THE COMMUNITY STRUCTURE AND INTERRELATIONSHIPS AMONG DARTERS (PERCIDAE) IN GLOVER CREEK, OKLAHOMA, USA

By

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Bachelor of Science in Fisheries Resources

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Moscow, Idaho

1977

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
July, 1981

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CREEK, OKLAHOMA, USA

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PREFACE

The purpose of this study was to investigate the ecological relationships within the darter community in Glover Creek, Oklahoma. The project was conducted in conjunction with research funded by the U.S. Fish and Wildlife Service, Office of Endangered Species, to obtain current information on the status of the threatened leopard darter, *Percina pantherina*, and to collect biological and ecological information concerning the species.

Foremost, I want to give honor, glory, and thanksgiving to my Lord and Savior, Jesus Christ, the Son of God. It might have been easy to become discouraged during the more arduous periods of this study had it not been for the grace and love of God.

I want to extend my sincere and personal appreciation to Dr. O. Eugene Maughan, who served magnanimously as my major professor and chairman of my graduate committee, for his guidance, encouragement, and support during the research, for carefully and contructively reviewing earlier drafts of this thesis and other manuscripts, and for taking so much time out of his busy schedule to advise me. I also extend my appreciation and gratitude to Dr. Michael D. Clady, who also served on my graduate committee, for reviewing this and other manuscripts, for always being available for consultation, and for cheerfully providing field assistance during those "easy days" on the Glover. I also thank Dr. Larry Talent, who willingly accepted my invitation to serve on my graduate committee, despite such short notice, and for contributing helpful suggestions, discussions, and editorial review of this thesis.

Special thanks go to Dr. Donald J. Orth, my cohort and fellow researcher on Glover Creek, for allowing me to coordinate my research with his own, for contributing so willingly of his time, assistance, ideas, and insight both in and out of the field, and for allowing me to include his data on leopard darters in this thesis. Special thanks also go to Geoff Russell for field assistance and for his invaluable experience and help in identifying the benthic organisms and stomach contents of darters.

I also want to thank Mary Batcheler, Charlotte Kruegler, Patti and Rob Lanford, Bill Layher, George Luker, Julie Saugstaad, Bill Schoch, Bob Tafanelli, and Keith Whisenant for their help both in the lab and in the field, often under severe weather conditions, for their ideas and suggestions, and their friendship during our time together.

I want to thank Mrs. Helen L. Murray, the Unit secretary, for typing the final draft of the manuscript. Lastly, but not least important, I want to thank Dr. David H. Bennett, my undergraduate adviser at the University of Idaho, for taking a very personal interest in my undergraduate education at a critical point in my life, for his encouragement and concern, and who initially instilled in me the desire to continue my education.

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CHAPTER I

INTRODUCTION

Living organisms interrelate with one another and with the environment in which they live. Ecology is the study of those interrelations, which one author has defined as the structure and function of nature (Odum 1971). Study of these interrelationships can be approached at various levels of complexity. Autecology is the study of an individual organism, usually a single species, and focuses on life history information, behavioral traits, and environmental requirements and tolerances. Synecology is the study of groups of species that are associated together as a unit, and is typically referred to as community ecology.

A major aspect of synecology is community structure, which is usually described in terms of species composition, diversity, distribution, and relative abundance. However, the underlying changes in environmental conditions and associated biological changes that ultimately influence and determine community structure over time are more difficult to address. Environmental variables, such as the chemical and physical characteristics of the environment, can be measured and correlated with community structure with relative accuracy. However, interactions between associated species and the effects of those interactions on community structure are more difficult to identify or measure quantitatively.

There are various types of biological interaction. Each interaction has variable effects, and may involve a number of relationships (Odum 1971). Of these interactions, competition for resources has dominated ecological thought and, hence, the ecological literature since the early work of Lotka (1925), Volterra (1926), and Gause (1934). This hypothesis is most often stated as the "Competitive Exclusion Principal" which states that when two species jointly utilize a vital resource that is in limited supply, one species will eventually eliminate the other species in that area where their distributions overlap (Hardin 1960; Haussman 1972; Jaeger 1974). Thus, the question is raised as to how similar species reduce competition and coexist to form closely interrelated communities.

Current theory suggests that resource partitioning is the major mechanism by which organisms reduce competition (Pianka 1973). Organisms can partition resources in three basic ways: temporally, spatially, or trophically. This concept has been hypothesized to be a significant determinant of population and community structure and a factor affecting species diversity (Schoener 1974; Pianka 1973, 1976). Pairs of potential competitors with a high degree of overlap in their distributions along one resource dimension, may often overlap relatively little or not at all along another resource dimension, presumably reducing or eliminating competition between them.

Most resource partitioning studies have concerned interspecific differences between adults. Since the degree or intensity of competition is correlated with species similarity, intraspecific competition has the potential for being more severe than interspecific competition. Thus, resource partitioning should theoretically occur to a greater degree and along more resource dimensions at the intraspecific level. Pianka (1976) has suggested that age specific changes in resource utilization may be an important mechanism for developing a population structure that efficiently utilizes available resources and which results in a greater degree of overall population success.

Little of the literature concerning resource partitioning applies to fishes (Schoener 1974), especially those in lotic ecosystems. However, one would expect to find resource partitioning among groups of similar stream fishes also. One such group of fishes are the darters where speciation has resulted in several lineages which occupy similar habitats (Page 1972). Thus, the question may be raised as to how darters partition resources to permit coexistence (Page and Schemske 1978). Several studies have indicated that sympatric darter species partition resources along all three resource axis: temporal, spatial, and trophic (Balesic 1971; Wynes 1979; Smart 1979; Smart and Gee 1979; O'Neil 1980; Lehtinen unpub.). Although intraspecific differences in resource utilization have been noted for several fish species (Gee and Northcote 1963; Coutant 1977; Keast 1977; Matthews and Hill 1979), no such evaluations have been made for darters.

Twenty-nine darter species occur in Oklahoma. Typically, they are restricted to eastern areas, although the distribution of several species extends into the central and western sections of the state (Miller and Robison 1973; Orth and Jones 1980). Most studies of darters in Oklahoma have concentrated on taxonomic and systematic descriptions (Moore and Rigney 1952; Linder 1955; Branson and Campbell 1969; Echelle et al. 1974, 1975, 1976) or biological inventories and studies of distributions (Paden 1948; Reeves 1953; Jenkins 1956; Blair

1959; Blair and Windle 1961; Riggs and Wade 1964; Branson 1967). In contrast only a single life history study has been conducted (Scalet 1971, 1972, 1973a, 1973b, 1974).

Previous collections in the Little River System (Reeves 1953; Jenkins 1956; Taylor and Wade 1972) indicated that a wide variety of darter species inhabited Glover Creek. These species included the johnny darter (*Etheostoma nigrum*), the orangebelly darter (*E. radiosum*), orangethroat darter (*E. spectabile*), slough darter (*E. gracile*), logperch (*Percina caprodes*), channel darter (*P. copelandi*), slenderhead darter (*P. phoxocephala*), dusky darter (*P. sciera*), and the endemic leopard darter (*P. pantherina*).

Knowledge of the leopard darter is especially important because the U.S. Fish and Wildlife Service (1978) declared it threatened in January 1978. This action gave the leopard darter full protection under the 1973 Endangered Species Act and set aside several areas in the Little River System, including a major portion of Glover Creek (Figure 1), as critical habitat.

My thesis concerns several aspects of darter ecology in a southeastern Oklahoma stream, Glover Creek. My objectives were: 1) to examine the general structure of darter populations throughout the drainage, i.e., species composition, relative abundance, distribution, and population sizes and densities; 2) to quantify utilization of important resources by the principal darter species, i.e., food and habitat; and 3) to examine resource partitioning among the principal darter species.

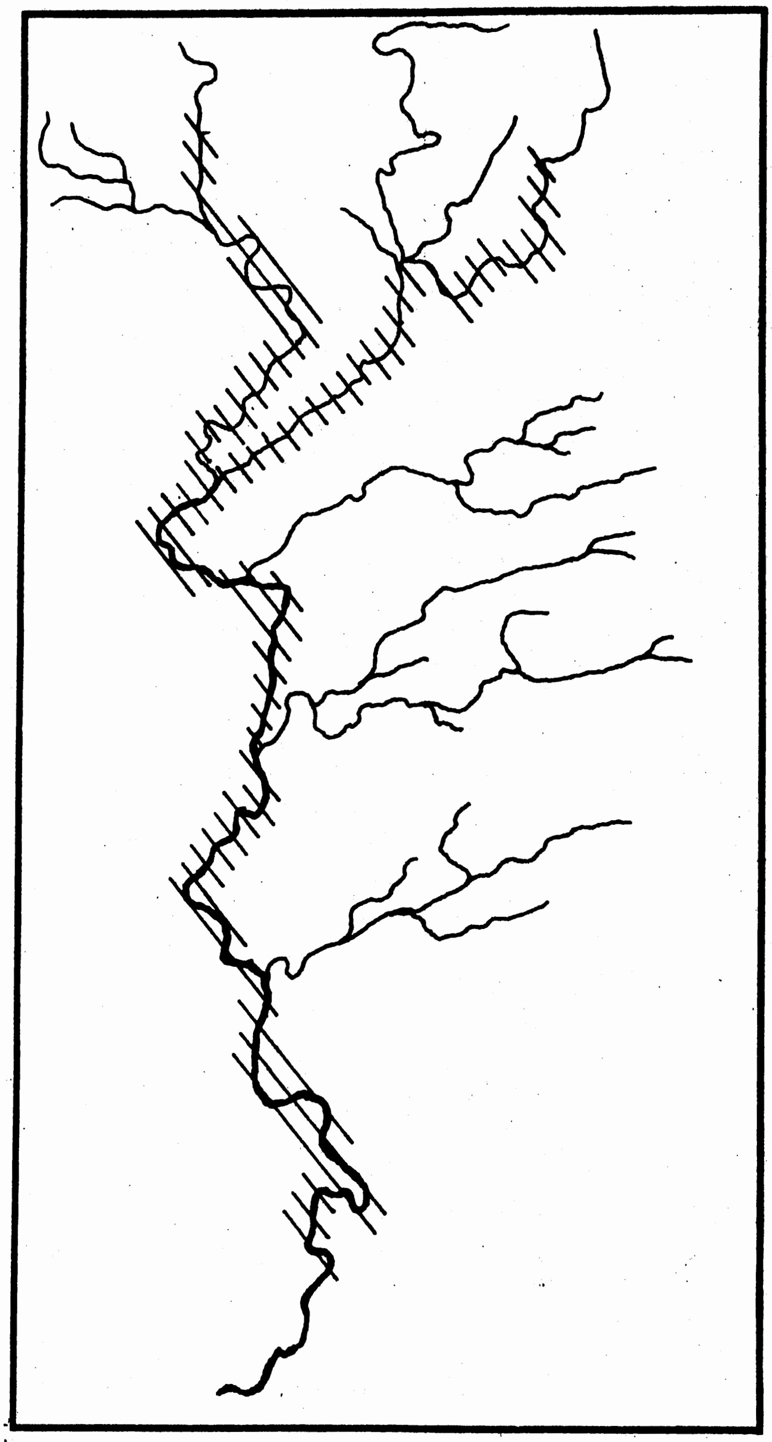

Figure 1. Critical habitat designated for the leopard darter on Glover Creek.

