radiosum		.245	
Winter 1979	3+7 Highway Bidge	-E. radiosum		.332	
		P. pantherina	1	.332	3.0
		P. caprodes	2	.332	6.0
		P. copelandi	4	.332	12.0
		E. nigrum	1	.332	3.0
		E. spectabile	3	.332	9.0
	71000	E. radiosum	30	.362	82.8
		E. nigrum	1	.362	2.7
	71300	E. radiosum	3	.396	7.5
	Cedar Creek	E. radiosum	22	.356	62.0
	Boy Scout Camp	E. radiosum	4	.379	10.5
	Carter Creek	E. radiosum	9	.274	33.3
		P. pantherina	1	.274	3.6
	Pine Creek	E. radiosum	31	.418	74.1
	County Rd. Crossing	E. radiosum	6	.511	11.7
		P. pantherina	1	.511	1.9
		P. copelandi	1	.511	1.9
	53300	E. radiosum	49	.926	52.9
	East Fk. 62000	E. radiosum	22	.488	45.0

Appendix III. Continued.

Season and year	Sampling location	Species	C	F(hrs)	c/f
Spring 1979	3+7 Highway Bridge	E. radiosum	52	.381	136.4
		P. copelandi	2	.381	5.2
	71000	E. radiosum	45	.325	138.4
		P. copelandi	4	.325	12.3
		P. pantherina	1	.325	3.0
	71300	E. radiosum		.397	
		P. caprodes	2	.397	5.0
	Cedar Creek	E. radiosum	42	.450	93.0
		P. caprodes	1	.450	2.0
	*Boy Scout Camp	E. radiosum	13	*.515	26.0
	Carter Creek	E. radiosum	9	.283	31.8
	72000	E. radiosum	47	.552	85.14
	Pine Creek	E. radiosum	31	.265	116.9
	County Rd. Crossing	E. radiosum	24	.340	70.6
		P. copelandi	1	.340	2.9
	**53300	E. radiosum	79	.806	98.0
		P. copelandi	3	.806	3.7
	East Fk. 62000	E. radiosum	27	.283	95.0
Summer 1979	3+7 Highway Bridge	E. radiosum	13	.594	21.8
		P. sciera	1	.594	1.7
	71000	E. radiosum	45	.423	106.4
		P. caprodes	1	.423	2.3
	71300	E. radiosum	34	.428	89.4
	Cedar Creek	E. radiosum	58	.461	126.0
	Boy Scout Camp	E. radiosum	30	.558	53.7
	Carter Creek	E. radiosum	32	.613	52.5
	Pine Creek	E. radiosum	45	.577	77.9
	County Rd. Crossing	E. radiosum	25	.448	55.8
	53300	E. radiosum	65	.590	110.0
	East Fk. 62000	E. radiosum		.658	
		P. pantherina	1	.658	1.5

Appendix III. Continued.

Season and year	Sampling year	Species	C	F(hrs)	c/f
Fall 1979	3+7 Highway Bridge	E. radiosum	48	.720	66.6
		P. pantherina	1	.720	1.4
		P. sciera	5	.720	6.9
		P. copelandi	1	.720	1.4
		E. spectabile	1	.720	1.4
	71000	E. radiosum	300	.533	563.0
		P. caprodes	4	.533	7.5
		P. pantherina	2	.533	3.7
	71300	**E. radiosum**	**51**	**.489**	**104.3**
		P. caprodes	1	.489	2.0
	Cedar Creek	E. radiosum	118	.420	281.0
	Boy Scout Camp	E. radiosum	27.	.827	32.6
		P. copelandi	2	.827	2.4
	Carter Creek	E. radiosum	31	.489	63.4
	Pine Creek	E. radiosum	60	.558	107.5
	County Rd. Crossing	E. radiosum	36	.504	71.4
	53300	E. radiosum	51	.424	120.2
	East Fk. 62000	E4 radiosum	23	.335	68.6
		P. pantherina	1	.335	3.0
Winter 1980	3+7 Highway Bridge	E. radiosum		.600	
		E. spectabile	9	.600	15.0
		P. sciera	1	.600	1.6
	71000	E. radiosum	78	.336	232.0
		P. pantherina	3	.336	8.9
		E. nigrum	2	.336	5.9
	71300	E. radiosum		.420	
		P. pantherina	4	.420	9.5
	Cedar Creek	E. radiosum	54	.531	102.0
	Boy Scout Camp	E. radiosum	50	.377	132.6
		P. pantherina	1	.377	2.6
		F. copelandi	1	.377	2.6
	Carter Creek	E. radiosum	38	.485	78.3
		P. pantherina	2	.485	4.1
	72000	E. radiosum		.508	
		P. pantherina	11	.508	21.0
	Pine Creek	E. radiosum	40	.505	79.2

Appendix III. Continued.

Season and year	Sampling year	Species	C	F(hrs)	c/f
Winter 1980 (continued)	County Rd. Crossing	E. radiosum	20	.552	36.2
	53300	E. radiosum	56	.540	103.7
	East Fk. 62000	E. radiosum	27	.580	46.5
Spring 1980	3+7 Highway Bridge	E. radiosum	41	.496	82.6
		E. spectabile	4	.496	8.0
		P. sciera	2	.496	4.0
	71000	E. radiosum	74	.411	180.05
		E. nigrum	4	.411	9.7
		P. caprodes	1	.411	2.4
		P. pantherina	2	.411	4.8
		P. copelandi	5	.411	12.1
	71300	E. radiosum	91	.528	172.3
		P. pantherina	5	.528	9.4
		P. caprodes	1	.528	1.9
		E. nigrum	3	.528	5.7
		P. copelandi	7	.528	13.2
	Cedar Creek	E. radisum	81	.327	247.0
	72000	E. radiosum	60	.425	141.2
		P. pantherina	3	.425	7.0
		E. nigrum	1	.425	2.3
	Pine Creek	E. radiosum	62	.338	183.4
		P. pantherina	1	.338	2.9
	County Rd. Crossing	E. radiosum	79	.417	189.4
		P. copelandi	2	.417	4.8
		P. pantherina	2	.417	4.8
	53300	E. radiosum	47	.774	60.7
		P. pantherina	2	.774	2.5
	East Fk. 62000	E. radiosum	29	.140	157.0
Summer 1980	3+7 Highway Bridge	E. radiosum	170	.571	297.7
		E. spectabile	11	.571	19.3
		E. nigrum	1	.571	1.7
		P. pantherina	1	.571	1.7
	71000	E. radiosum	317	.638	496.8
		P. caprodes	6	.638	9.4
	71300	E. radiosum	68	.487	139.6
	Cedar Creek	E. radiosum	129	.401	322.0

Appendix III. Continued.

Season and year	Sampling year	Species	C	F(hrs)	c/f
Summer 1980 (Continued)	Boy Scout Camp	E. radisum	65	.393	165.3
		P. caprodes	1	.393	2.5
	Carter Creek	E. radiosum	46	.383	120.0
	72000	E. radiosum	31	.165	187.8
	Pine Creek	E. radiosum	35	.232	150.8
	County Rd. Crossing	E. radiosum	26	.418	62.2
	53300	E. radiosum	67	.519	129.1
	East Fk. 62000	E. radiosum	22	.140	157.0
		P. pantherina	3	.140	21.4

*Effort was estimated using the mean effort expended at that site during the study.

**Values are the sum of two sampling efforts conducted at that site during that season.

Appendix IV. Population estimates of darter species from November 1977 to July 1980.