CHAPTER II

DESCRIPTION OF STUDY AREA

Glover Creek is a tributary of the Little River in McCurtain County, Oklahoma (Figure 2), which has its source in the Beaver Bend Hills subsection of the Ouachita Mountains in the vicinity of the McCurtain-LeFlore County line. The drainage basin of Glover Creek is 56.3 km long, 32.2 km wide, and drains an area of approximately 876 km^2. The main stem of Glover Creek, from its mouth to the confluence of the East and West Fork tributaries, 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, at its source. The average slope is 2.3 m/km, varying 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 that are heavily forested with oak and pine. Commercial timber harvesting is the principal economic activity and much of the watershed is owned or leased by the Weyerhauser Company. A small percentage of the area is under agricultural cultivation. The lower reaches of Glover Creek are surrounded by low, fertile flatlands that enter the flood plains of the Gulf Coastal Plains. This area is devoted to livestock grazing, with most of the former woodlands

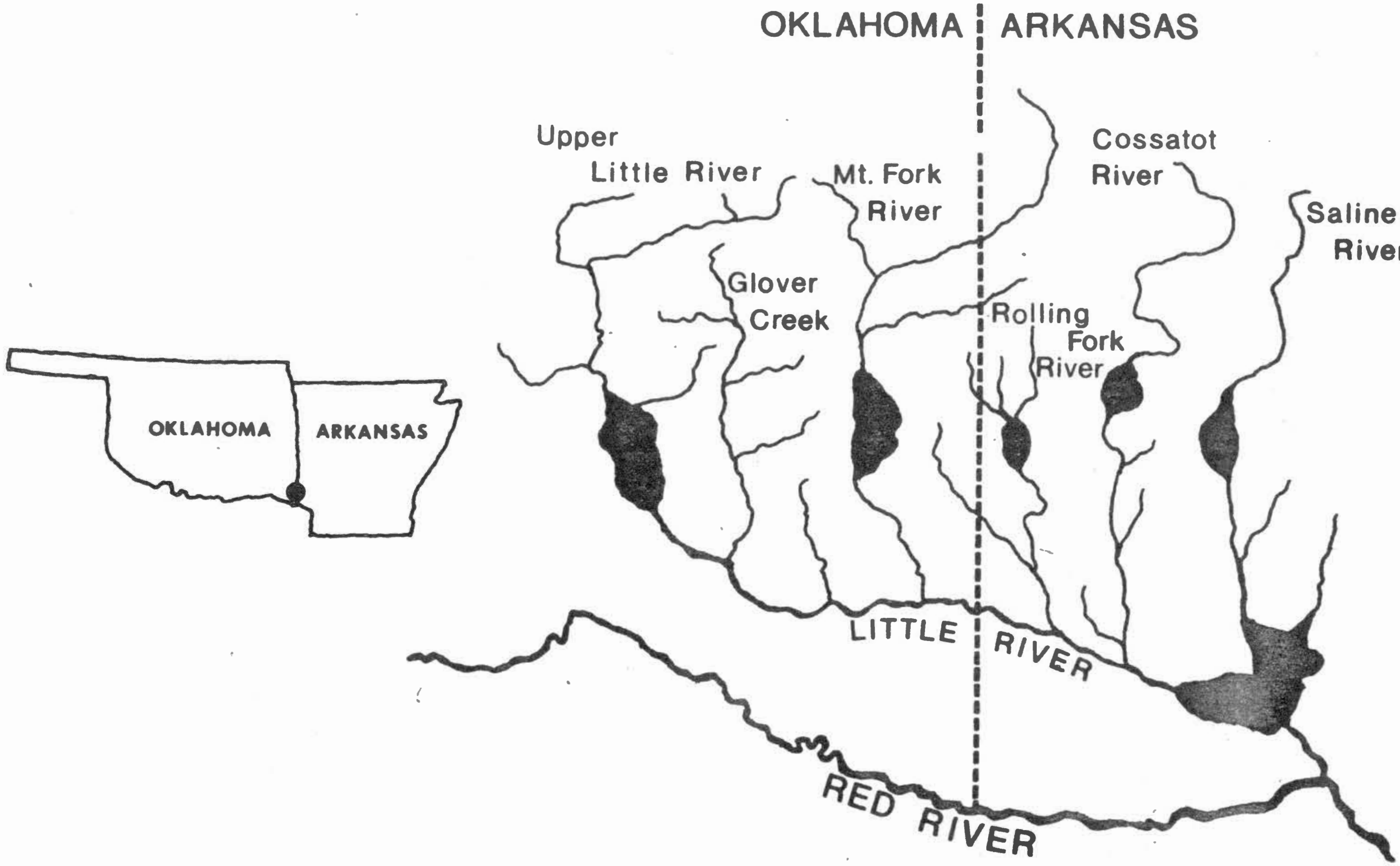

Figure 2. Little River System, Oklahoma and Arkansas.

converted to improved pasturelands.

Above Carter Creek, the stream habitat consists of shallow, wide, bedrock bottomed pools separated by low bedrock and boulder falls, runs, chutes, and riffles (U.S. Army Crops of Engineers 1975). Below the confluence with Carter Creek the stream changes characteristics. Habitat becomes mostly deep, long pools separated by shallow, relatively narrow riffles. Spring flooding in all areas keeps the stream well scoured and results in a stream bottom dominated by bedrock, boulder, and rubble. During the summer, extensive growths of water willow, *Justica sp*., develop in shallow, slow current areas and along the shallow shorelines of pools.

Glover Creek is the last unimpounded tributary of the Little River. The basin characteristics and annual precipitation patterns cause the lower flood plains to flood an average of three times each year, with an estimated annual flood damage of $1,083,900.00 to agricultural development and rural structures. The U.S. Army Corps of Engineers, Tulsa District, proposed to prevent these losses by constructing Lukfata Lake for flood control and water supply. However, funds were not appropriated for the project and recently the stream has been designated as critical habitat for the leopard darter.

The study was conducted in the upper reaches of Glover Creek, above the state highway 3 and 7 bridge crossing (Figure 3). A total of 14 sampling sites were selected: nine sites on the main stem of Glover Creek, two sites each on the East Fork and West Fork, and one site each on Pine, Carter, and Cedar creeks. A complete description and the legal location of each sampling site is included as Appendix A.

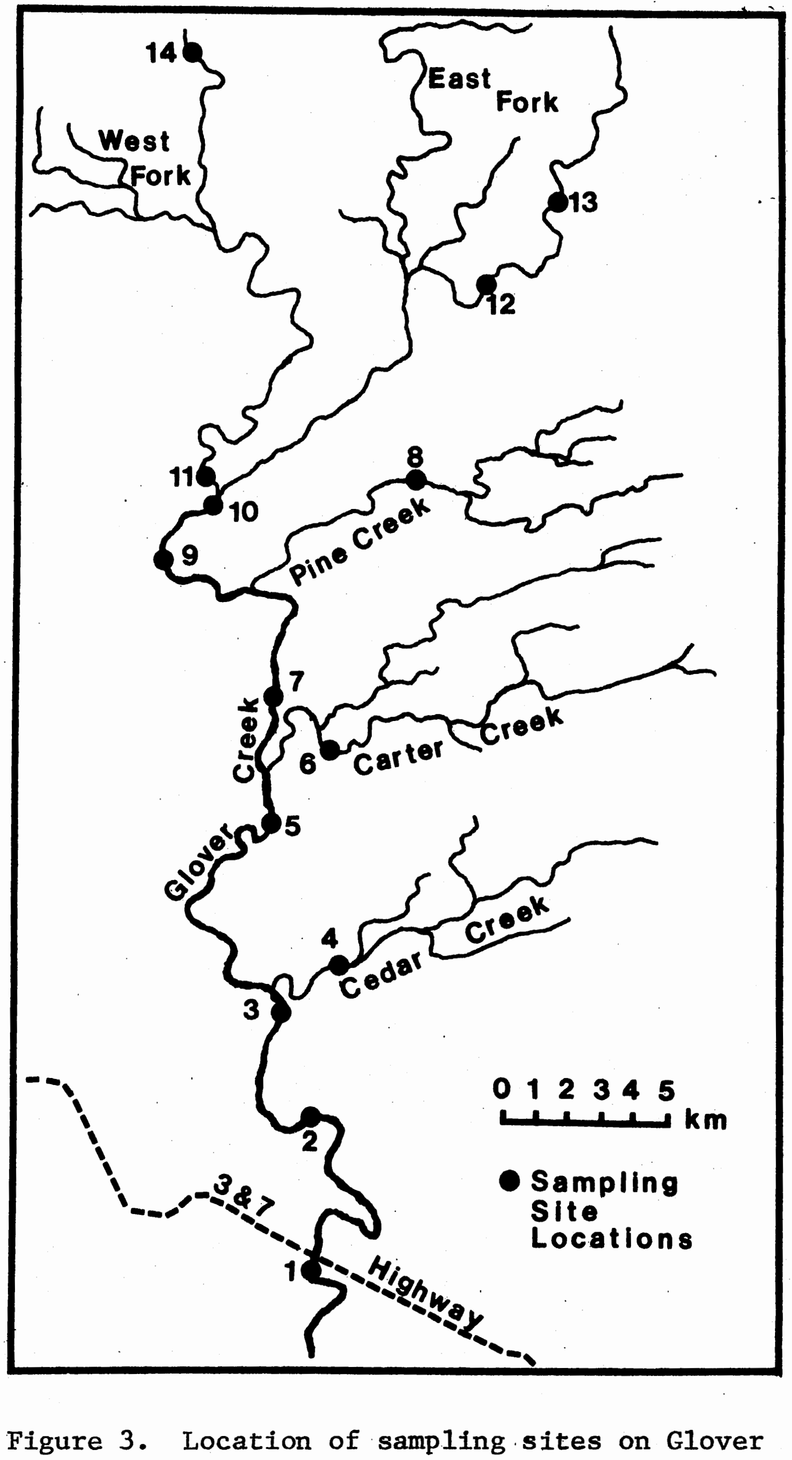

Figure 3. Location of sampling sites on Glover Creek, McCurtain County, Oklahoma.

CHAPTER III

METHODS AND MATERIALS

Samples were collected quarterly from November 1978 to July 1980. Field collections were generally taken during the same periods in each recurring season except during high water.