Sampling period/date	Site	Species	C	N	95% C.I.	Std. err.	Site length (m)	Site area (m2)	Density 2	ha	N/100 m
*Fall 1977											
15 Nov.	61200 m.s.(P)	P. caprodes	1	1	1-3	1.2	45.3	631	.0016	16	2.2
16 Nov.	74100 m.s.(P)	P. pantherina	2	2	2-4	1.1	44.5	892	.0022	22	4.5
10 Dec.	71300 m.s.	E. radiosum	11	11	11-12	0.3	41.3	450	.0224	224	542.0
		P. pantherina	1	1	1-1	0.0	41.3	450	.0022	22	2.4
	74100 m.s.(R)	E. radiosum	51	62	51-79	8.7	42.3	580	.1069	1,069	146.0
		E. nigrum	1	1	1-2	0.7	42.3	580	.0017	17	2.3
		P. caprodes	1	1	1-2	0.7	42.3	580	.0017	17	2.3
*Winter 1978											
10 Jan.	74100 m.s.(P)	P. caprodes	3	3	3-5	1.1	44.5	884	.0034	34	6.7
		P. pantherina	4	4	4-7	1.5	44.5	884	.0045	45	9.0
11 Jan.	74100 m.s.(R)	E. radiosum	57	187	52-691	257.1	42.3	545	.3431	3,431	442.0
12 Jan.	71300 m.s.	E. radiosum	57	66	57-81	7.4	41.3	344	.1918	1,918	159.0
13 Jan.	61200 m.s.(P)	-	-	-	-	-	45.3	675			
*Spring 1978											
9 Apr.	61200 m.s.(P)						45.3	664			
10 Apr.	74100 m.s.(P)	E. radiosum	3	3	3-6	1.3	44.5	941	.0032	32	6.7
		P. copelandi	1	1	1-1	0.0	44.5	941	.0010	10	2.2
		P. pantherina	2	2	2-3	0.4	44.5	941	.0021	21	4.5
16 Apr.	74100 m.s.(R)	E. radiosum	41	52	41-74	9.9	42.3	707	.0735	735	123.0
		P. caprodes	1	1	1-1	0.0	42.3	707	.0014	14	2.3
		P. pantherina	3	3	3-5	1.3	42.3	707	.0042	42	7.0
17 Apr.	61200 m.s.(R)	E. radiosum	25	27	25-33	2.9	41.0	429	.0629	629	66.0
		P. caprodes	5	5	5-5	0.2	41.0	429	.0116	116	12.0
		P. copelandi	12	13	12-18	2.3	41.0	429	.0303	303	32.0

Appendix IV. Continued.

Sampling period/date	Site	Species	C	N	95% C.I.	Std. err.	Site length (m)	Site area (m)	Density m	Density ha	Density N/100 m
*Summer 1978											
12 Jul.	61200 m.s.(R)	E. _radiosum_	33	42	33-60	9.2	41.0	97	.4330	4,300	102.4
		P. _caprodes_	1	1	1-2	0.7	41.0	97	.0103	103	2.4
13 Jul.	74100 m.s.(R)	E. _radiosum_	46	74	46-127	27.1	42.3	269	.2751	2,751	175.0
20 Jul.	74100 m.s.(P)	E. _radiosum_	34	56	34-106	25.6	44.5	787	.0711	711	126.0
		P. _caprodes_	3	3	3-4	0.3	44.5	787	.0038	38	6.7
21 Jul.	61200 m.s.(P)	E. _radiosum_	1	1	1-1	0.0	45.3	620	.0016	16	2.2
		P. _caprodes_	7	9	7-21	6.0	45.3	620	.0145	145	20.0
		P. _copelandi_	1	1	1-2	0.7	45.3	620	.0016	16	2.2
		P. _pantherina_	5	5	5-6	0.2	45.3	620	.0080	80	11.0
Fall 1978											
**15 Oct.	74100 m.s.(P)	E. _radiosum_	27	34	27-50	8.1	44.5	615	.0553	553	76.4
		P. _caprodes_	1	1	1-1	0.0	44.5	615	.0016	16	2.2
		P. _pantherina_	2	2	2-3	0.4	44.5	615	.0032	32	4.5
**16 Oct.	61200 m.s.(P)	E. _radiosum_	2	2	2-2	0.0	45.3	620	.0032	32	4.4
		P. _caprodes_	1	1	1-1	0.0	45.3	620	.0016	16	2.2
**21 Oct.	74100 m.s.(R)	E. _radiosum_	146	225	148-302	39.3	42.3	185	1.2200	12,200	532.0
**23 Oct.	61200 m.s.(R)	E. _radiosum_	118	145	118-172	13.7	41.0	97	1.4948	14,948	353.0
Winter 1979											
** 4 Jan.	61200 m.s.(R)	E. _radiosum_	65	109	65-179	35.7	41.0	488	.2233	2,233	266.0
7 Jan.	East Fork m.s.	P. _pantherina_	2	2	2-2	0.0	31.0	322	.0062	62	6.4
** 9 Jan.	74100 m.s.(P)	E. _radiosum_	4	4	4-4	0.0	44.5	947	.0042	42	9.0
**10 Jan.	74100 m.s.(R)	E. _radiosum_	32	44	32-69	12.8	42.3	748	.0588	588	104.0
		P. _pantherina_	1	1	1-2	0.7	42.3	748	.0013	13	2.3
**12 Jan.	61200 m.s.(P)	E. _radiosum_	5	5	5-7	1.2	45.3	669	.0075	75	11.0
		P. _pantherina_	2	2	2-7	2.3	45.3	669	.0030	30	4.5

Appendix IV. Continued.