Five sites were selected for conducting population estimates and measuring habitat availability: two locations on the main stem of Glover Creek (Sites 3 and 7), one on the East Fork (Site 12), and two on the West Fork (Sites 11 and 14). Sites 11 and 14, on the West Fork, consisted of an upstream riffle area and a downstream pool. Because of their large size, both of these sites were divided into subareas, a pool area (P) and riffle area (R), and data from each subarea were analyzed and reported separately. Permanent transects, running perpendicular to the direction of flow, were established at approximately 15 m intervals along the length of each site. Habitat availability was measured along these transects. After the summer of 1979, the riffle area at Site 11 was abandoned and only the pool area was sampled the subsequent year.

Population estimates were made by using the depletion method described by Carle and Maughan (1980) and the maximum likelihood estimator (Carle and Strubb 1978). The procedures involved completely enclosing the site with blocknets (30 m) of 6 mm mesh. Darters were then collected with a boatmounted, D.C. pulse, electrofishing unit equipped with two, remote, hand-held electrodes. The electrodes were used to disturb the substrate, when possible, while water currents swept stunned darters into dipnets held just downstream. A unit of effort was one complete pass through the area using this technique. Successive passes were made to obtain a depletion. During periods of low flow, Smith-Root Type VII backpack electrofishing units were used in place of the boatmounted unit.

Densities were estimated on per area and linear bases. The estimated population size of each darter species was divided by the total area of the sampling site to give a per area estimate, and by the total length of the sampling site to give numbers per 100 m of stream.

Additional specimens were also collected at nine other sampling sites so that I could more extensively evaluate species composition, relative abundance, distribution, habitat utilization, and food habits. Five of these sites were located on the main stem of Glover Creek and one site each was located on the East Fork, Pine, Carter, and Cedar creeks. These sites were not enclosed during sampling and Smith-Root Type VII backpack electrofishing units were used to collect darters. Samples were obtained by shocking as much area as possible in a 1 to 2-hour time limit. The shocking unit recorded the total number of seconds that electrical current was actually on and these data were used to estimate sampling effort.

Preference for a particular range of habitat values was determined by comparing use by darters with availability. Habitat availability was determined each season, when actual measurements were possible, by measuring the water depth, water velocity, and substrate type at 1 m intervals along each transect at each site. These point measurements represented average values of depth, velocity, and substrate type for a segment 1 m wide, and extending halfway to the nearest upstream and downstream transects (depicted by the cross-hatched area, Figure 4). Depth was measured using a metric wading rod, water velocity was measured at .6 of the depth using a Pygmy-Gurley current meter, and substrates were classified using the Modified Wentworth Partical Size Scale (Bovee and Cochnauer 1977; Appendix B) and were given a numerical value from 1 to 8. Mixtures of adjacent categories were coded to intermediate values. Surface area of each segment was then equal to length times width. The amount of surface area at each site for each interval of depth, velocity, and substrate type was calculated by summing the areas of those segments for each respective interval of depth, velocity, and substrate type (Orth 1980). During some seasons, high water precluded actual measurements of habitat availability. At these times, stream hydraulics simulation computer programs were used to predict depths, velocities, and substrates along each transect (Main 1978; Bovee and Milhous 1978; Orth 1980).

Actual habitat availability for orangebelly darters was calculated each season at sites 12 and 14(R) from October 1979 to July 1980. During population estimates at these sites, the water depth, water velocity, and substrate type was recorded at each orangebelly darter capture location. In addition, each specimen was measured (total length to the nearest mm) so that I could evaluate differential habitat utilization between juveniles and adults.

Pooled data from both sites were analyzed each season. Fre-

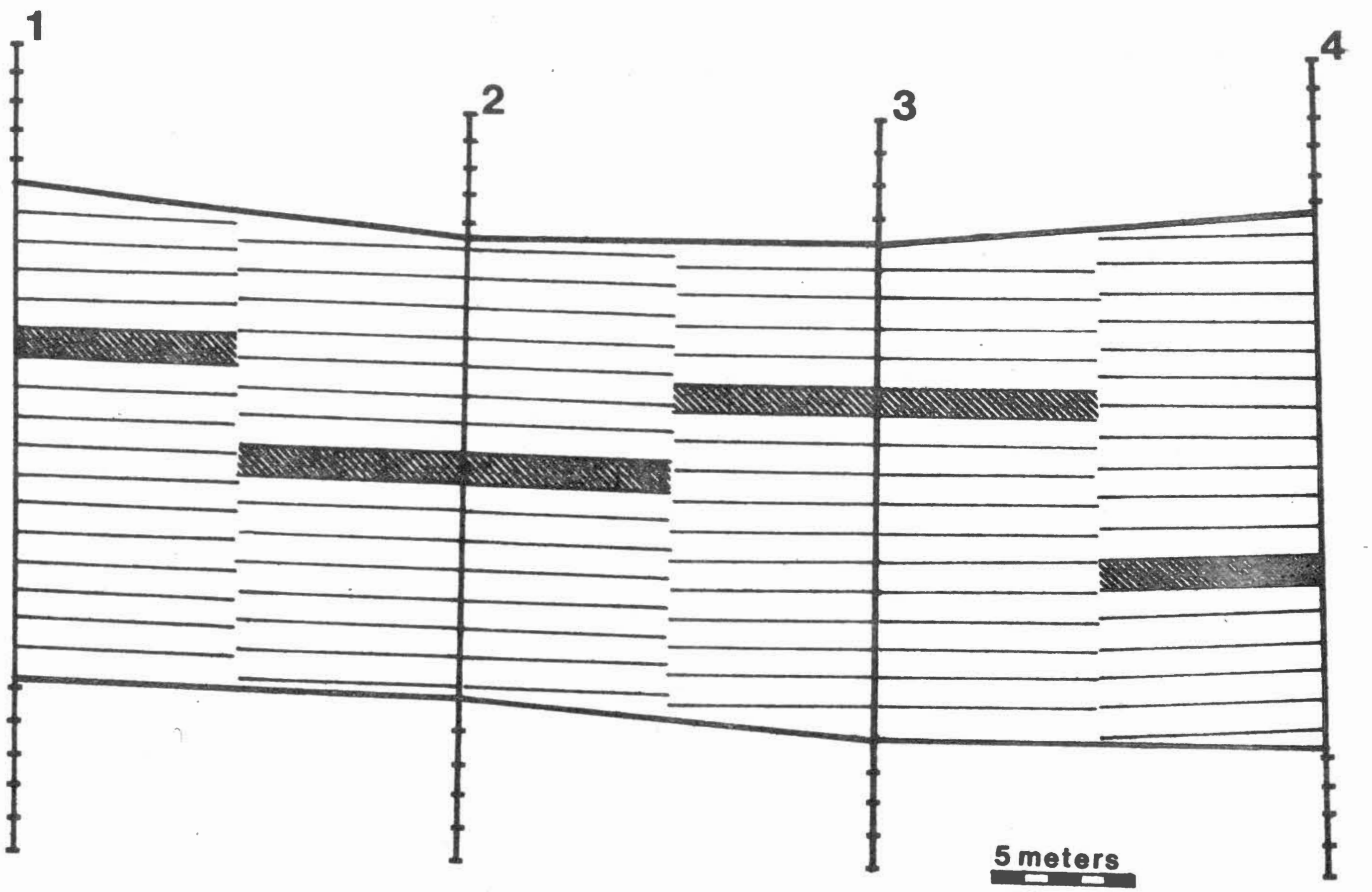

Figure 4. Schematic representation of a sampling site subdivided along each transect. Habitat availability is estimated by summing the surface area of each segment (depicted by crosshatched areas) for each interval of water depth, water velocity, and substrate type (Orth 1980).

quencies of occurrence of orangebelly darters in one-way water depth, water velocity, and substrate tables were multiplied by the ratio of estimated population size to capture number (Orth 1980). The adjusted frequencies were then divided by the surface area sampled at both sites in the respective interval to obtain an estimate of actual density (number/m^2) (Orth 1980). A chi-square goodness of fit test (Conover 1971: 185-187) was used to test the null hypothesis that the distribution of densities along each habitat parameter did not vary from uniform. A significance level of .05 was used to reject the null hypothesis. This procedure was then repeated separately for juveniles and adults. Intervals for which observed values were greater than expected values identified the preferred range and the highest density identified the most preferred interval. A chi-square test of independence (Conover 1971: 154-156) was then used to test the null hypothesis of independence between the distribution of juvenile and adult densities along each habitat parameter. A significance level of .05 was used to reject the null hypothesis.

For other darter species, a composite measure of habitat availability was obtained by summing measurements at each site over all seasons during the study period. Where data on habitat utilization were not sufficient for statistical analysis (johnny darters, dusky darters, and orangethroat darters), the data were pooled over all sites and seasons and frequency distributions for water depth, water velocity, and substrate types were constructed. For those species where data were sufficient for statistical analysis, frequencies in each interval of water depth, water velocity, and substrate type were divided by the composite measure of available area for the respective interval to obtain an estimate of relative density. A chi-square goodness of fit test (Conover 1971) was used to test the null hypothesis that the distribution of densities along each habitat parameter did not vary from uniform. A significance level of .10, rather than .05, was used to reject the null hypothesis since data were combined over all seasons and years. The preferred range was indicated when observed values were greater than expected values and the highest relative density within the preferred range of the habitat parameter identified the most preferred interval. Independence between habitat parameters was tested using a chi-square test of independence for: depth-velocity, depth-substrate, and velocity-substrate (Conover 1971). A significance level of .10 was used to reject the null hypothesis.

Samples of benthic macroinvertebrates were taken in a riffle area at Site 10 each season from October 1979 to July 1980 to estimate food availability for orangebelly darters. A circular depletion sampler (similar to a Hess sampler) was used. Organisms were preserved in the field with 10% formalin and were separated and identified using keys by Usinger (1968), Merritt and Cummins (1978), Pennack (1953), Wiggins (1977), and Edmunds et al. (1976).

Food habits were determined for all species except leopard darters. Food habits of orangebelly darters were determined by collecting a sample of about 50 fish at Site 10 each season from October 1979 to July 1980. Specimens of other darter species were taken at all sampling sites. Stomachs were removed in the laboratory and the contents were identified and counted. Electivity indices (Strauss 1978) were calculated for various items in the diet of juvenile and adult orangebelly darters and chi-square tests of independence

(Conover 1971) were used to test the null hypothesis that diet was independent of age. Juvenile and adult orangebelly darters were distinguished by examining length frequency distributions and scales.

I investigated resource partitioning by calculating niche breadth and niche overlap values using the equations described by Pianka (1973). Interspecific differences in habitat utilization and food habits between logperch, leopard darters, and channel darters were examined. Intraspecific differences between juvenile and adult orangebelly darters were examined similarly.

CHAPTER IV

RESULTS

Species Composition

Seven species of darters were collected from November 1978 to July 1980: orangebelly darter, orangethroat darter, johnny darter, logperch, channel darter, leopard darter, and dusky darter. Number of species present at each site was greatest at Site 1 but decreased abruptly at sites farther upstream (Table 1). Darters most commonly found together, and which constitute the principal species of the darter community, were orangebelly darters, logperch, channel darters, and leopard darters.

Species Distribution

Darters occurred throughout the study area but the distribution of individual species varied considerably. Orangebelly darters were captured at every site (Figure 5A) and leopard darters were captured at every site except Site 4 (Figure 5B). Logperch and channel darters were captured throughout the entire extent of the study area (Figure 5C and 5D, respectively) but were collected primarily in the main stem of Glover Creek and the larger tributaries of the East and West Forks. Johnny darters were present primarily in the lower main stem, although one individual was taken at site 14 in the upper West Fork (Figure 5E). Dusky darters and orangethroat darters were

Table 1. Total catch at each sampling site, the combined total catch, and percent of combined total catch of each darter species collected in Glover Creek from November 1978 to July 1980 (summarized from Appendices C, D and E).

Sampling site	E. radiosum	E. nigrum	E. spectabile	P. caprodes	P. copelandi	P. pantherina	P. sciera	Total
1	516	2	28	3	8	3	9	569
2	889	7	0	12	11	8	0	927
5	547	3	0	5	7	10	0	572
4	504	0	0	1	0	0	0	505
5	246	0	0	1	8	2	0	257
6	190	0	0	0	0	3	0	193
7	614	1	0	5	0	17	0	638
8	307	0	0	0	0	1	0	308
9	216	0	0	0	4	3	0	223
10	448	0	0	0	3	3	0	454
11	1158	0	0	7	10	25	0	1200
12	1033	0	0	2	1	5	0	1041
13	156	0	0	0	0	5	0	161
14	1230	1	0	32	31	34	0	1328
Total	8054	14	28	68	83	119	9	8375
%	96.2	0.2	0.3	0.8	1.0	1.4	0.1	100

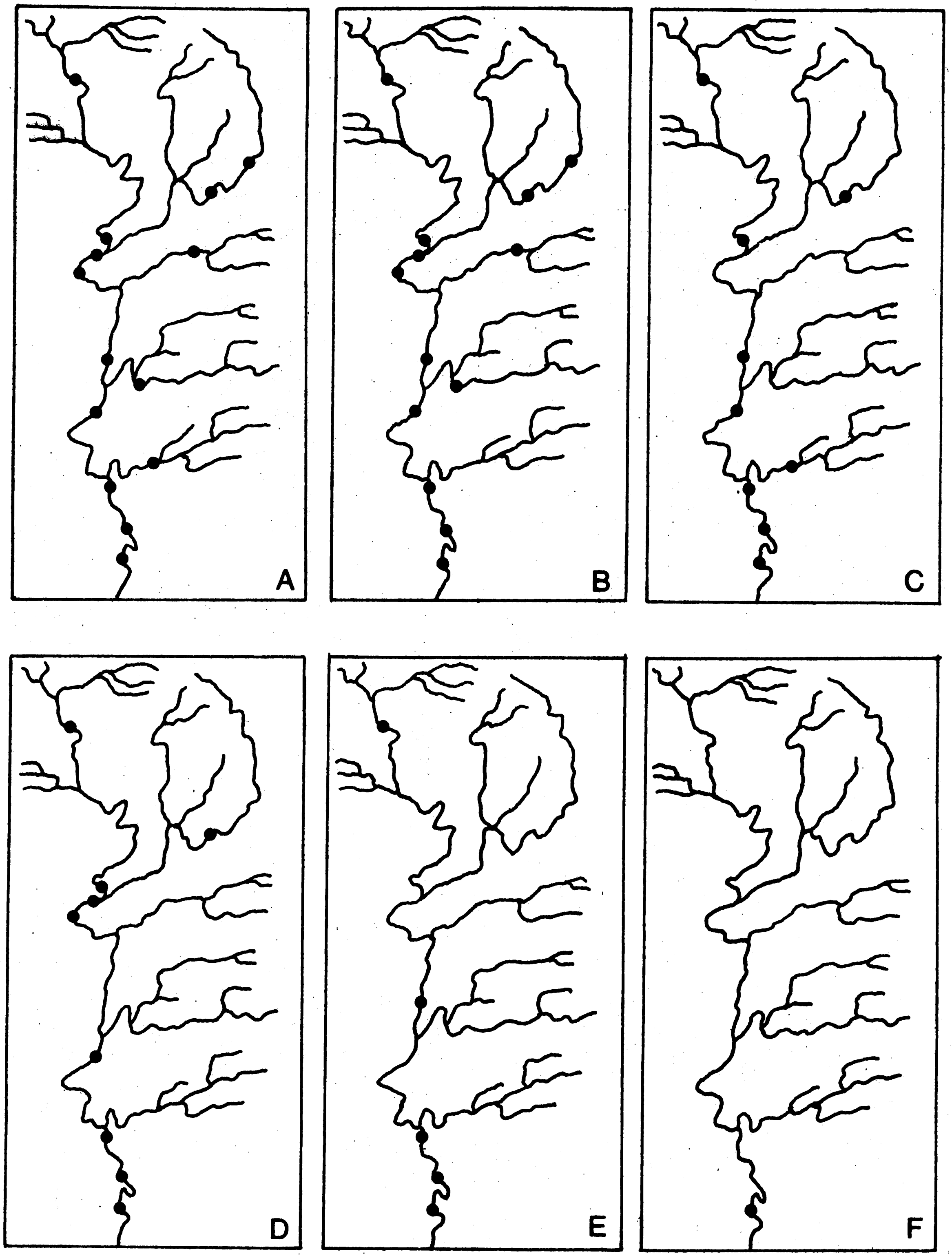

Figure 5. Distribution of darters in Glover Creek, Oklahoma: A) orangebelly darter; B) leopard darter; C) logperch; D) channel darter; E) johnny darter; F) orangethroat and dusky darters.

collected exclusively at Site 1 (Figure 5F).

Relative Abundance

A total of 8,375 darters were collected: 8,054 orangebelly darters, 14 johnny darters, 28 orangethroat darters, 68 logperch, 83 channel darters, 119 leopard darters, and 9 dusky darters (Table 1). Orangebelly darters were the most abundant species at every site and made up approximately 96% of the total catch. Leopard darters were the second most abundant species but made up only a small percentage of the total catch (1.4%). Channel darters (1.0%), logperch (0.8%), and the remaining species (johnny darters, orangethroat darters, and dusky darters) constituted still smaller proportions. Orangethroat darters contributed only 0.3% to the total catch but were the second most abundant species at Site 1.

Species Densities

A total of 41 population estimates were made during the study period: 3 at Site 3, 3 at Site 7, 8 at Site 11(P), 4 at Site 11(R), 8 at Site 14(P), 8 at Site 14(R), and 7 at Site 12. Sites 3 and 7 were located on the main stem of Glover Creek and population estimates could only be made at these locations during periods of low water levels, primarily summer and fall.

Orangebelly darters had the largest populations and the highest densities. Densities ranged from $1.0558/m^2$ (104/100 m) at Site 11(R) in January 1979 to $2.1678/m^2$ (1041/100 m) at Site 12 in July 1980 (Table 2), for riffle sites. Mean densities for riffle sites ranged from $.7935/m^2$ at Site 7 to $1.0871/m^2$ at Site 12. Densities in pool

Table 2. Population estimates and densities (N/m^2) of orangebelly darters in Glover Creek, Oklahoma from November 1978 to July 1980 (summarized from Appendix E).

	Sampling site													
	11(R)		11(P)		14(R)		14(P)		12		7		3	
Season	N	D	N	D	N	D	N	D	N	D	N	D	N	D
1978														
Nov.	225	1.2200	34	.0553	145	1.4948	2	.0032	*	*	*	*	*	*
1979														
Jan.	44	.0558	4	.0042	109	.2233	5	.0075	*	*	*	*	*	*
Mar.-Apr.	511	.7373	21	.0225	190	.3893	4	.0060	216	.8150	*	*	*	*
Jun.-Jul.	619	1.1613	61	.0680	272	.9891	21	.0324	199	.9476	489	.6581	131	.4352
Oct.	*	*	*	*	406	1.7424	*	*	258	1.2585	*	*	*	*
1980														
Jan.	*	*	*	*	314	.8945	*	*	78	.2785	*	*	*	*
Mar.	*	*	*	*	478	1.3579	*	*	247	1.0555	*	*	*	*
Jul.	*	*	299	.4124	40	.1951	55	.0841	323	.1678	144	.9290	305	1.5099
$\bar{X}$	350	.7943	84	.1124	244	.9108	17	.0266	220	1.0871	316	.7935	218	.9725

*Estimate of population size or density was not made.

sites ranged from $.0032/m^2$ (4/100 m) at Site 14(P) in October 1978 to $.4124/m^2$ (672/100 m) at Site 11 (P). Mean densities between pool sites ranged from $.266/m^2$ at Site 14(P) to $.1124/m^2$ at Site 11(P).

Densities of leopard darters, logperch, and channel darters were considerably lower than those of orangebelly darters but were relatively similar with one another. Leopard darters were captured in 19 of the 41 population estimates. Densities ranged from 0 to $.0170/m^2$, with the higher densities occurring most often in pool sites (Table 3). However, the highest density estimated ($.0170/m^2$) was in a riffle site, 14(R), in March 1980. Logperch were also captured during 19 estimates. Densities ranged from 0 to $.0150/m^2$ (Table 4), and reached their highest densities in pools. Channel darters were captured during 15 estimates, and again, captures were more frequent in pools. Densities ranged from 0 to $.0512/m^2$, but generally were lower than those of both leopard darters and logperch (Table 5). Johnny darters, orangethroat darters, and dusky darters were never captured during population estimates.

Habitat

Dusky Darter

Dusky darters were captured in areas characterized by shallow water 8 to 40 cm deep (Figure 6A), water velocities ranging from 0 to 30 cm/s (Figure 6B), and substrates such as sand and gravel (Figure 6C). Captures were most frequent close to shore where vegetation was present and organic debris had accumulated.

Table 3. Population estimates and densities (N/m^2) of leopard darters in Glover Creek, Oklahoma, from November 1978 to July 1980 (summarized from Appendix E).