Sampling period/date	Site	Species	C	N	95% C.I.	Std. err.	Site length (m)	Site area (m2)	Density m^2	Density ha	Density N/100 m
Spring 1979											
**28 Apr.	61200 m.s.(R)	E. radiosum	121	190	121-267	39.3	41.0	488	.3893	3,893	463.0
		P. caprodes	4	4	4-8	2.0	41.0	488	.0082	82	9.7
		P. copelandi	21	25	21-36	5.6	41.0	488	.0512	512	61.0
		P. pantherina	1	1	1-2	0.7	41.0	488	.0020	20	2.4
**29 Apr.	61200 m.s.(P)	E. radiosum	4	4	4-7	1.5	45.3	667	.0060	60	8.8
		P. caprodes	4	4	4-4	0.3	45.3	667	.0060	60	8.8
		P. copelandi	4	4	4-7	1.5	45.3	667	.0060	60	8.8
		P. pantherina	1	1	1-3	1.2	45.3	667	.0015	15	2.2
**12 Jun.	74100 m.s.(P)	E. radiosum	20	21	20-25	2.0	44.5	931	.0225	225	47.0
		P. copelandi	2	2	2-4	1.0	44.5	931	.0022	22	4.5
**13 Jun.	74100 m.s.(R)	E. radiosum	410	511	482-660	45.3	42.3	693	.7373	7,373	1208.0
		P. caprodes	1	1	1-1	0.0	42.3	693	.0014	14	2.3
15 Jun.	East Fork m.s.	E. radiosum	167	216	174-257	21.1	31.0	265	.8150	8,150	696.0
Summer 1979											
18 Jul.	East Fork m.s.	E. radiosum	170	199	175-223	12.2	31.0	210	.9476	9,476	644.0
20 Aug.	71300 m.s.	E. radiosum	121	131	121-142	5.6	41.3	301	.4352	4,352	317.0
		P. caprodes	1	1	1-2	0.7	41.3	301	.0033	33	2.4
21 Aug.	72000 m.s.	E. radiosum	355	489	410-568	40.3	34.6	743	.6581	6,581	141.0
		P. caprodes	4	4	4-8	0.0	34.6	743	.0054	54	11.5
		P. pantherina	1	1	1-1	2.0	34.6	743	.0013	13	3.0
**23 Aug.	74100 m.s.(R)	E. radiosum	335	619	408-829	107.4	42.3	533	1.1613	11,613	1463.0
		P. copelandi	1	1	1-1	0.0	42.3	533	.0019	19	2.3
**24 Aug.	61200 m.s.(R)	E. radiosum	224	272	237-306	17.5	41.0	275	.9891	9,891	663.0
		P. caprodes	3	3	3-5	1.3	41.0	275	.0109	109	7.3

Appendix IV. Continued.

Sampling period/date	Site	Species	C	N	95% C.I.	Std. err.	Site length (m)	Site area (m^2)	Density m^2	Density ha	Density N/100 m
** 1 Sept.	61200 m.s.(P)	E. radiosum	20	21	20-25	2.0	45.3	648	.0234	324	46.0
		P. caprodes	1	1	1-2	0.4	45.3	648	.0015	15	2.2
		P. copelandi	1	1	1-3	1.2	45.3	648	.0015	15	2.2
		P. pantherina	1	1	1-3	1.2	45.3	648	.0015	15	2.2
** 2 Sept.	74100 m.s.(P)	E. radiosum	59	61	59-65	2.2	44.5	896	.0680	680	137.0
		P. caprodes	2	2	2-7	2.4	44.5	896	.0022	22	4.5
		P. copelandi	4	4	4-4	0.0	44.5	896	.0044	44	9.0
		P. pantherina	11	12	11-17	2.7	44.5	896	.0134	134	27.0
Fall 1979											
20 Oct.	7200 m.s.	P. caprodes	1	1	1-5	1.6	34.6	828	.0012	12	2.9
		P. pantherina	2	2	2-5	2.6	34.6	828	.0024	24	6.0
21 Oct.	71300 m.s.						41.3				
22 Oct.	74100 m.s.(P)	P. caprodes	1	1	1-2	0.7	44.5	825	.0012	12	2.2
		P. copelandi	1	1	1-5	2.0	44.5	825	.0012	12	2.2
		P. pantherina	5	5	5-6	0.4	44.5	825	.0060	60	11.2
27 Oct.	61200 m.s.(R)	E. radiosum	269	406	310-502	49.1	41.0	233	1.7424	17,424	990.0
28 Oct.	61200 m.s.(P)	P. copelandi	1	1	1-1	0.0	45.3	654	.0015	15	2.2
10 Nov.	East Fork m.s.	E. radiosum	231	258	238-278	10.2	31.0	205	1.2585	12,585	832.0
Winter 1980											
4 Jan.	East Fork m.s.	E. radiosum	71	78	71-88	5.0	31.0	280	.2785	2,785	251.0
		P. pantherina	2	2	2-4	1.0	31.0	280	.0071	71	6.4
5 Jan.	61200 m.s.(P)	P. caprodes	8	10	8-20	5.2	45.3	663	.0150	150	22.0
		P. pantherina	11	11	11-20	0.6	45.3	663	.0165	165	24.0
23 Feb.	61200 m.s.(R)	E. radiosum	96	314	96-852	274.5	41.0	351	.8945	8,945	766.0
		P. caprodes	3	3	3-4	0.7	41.0	351	.0085	85	7.3
		P. pantherina	4	4	4-4	0.0	41.0	351	.0114	114	9.7