Season	Sampling site													
	11(R)		11(P)		14(R)		14(P)		12		7		3	
	N	D	N	D	N	D	N	D	N	D	N	D	N	D
1978														
Nov.	0	.0000	2	.0032	0	.0000	0	.0000	*	*	*	*	*	*
1979														
Jan.	1	.0013	0	.0000	0	.0000	2	.0030	2	.0062	*	*	*	*
Mar.-Apr.	0	.0000	0	.0000	1	.0020	1	.0015	0	.0000	*	*	*	*
Jun.-Jul.	0	.0000	12	.0134	0	.0000	1	.0015	0	.0000	1	.0013	0	.0000
Oct.	*	*	5	.0060	0	.0000	0	.0000	0	.0000	2	.0024	0	.0000
1980														
Jan.	*	*	0	.0000	4	.0114	11	.0165	2	.0071	*	*	*	*
Mar.	*	*	6	.0064	6	.0170	7	.0103	1	.0043	*	*	*	*
Jul.	*	*	0	.0000	0	.0000	3	.0045	0	.0000	0	.0000	0	.0000
$\bar{X}$		.0004		.0036		.0038		.0047		.0017		.0012		.0000

*Estimate of population size or density was not made.

Table 4. Population estimates and densities (N/m^2) of logperch in Glover Creek, Oklahoma, from November 1978 to July 1980 (summarized from Appendix E).

	Sampling sites													
	11(R)		11(P)		14(R)		14(P)		12		7		3	
Season	N	D	N	D	N	D	N	D	N	D	N	D	N	D
1978														
Nov.	0	.0000	1	.0016	0	.0000	1	.0016	*	*	*	*	*	*
1979														
Jan.	0	.0000	0	.0000	0	.0000	0	.0000	0	.0000	*	*	*	*
Mar.-Apr.	1	.0014	0	.0000	4	.0082	4	.0060	0	.0000	*	*	*	*
Jun.-Jul.	0	.0000	2	.0022	3	.0109	1	.0015	0	.0000	4	.0054	1	.0033
Oct.	*	*	1	.0012	0	.0000	0	.0000	0	.0000	1	.0012	0	.0000
1980														
Jan.	*	*	1	.0010	3	.0085	10	.0150	0	.0000	*	*	*	*
Mar.	*	*	0	.0000	0	.0000	6	.0088	2	.0085	*	*	*	*
Jul.	*	*	1	.0014	0	.0000	2	.0030	0	.0000	0	.0000	0	.0000
$\bar{X}$		.0004		.0010		.0034		.0044		.0012		.0033		.0011

*Estimates of population size or density was not made.

Table 5. Population estimates and densities (N/m^2) of channel darters in Glover Creek, Oklahoma, from November 1978 to July 1980 (summarized from Appendix E).

	Sampling sites													
	11(R)		11(P)		14(R)		14(P)		12		7		3	
Season	N	D	N	D	N	D	N	D	N	D	N	D	N	D
<u>1978</u>														
Nov.	0	.0000	1	.0016	0	.0000	0	.0000	*	*	*	*	*	*
<u>1979</u>														
Jan.	0	.0000	0	.0000	0	.0000	0	.0000	0	.0000	*	*	*	*
Mar.-Apr.	0	.0000	2	.0022	25	.0512	4	.0060	0	.0000	*	*	*	*
Jun.-Jul.	1	.0019	4	.0044	0	.0000	1	.0015	0	.0000	0	.0000	0	.0000
Oct.	*	*	1	.0012	0	.0000	1	.0015	0	.0000	0	.0000	0	.0000
<u>1980</u>														
Jan.	*	*	1	.0010	0	.0000	0	.0000	0	.0000	*	*	*	*
Mar.	*	*	1	.0011	2	.0057	1	.0015	1	.0043	*	*	*	*
Jul.	*	*	0	.0000	0	.0000	1	.0015	0	.0000	0	.0000	0	.0000
$\bar{X}$		.0005		.0014		.0071		.0015		.0006		.0000		.0000

*Estimate of population size or density was not made.

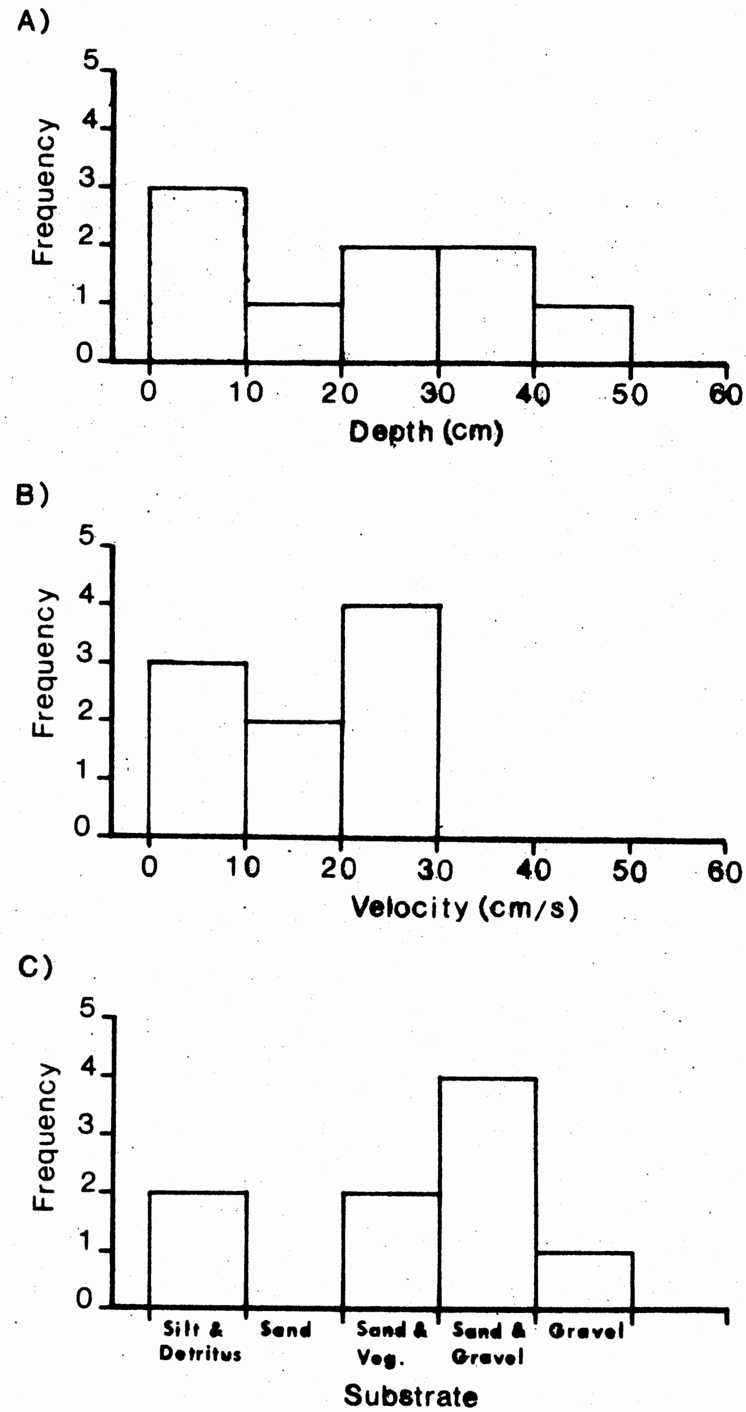

Figure 6. Habitat use by dusky darters in Glover Creek, Oklahoma: A) frequency distribution in 10 cm water depth intervals; B) frequency distribution in 10 cm/s water velocity intervals; C) frequency distribution over various substrate types.

Johnny Darter

Johnny darters were captured over a relatively wide range of habitat condition. However, they tended to be most abundant in pools or in calm areas along the shores where water was 21 to 30 cm deep over gravel substrate (Figure 7A, B, and C).

Orangethroat Darter

Orangethroat darters were captured most frequently in shallow riffles at depth from 6 to 30 cm (Figure 8A) and water velocities less than 30 cm/s (Figure 8A), although they were present in areas having water velocities as high as 92 cm/s. This species typically occurred over gravel and gravel-rubble substrates (Figure 9).

Logperch

Logperch were captured most frequently in pools, although in spring they were occasionally taken in deeper riffles and runs. Captures were made at depths ranging from 17 to 106 cm (Table 6) but preferred ($P<.001$)[1] depths $\geq$ 40 cm. Relative density was highest at depths $\geq$ 80 cm. Logperch were captured in areas having water velocities ranging from 0 to 59 cm/s (Table 6) but preferred ($P<.10$) velocities $\leq$ 19 cm/s. Logperch were captured over a relatively wide range of substrates (Table 6), but preferred ($P<.10$) rubble-boulder, boulder, and boulder-bedrock. Relative densities were highest over boulder substrate. Water velocity was the only habitat variable

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[1]All statistical tests concerning habitat preferences are included as Appendix F.

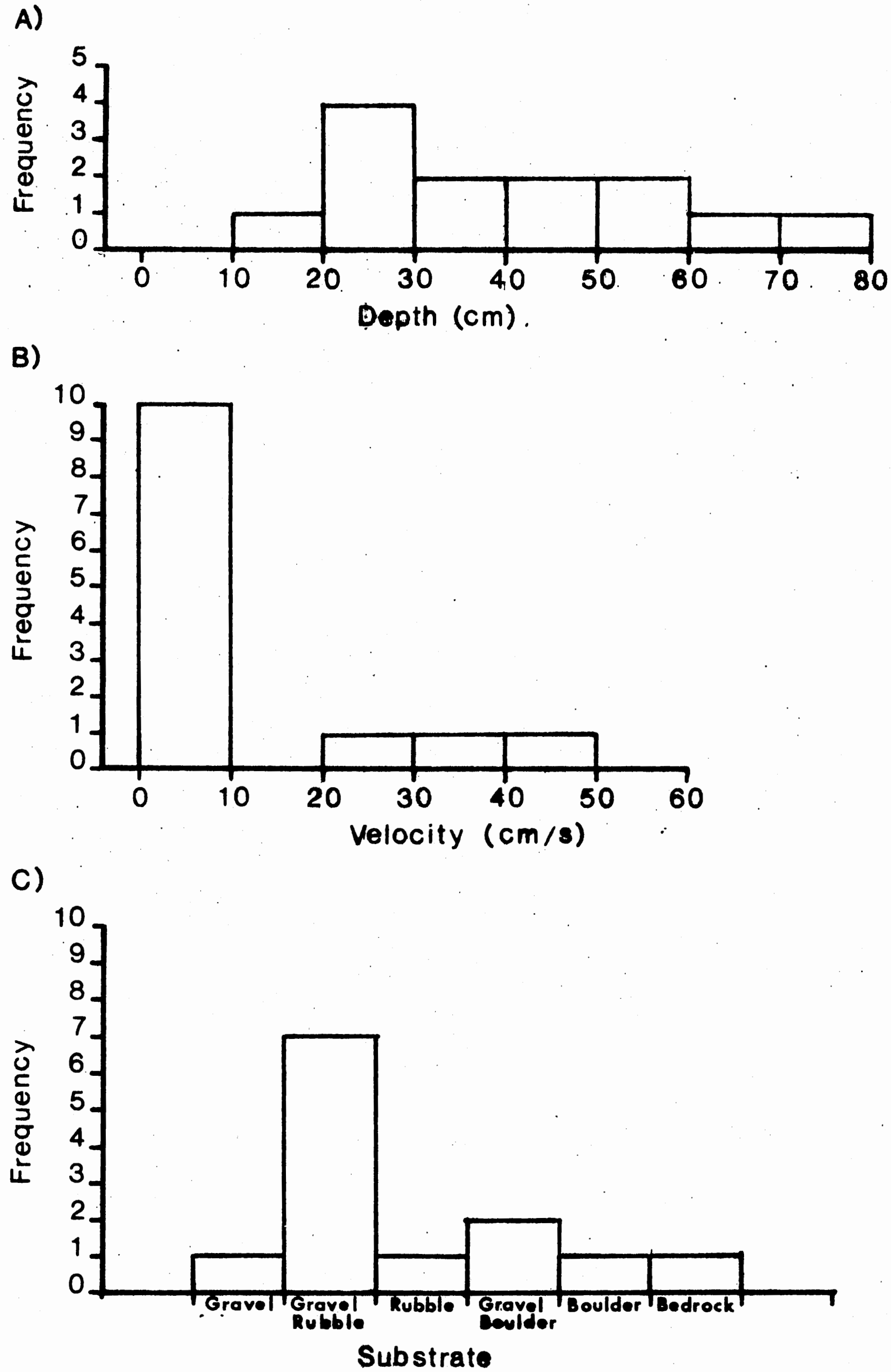

Figure 7. Habitat use by johnny darters in Glover Creek, Oklahoma: A) frequency distribution in 10 cm water depth intervals; B) frequency distribution in 10 cm/s water velocity intervals; C) frequency distribution over various substrate types.

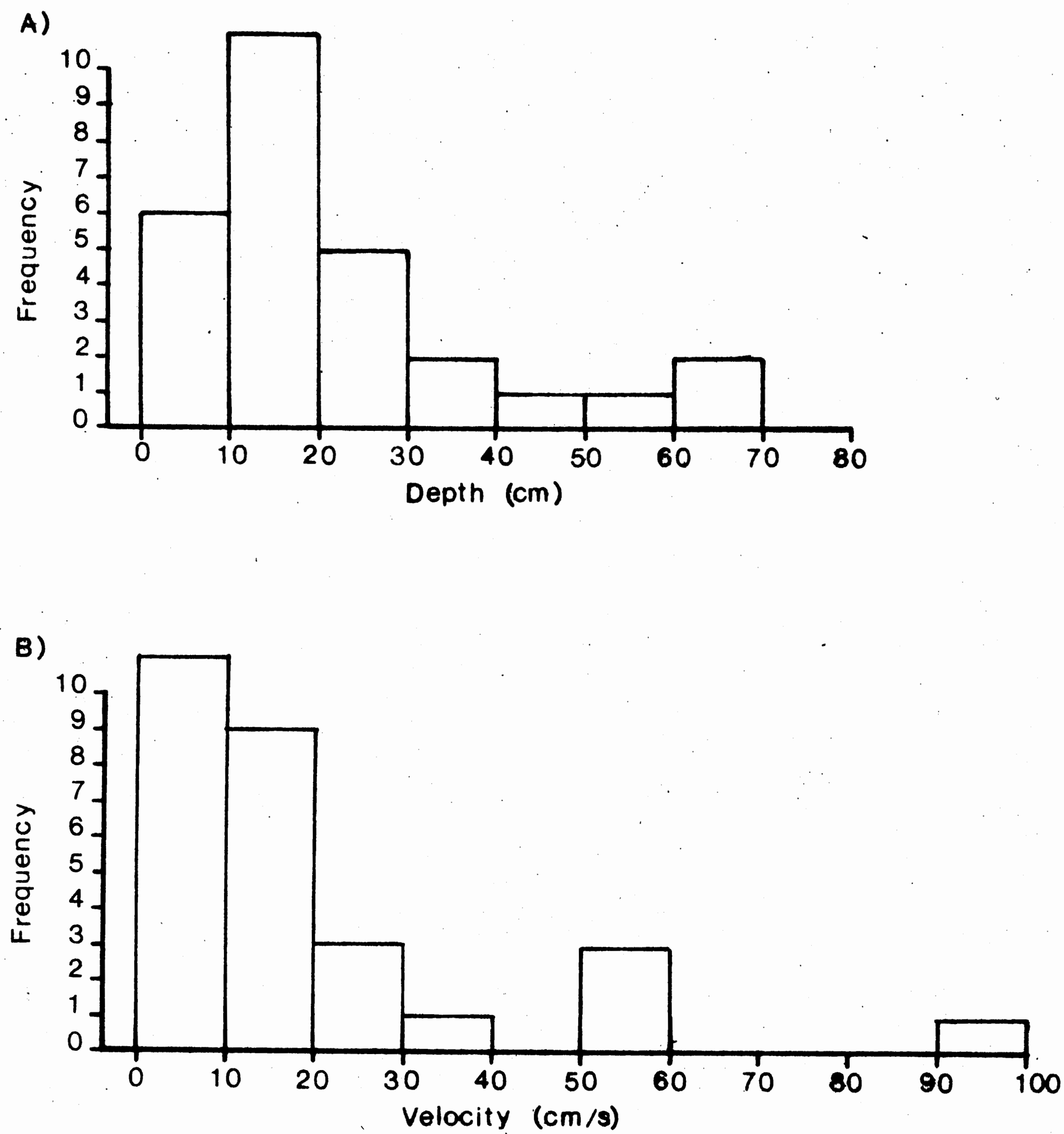

Figure 8. Habitat use by orangethroat darters in Glover Creek, Oklahoma: A) frequency distribution in 10 cm water depth intervals; B) frequency distribution in 10 cm/s water velocity intervals.

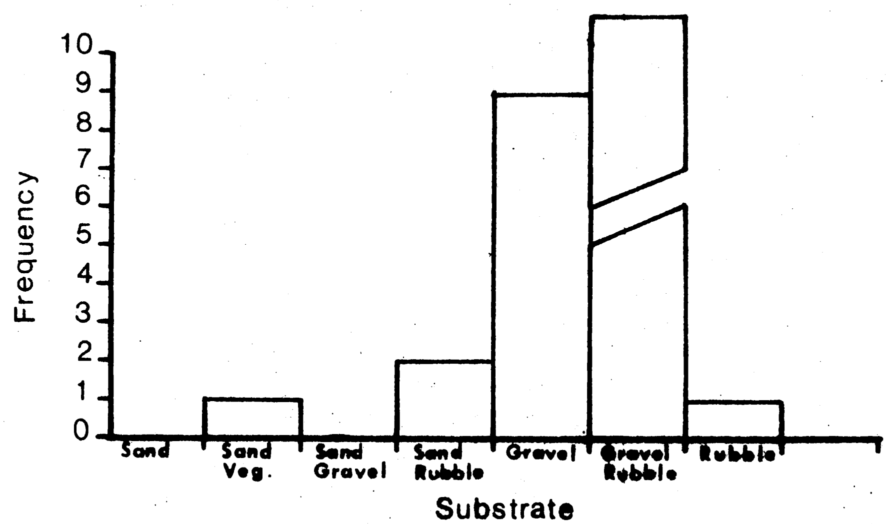

Figure 9. Habitat use by orangethroat darters in Glover Creek, Oklahoma: frequency distribution over various substrate types.

Table 6. Frequency of occurrence, area available, and relative density of logperch in various water depth, water velocity, and substrate type intervals.

Habitat variable	Area (m^2)	Frequency (N)	Relative density (N/m^2)
Depth interval (cm)			
0 - 19	9133.3	1	.00011
20 - 39	9582.6	12	.00125
40 - 59	5925.7	15	.00253
60 - 79	3467.1	10	.00288
$\geq$ 80	3540.9	11	.00311
	T=25.8 (d.f.=4) P<.001		
Velocity interval (cm/s)			
0 - 19	25416.0	47	.00185
20 - 39	3442.4	1	.00029
40 - 59	1602.1	1	.00062
60 - 79	830.5	0	.00000
$\geq$ 80	347.1	0	.00000
	T=8.9 (d.f.=4) P<.10		
Substrate type			
4.0	398.7	0	.00000
4.5	275.3	0	.00000
5.0	407.7	1	.00245
5.5	6641.2	7	.00105
6.0	4591.9	5	.00109
6.5	10123.2	16	.00158
7.0	5127.8	14	.00273
7.5	1553.0	3	.00193
8.0	2531.1	3	.00118
	T=8.8 (d.f.=8) P<.10		

tested that was completely independent of other variables. Depth and substrate were interdependent ($P<.025$), so shallow water was associated with smaller substrates and deeper water associated with larger substrates.

Channel Darter

Channel darters tended to be most common in pools and deep runs, but were also regularly taken in riffles in spring. Captures occurred at depths from 5 to 90 cm (Table 7) and did not prefer any particular depth. However, relative densities were generally higher at depths ranging from 20 to 79 cm. Water velocities at capture locations ranged from 0 to 73 cm/s (Table 7) but significant preference ($P<.025$) was exhibited for water velocities from 20 to 59 cm/s (Table 7). Channel darters occurred over many substrates (Table 7) but preferred ($P<.005$) sand-gravel, gravel, gravel-rubble, and bedrock. Relative densities were highest over the smaller substrate types. Of the habitat variables tested, only substrate and velocity showed an independent relationship ($P<.25$). Depth was significantly dependent upon velocity ($P<.05$) and substrate ($P<.005$).

Leopard Darter

Leopard darters occurred most frequently in pools, although in spring and winter several captures were made in riffles and runs. Leopard darters were captured at depths ranging from 8 to 122 cm (Table 8) but exhibited a significant preference ($P<.001$) for depths ranging from 20 to 79 cm. The highest densities occurred from 60 to 79 cm. Leopard darters were captured in areas having water velocities

Table 7. Frequency of occurrence, area available, and relative density of channel darters in various water depth, water velocity, and substrate type intervals.