Appendix IV. Continued.

Sampling period/date	Site	Species	C	N	95% C.I.	Std. err.	Site length (m)	Site area (m)	Density $\bar{m}$	Density ha	Density N/100 m
24 Feb.	74100 m.s.(P)	P. copelandi	1	1	1-1	0.0	44.5	931	.0010	10	2.2
		P. caprodes	1	1	1-2	0.7	44.5	931	.0010	10	2.2
Spring 1980											
8 Mar.	East Fork m.s.	E. radiosum	160	247	165-328	41.3	31.0	234	1.0555	10,555	796.0
		P. caprodes	2	2	2-5	1.6	31.0	234	.0085	85	6.4
		P. copelandi	1	1	1-2	0.4	31.0	234	.0043	43	3.2
		P. pantherina	1	1	1-5	2.2	31.0	234	.0043	43	3.2
9 Mar.	61200 m.s.(R)	E. radiosum	227	478	227-739	133.5	41.0	352	1.3479	13,579	1166.0
		P. copelandi	2	2	2-2	0.0	41.0	352	.0057	57	4.8
		P. pantherina	6	6	6-7	0.4	41.0	352	.0170	170	14.6
10 Mar.	61200 m.s.(P)	P. caprodes	6	6	6-9	1.5	45.3	677	.0088	88	13.2
		P. copelandi	1	1	1-5	2.2	45.3	677	.0015	15	2.2
		P. pantherina	5	7	5-22	7.6	45.3	677	.0103	103	15.4
11 Mar.	74100 m.s.(P)	P. copelandi	1	1	1-1	0.0	44.5	928	.0011	11	2.2
		P. pantherina	6	6	6-7	0.4	44.5	928	.0064	64	13.4
Summer 1980											
15 Jul.	61200 m.s.(P)	E. radiosum	47	55	47-68	6.8	45.3	654	.0841	841	121.0
		P. caprodes	2	2	2-4	1.0	45.3	654	.0030	30	4.4
		P. copelandi	1	1	1-2	0.7	45.3	654	.0015	15	2.2
		P. pantherina	3	3	3-3	0.0	45.3	654	.0045	45	6.6
16 Jul.	61200 m.s.(R)	E. radiosum	32	40	32-56	8.3	41.0	205	.1951	1,951	97.5
17 Jul.	East Fork m.s.	E. radiosum	234	323	258-388	33.1	31.0	149	2.1678	21,678	1041.0

Appendix IV. Continued.

Sampling period/date	Site	Species	C	N	95% C.I.	Std. err.	Site length (m)	Site area (m)	Density		
									m^2	ha	N/100 m
Summer 1980											
18 Jul.	71300 m.s.	E. _radiosum_	210	305	231-378	37.6	41.3	202	1.5099	15,099	738.0
19 Jul.	74100 m.s.(P)	E. _radiosum_	202	299	219-378	40.7	44.5	725	.4124	4,124	672.0
		P. _caprodes_	1	1	1-2	0.7	44.5	725	.0014	14	2.2
20 Jul.	72000 m.s.	E. _radiosum_	80	144	80-243	50.5	34.6	155	.9290	9,290	416.0

*Population estimates conducted by Orth (1980).

**Population estimates conducted in conjunction with Orth.