Habitat variable	Area (m^2)	Frequency (N)	Relative density (N/m^2)
Depth interval (cm)			
0 - 19	9133.3	8	.00087
20 - 39	9582.6	19	.00198
40 - 59	5925.7	11	.00185
60 - 79	3467.1	8	.00231
≥ 80	3540.9	2	.00056
	T=7.35 (d.f.=4) P<.25		
Velocity interval (cm/s)			
0 - 19	25416.0	30	.00118
20 - 39	3442.4	11	.00319
40 - 69	1602.1	6	.00374
60 - 79	830.5	1	.00120
≥ 80	347.1	0	.00000
	T=13.16 (d.f.=4) P<.025		
Substrate type			
4.0	398.7	0	.00000
4.5	275.3	3	.01089
5.0	407.7	3	.00736
5.5	6641.2	17	.00256
6.0	4591.9	5	.00109
6.5	10123.2	5	.00049
7.0	5127.8	4	.00078
7.5	1553.0	1	.00064
8.0	2531.1	8	.00361
	T=22.9 (d.f.=8) P<.005		

Table 8. Frequency of occurrence and relative density of leopard darters in various water depth, water velocity, and substrate type intervals.[1]

Variable and interval	Area available	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
	T = 37.00 (4 d.f.) P<.001		
Velocity (cm/s)			
0 - 19	25,416.066	116	.00456
20 - 39	3,442.520	10	.00290
49 - 59	1,602.170	3	.00187
60 - 79	830.490	0	.00000
≥ 80	347.150	1	.00288
	T = 7.96 (4 d.f.) P<.10		
Substrate			
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	5	.00322
8.0	2,531.153	5	.00197
	T = 14.61 (8 d.f.) P<.10		

[1]Twenty leopard darters collected by Don Orth (1980) in Glover Creek from August 1977 to July 1978 are included in the above analysis.

ranging from 0 to 96 cm/s (Table 8) but preferred ($P<.10$) velocities from 0 to 19 cm/s. A wide variety of substrates were used by leopard darters, although they preferred ($P<.10$) rubble, rubble-boulder, and boulder substrates. Relative densities were highest over boulders. Water velocity was the only habitat variable tested that was completely independent of other variables measured. Conversely, depth and substrate were not independent ($P<.025$) of one another.

Orangebelly Darter

Orangebelly darters were most abundant in riffles and runs during every season, although younger individuals were occasionally taken in the shallow shoreline areas of pools adjacent to riffles. Adults did, however, show a tendency to move out of riffles into deeper water during periods of excessively low water.

During October 1979, water levels were low, surface flow was reduced, and in riffles the larger boulder substrates were partially exposed. Under these conditions, orangebelly darters preferred water deeper than 10 cm ($P<.001$), velocities less than 9 cm/s ($P<.05$), and rubble-boulder substrates ($P<.001$) (Table 9). Densities were highest at depths $\geq$ 20 cm, water velocities $\leq$ 9 cm/s, and over rubble substrate.

During January 1980, water levels were higher than the preceeding fall with considerable flow over riffle areas. Under these conditions, orangebelly darters preferred water deeper than 20 cm ($P<.001$), water velocities between 10 and 39 cm/s and $\geq$ 50 cm/s ($P<.001$), and gravel-rubble, rubble, and boulder substrates ($P<.001$) (Table 10).

During March 1980, water levels continued to be relatively high,

Table 9. Total area sampled, frequency of capture, and density of orangebelly darters in various intervals of water depth, water velocity, and substrate types in Glover Creek, Oklahoma during October 1979.

Habitat variable	Area sampled (m^2)	Frequency (N)	Density N/m^2
Depth (cm)			
0 - 9	233.8	285	1.219
10 - 19	151.0	314	2.079
≥ 20	54.1	116	2.144
		T = 51.79 P<.001	
Velocity (cm/s)			
0 - 9	385.4	598	1.552
≥ 10	53.5	64	1.196
		T = 3.89 P<.05	
Substrate			
5.5	22.7	30	1.321
6.0	83.7	210	2.509
6.5	186.3	305	1.637
7.0-7.5	77.1	60	.778
8.0	70.2	53	.755
		T = 112.69 P<.001	

Table 10. Total area sampled, frequency of capture, and density of orangebelly darters in various intervals of water depth, water velocity, and substrate types in Glover Creek, Oklahoma during January 1980.

Habitat variable	Area sampled (m^2)	Frequency (N)	Density N/m^2
Depth (cm)			
0 - 9	114.2	6	.052
10 - 19	166.2	88	.529
20 - 29	254.8	213	.836
30 - 39	89.9	77	.856
≥ 40	6.1	8	1.311
		T = 94.94 P<.001	
Velocity (cm/s)			
0 - 9	206.5	83	.402
10 - 19	145.7	107	.734
20 - 29	135.8	94	.692
30 - 39	46.0	51	1.108
40 - 49	67.3	20	.297
50 - 59	21.9	20	.913
60 - 69	2.3	5	2.174
≥ 70	5.5	10	1.818
		T = 75.07 P<.001	
Substrate			
5.0-5.5	4.5	29	6.444
5.0	160.3	141	.879
6.5	316.4	153	.483
7.0-7.5	95.6	64	.669
8.0	54.4	5	.092
		T = 307.89 P<.001	

but were somewhat lower than during the previous winter. Under these conditions, orangebelly darters preferred areas 10 to 29 cm deep ($P<.001$), water velocities from 20 to 29 cm/s and $\geq$ 40 cm/s ($P<.001$), and rubble and boulder substrates ($P<.001$) (Table 11).

During July 1980, water levels were lower than during any preceding season. Surface flow was unmeasurable and extensive areas of substrate in riffle areas were completely exposed. Under these conditions, orangebelly darters preferred water $\geq$ 10 cm deep ($P<.001$) and boulder substrates ($P<.001$) (Table 12).

Food Habits

Benthic Macroinvertebrates

Benthic macroinvertebrates collected in Glover Creek included members of the phyla Nematoda, Annelida, Mollusca, and the classes Crustacea and Insecta. Aquatic insects comprised approximately 90% of the total number of organisms collected. Abundance (total numbers) of organisms varied seasonally as follows: 4235 in October 1979; 1906 in January 1980; 4485 in March 1980; and 8686 in July 1980 (Table 13). However, diversity of benthics and total numbers collected were not related. Diversity was highest during those seasons when total numbers were highest (July 1980) and lowest (January 1980).

Total numbers of benthic invertebrates were distributed approximately as follows: ephemeropterans constituted 15 to 31%, mostly represented by *Stenonema* *sp*., *Heptagenia* *sp*., *Isonychia* *sp*., and *Caenis* *sp*.; Plecoptera constituted 6 to 28%, mostly represented by *Neoperla* *sp*.; Trichoptera constituted 3 to 21%, mostly represented by

Table 11. Total area sampled, frequency of capture, and density of orangebelly darters in various intervals of water depth, water velocity, and substrate types in Glover Creek, Oklahoma during March 1980.

Habitat variable	Area sampled (m^2)	Frequency (N)	Density N/m^2
Depth (cm)			
0 - 9	175.7	32	.182
10 - 19	225.1	354	1.573
20 - 29	121.8	288	2.364
$\geq$ 30	36.6	48	1.311
		T = 289.99 P<.001	
Velocity (cm/s)			
0 - 9	263.9	333	1.262
10 - 19	186.3	218	1.170
20 - 29	52.0	76	1.461
30 - 39	37.7	34	.902
40 - 49	12.5	25	2.000
$\geq$ 40	7.1	38	5.352
		T = 103.08 P<.001	
Substrate			
6.0	109.6	143	1.304
6.5	263.2	307	1.166
7.0	71.6	200	2.793
7.5	70.5	35	.496
8.0	44.9	30	.668
		T = 178.24 P<.001	

Table 12. Total area sampled, frequency of capture, and density of orangebelly darters in various intervals of water depth, water velocity, and substrate types in Glover Creek, Oklahoma during July 1980.

Habitat variable	Area sampled (m^2)	Frequency (N)	Density N/m^2
Depth (cm)			
0 - 9	277.7	270	.972
10 - 19	71.2	74	1.039
$\geq$ 20	6.1	20	3.278
		T = 31.48 P<.001	
Velocity (cm/s)			
$\geq$ 5	355.0	363	1.432
Substrate			
6.0	20.7	16	.773
6.5	239.6	159	.663
7.0	6.8	152	22.352
7.5	34.3	15	.437
8.0	53.6	21	.392
		T = 3114.74 P<.001	

Table 13. Frequency (N) and relative frequency (R.F.) of benthic macroinvertebrates collected in Glover Creek, Oklahoma from October 1979 to July 1980.

Taxa	Oct. 1979		Jan. 1980		Mar. 1980		Jul. 1980	
	N	R.F.	N	R.F.	N	R.F.	N	R.F.
Nematoda	117	.027	2	.001	8	.001	0	.000
Annelida								
Lumbriculidae	322	.076	239	.125	493	.109	116	.013
Piscicola sp.	0	.000	0	.000	1	*	0	.000
Mollusca								
Gastropoda								
Ferrissia sp.	4	*	1	*	0	.000	1	*
Physidae	0	.000	0	.000	1	*	0	.000
Acarina	0	.000	0	.000	48	.010	0	.000
Crustacea								
Amphipoda								
Hyallela sp.	2	*	3	.001	0	.000	0	.000
Isopoda								
Lirceus sp.	0	.000	0	.000	1	*	2	*
Insecta								
Ephemeroptera	768	.181	340	.178	679	.151	2719	.313
Baetisca sp.	3	*	2	.001	4	*	0	.000
Stenonema sp.	374	.088	201	.105	213	.047	667	.076
Stenacron sp.	69	.016	1	*	21	.004	174	.020
Heptagenia sp.	0	.000	10	.005	10	.002	294	.033
Rithrogenia sp.	0	.000	0	.000	12	.002	0	.000
Isonychia sp.	109	.025	39	.020	14	.003	302	.034
Baetis sp.	3	*	8	.004	104	.023	33	.003
Pseudocloeon sp.	1	*	61	.032	266	.059	7	*

Table 13. Continued.

Taxa	Oct. 1979 N	Oct. 1979 R.F.	Jan. 1980 N	Jan. 1980 R.F.	Mar. 1980 N	Mar. 1980 R.F.	Jul. 1980 N	Jul. 1980 R.F.
Ephemeroptera (Cont'd)								
Centroptilium sp.	0	.000	0	.000	0	.000	2	*
Caenis sp.	32	.007	7	.003	17	.003	293	.033
Tricorythodes sp.	2	*	0	.000	0	.000	32	.003
Ephemerella sp.	4	*	1	*	12	.002	0	.000
Leptophlebia sp.	169	.039	10	.005	6	.001	0	.000
Choroterpes sp.	0	.000	0	.000	0	.000	507	.058
Hexagenia sp.	1	*	0	.000	0	.000	225	.026
Ephemera sp.	1	*	0	.000	0	.000	0	.000
Ephron sp.	0	.000	0	.000	0	.000	183	.021
Odonata								
Argia sp.	75	.017	7	.003	12	.002	32	.003
Gomphidae	0	.000	0	.000	0	.000	20	.003
Plecoptera	272	.064	540	.283	490	.109	693	.079
Neoperla sp.	231	.054	42	.022	227	.050	668	.077
Acroneuria sp.	4	*	8	.004	6	.001	25	.002
Perlesta sp.	0	.000	0	.000	189	.042	0	.000
Taeniopteryx sp.	37	.008	34	.017	0	.000	0	.000
Strophopteryx sp.	0	.000	126	.066	0	.000	0	.000
Hydroperla sp.	0	.000	22	.011	2	*	0	.000
Isoperla sp.	0	.000	0	.000	34	.007	0	.000
Allocapnia sp.	0	.000	307	.161	1	*	0	.000
Nemura sp.	0	.000	0	.000	18	.004	0	.000
Chloroperlidae	0	.000	0	.000	5	.001	0	.000
Unidentified	0	.000	1	*	8	.001	0	.000
Hemiptera								
Veliidae	0	.000	0	.000	0	.000	1	*
Unidentified	2	*	0	.000	0	.000	0	.000

Table 13. Continued.

Taxa	Oct. 1979 N	Oct. 1979 R.F.	Jan. 1980 N	Jan. 1980 R.F.	Mar. 1980 N	Mar. 1980 R.F.	Jul. 1980 N	Jul. 1980 R.F.
Megaloptera								
Corydalus sp.	39	.009	25	.013	55	.012	114	.013
Sialis sp.	0	.000	0	.000	0	.000	11	.001
Trichoptera	824	.194	63	.033	240	.053	1838	.211
Chimarra sp.	708	.167	27	.014	120	.026	774	.008
Wormaldia sp.	0	.000	0	.000	2	*	0	.000
Ceraclea sp.	1	*	0	.000	0	.000	0	.000
Dibusa sp.	0	.000	21	.011	0	.000	0	.000
Hydroptilia sp.	0	.000	1	*	25	.005	0	.000
Stactobiella sp.	0	.000	0	.000	3	*	0	.000
Helicopsyche sp.	1	*	1	*	1	*	31	.003
Hydatophylax sp.	6	.001	0	.000	0	.000	0	.000
Agapetus sp.	0	.000	1	*	34	.007	0	.000
Rhyacophila sp.	0	.000	1	*	35	.007	0	.000
Hydropsyche sp.	0	.000	1	*	0	.000	28	.003
Neuroclipsis sp.	0	.000	1	*	0	.000	0	.000
Micrasema sp.	0	.000	0	.000	8	.001	0	.000
Polycentropus sp.	0	.000	0	.000	0	.000	8	*
Nyctophylax sp.	0	.000	0	.000	0	.000	1	*
Oecetis sp.	0	.000	0	.000	0	.000	1	*
Unidentified	108	.025	9	.004	12	.002	**995	.114
Lepidoptera								
Paragyractis sp.	6	.001	0	.000	10	.002	168	.019
Coleoptera	1690	.400	501	.262	2069	.461	2752	.317
Stenelmis sp.								
Larvae	1457	.344	364	.191	1840	.410	2196	.252
Adults	135	.031	103	.054	203	.045	346	.039

Table 13. Continued.

Taxa	Oct. 1979 N	Oct. 1979 R.F.	Jan. 1980 N	Jan. 1980 R.F.	Mar. 1980 N	Mar. 1980 R.F.	Jul. 1980 N	Jul. 1980 R.F.
Coleoptera (Cont'd)								
Microcylleopus sp.	4	*	1	*	2	*	194	.022
Heterelmis sp.	19	.004	3	*	2	*	6	*
Dubiraphia sp.	1	*	0	.000	2	*	1	*
Psephenus sp.	72	.017	29	.015	19	.004	7	*
Berosus sp.	1	*	0	.000	0	.000	0	.000
Helichus sp.	1	*	1	*	1	*	2	*
Diptera	114	.027	185	.097	378	.084	227	.026
Tabanus sp.	13	.003	2	.001	11	.002	12	.001
Hexatoma sp.	21	.005	18	.009	40	.009	73	.008
Chironomidae	35	.008	121	.063	277	.061	141	.016
Simulium sp.	40	.009	40	.021	31	.007	0	.000
Atrichopogon sp.	1	*	0	.000	0	.000	0	.000
Empididae	3	*	0	.000	18	.004	8	.000
Dolichpodidae	1	*	0	.000	0	.000	0	.000
Tipula sp.	0	.000	4	.002	0	.000	0	.000
Unidentified	0	.000	0	.000	1	*	1	*
Total	4235		1906		4485		8686	
Diversity (B)	5.928		9.581		5.041		9.165	

*Less than .001

**Unidentified Hydroptilidae

Chimarra sp. and the family Hydroptilidae; Diptera constituted 2 to 9%, mostly represented by Chironomidae and Simulium sp.; Coleoptera, mostly the larval form of Stenelmis sp., constituted 26 to 46%. Other orders present in low numbers included Hemiptera, Odonata, Lepidoptera, and Megaloptera.

Johnny Darter

The major food items in the stomachs of johnny darters were microcrustaceans, Cladocera (43%) and copepods (10%), and aquatic waterbears, Microbiotus sp. (39%). Several species of aquatic insects were present in stomachs but contributed only 5% to the diet (Table 14).

Dusky Darter

Aquatic insects were the primary food items found in the stomachs of dusky darters (97%) (Table 15). Ephemeropterans composed 80%, primarily Pseudocloeon sp., and trichopterans and plecopterans contributed 14% and 3%, respectively.

Orangethroat Darter

Chironomids were the most numerous items, 64%, in the stomachs of orangethroat darters. Ephemeropterans were the only other aquatic insects present, constituting 19%. Cladocera and copepods contributed 6% and 3%, respectively (Table 16).

Logperch

Chironomids were the most common items found in the stomachs of logperch (Table 17). Dipterans composed 54% of the total,

Table 14. Frequency and relative frequency (percentage of total number) of various food items found in the diet of johnny darters[1] collected in Glover Creek, Oklahoma from November 1978 to July 1980.

Food item	Frequency	Relative frequency
Tartigrada		
Microbiotus sp.	45	.39
Unidentified	1	*
Hydracarina	2	.02
Rototaria	1	*
Copepoda	12	.10
Cladocera	50	.43
Ehphemeroptera		
Pseudocloeon sp.	1	*
Diptera		
Chironomidae	3	.03
Simulium sp.	1	*
Total	116	

[1]Number of stomachs containing food = 2 (TL = 41 mm to 47 mm).

*Constitutes less than .01.

Table 15. Frequency and relative frequency (percentage of total number) of various food items found in the diet of dusky darters* collected in Glover Creek, Oklahoma from November 1978 to July 1980.

Food item	Frequency	Relative frequency
Gastropoda	1	.03
Ephemeroptera		
Baetis sp.	5	.18
Psuedocloeon sp.	17	.59
Tricorythodes sp.	1	.03
Plecoptera		
Perlesta sp.	1	.03
Trichoptera		
Chimarra sp.	2	.08
Rhyacophilia sp.	1	.03
Hydroptilia sp.	1	.03
Total	29	

*Number of stomachs containing food = 4 (TL = 55 mm to 98 mm).

Table 16. Frequency and relative frequency (percentage of total number) of various food items found in the diet of orange-throat darters[1] collected in Glover Creek, Oklahoma from November 1978 to July 1980.

Food item	Frequency	Relative frequency
Annelida		
Lumbriculidae	1	*
Hydracarina	3	.02
Copepoda	4	.03
Cladocera	8	.06
Ephemeroptera		
Baetis _sp_.	2	.01
Pseudocloeon _sp_.	16	.11
Caenis _sp_.	1	*
Stenonema _sp_.	2	.01
Choroterpes _sp_.	1	*
Tricorythodes _sp_.	6	.04
Plecoptera		
Neoperla _sp_.	2	.01
Taeniopteryx _sp_.	1	*
Diptera		
Chironomidae	92	.64
Simulium _sp_.	2	.01
Trichoptera		
Chimarra _sp_.	3	.02
Total	144	

[1]Number of stomachs containing food = 15 (TL = 25 mm to 46 mm).

*Constitutes less than .01.

Table 17. Frequency and relative frequency (percentage of total number) of various food items found in the diet of logperch[1] collected in Glover Creek, Oklahoma from November 1978 to July 1980.

Food item	Frequency	Relative frequency
Gastropoda	83	.06
Physa sp.	10	*
Ferrissia sp.	69	.05
Planorbidae	4	*
Pelecypoda	2	*
Copepoda	1	*
Cladocera	3	*
Isopoda		
Lirceus sp.	1	*
Megaloptera		
Corydalus sp.	3	*
Odonata	15	
Gomphidae	1	*
Argia sp.	14	.01
Ephemeroptera	264	.21
Baetis sp.	41	.03
Pseudocloeon sp.	60	.05
Heptagenia sp.	5	*
Stenonema sp.	66	.05
Stenacron sp.	2	*
Caenis sp.	53	.04
Isonychia sp.	1	*
Tricorythodes sp.	1	*
Choroterpes sp.	12	*
Leptophlebia sp.	6	*
Potamanthus sp.	15	.01
Hexagenia sp.	1	*
Ephemerella sp.	1	*
Plecoptera	27	.02
Allocapnia sp.	16	.01
Acroneuria sp.	1	*
Neoperla sp.	5	*
Isoperla sp.	1	*
Chloroperlidae	2	*
Unidentified	2	*
Tricoptera	135	.10
Chimarra sp.	35	.03
Hydropsyche sp.	1	*
Nyctiophylax sp.	12	*
Polycentropus sp.	6	*
Agapetus sp.	22	.02

Table 17. Continued.

Food item	Frequency	Relative Frequency
Tricoptera (Cont'd)		
Hydroptilia sp.	1	*
Unidentified	58	.04
Lepidoptera		
Paragyractis sp.	8	*
Diptera	690	.54
Simulium sp.	181	.14
Chironomidae	509	.40
Coleoptera		
Stenelmis sp.	2	*
Psephenus sp.	12	*
Ectoporia sp.	21	.01
Total	1267	

[1]Number of stomachs containing food = 52 (TL = 85 mm to 146 mm).

*Constitutes less than .01.

ephemeropterans composed 21%, primarily *Pseudocloeon* *sp*., *Stenonema* *sp*., *Caenis* *sp*., and *Baetis* *sp*., and trichopterans contributed 10%, primarily *Chimarra* *sp*. Other organisms present in lesser numbers included *Ferrissia* *sp*. and Plecoptera.

Channel Darter

Chironomids were the most numerous items in the stomachs of channel darters, composing 32% (Table 18). Other major items included *Pseudocloeon* *sp*. (20%), Copepoda (22%), and Cladocera (14%).

Orangebelly Darter

A wide variety of organisms were present in the stomachs of orangebelly darters each season, although the frequency of occurrence shifted somewhat between seasons (Table 19). In October 1979, Diptera were the major food items (71.8%) and had an electivity index (L) of +.691. Copepods were the second most common item (12.6%), with an electivity index of +.126. Although Trichoptera and Plecoptera were the next most frequent items in the diet (2.8% and 3.0%, respectively), these items had negative electivity indices. Coleoptera, primarily *Stenelmis* *sp*. larvae, were the least selected food items (L = -.342).

In January 1980, the diet of orangebelly darters consisted primarily of Diptera (57%), Plecoptera (23.1%), Copepoda (9.2%), and Cladocera (5.5%) (Table 19). In this season, Diptera were the most preferred items (L = +.476) although electivity indices for Copepoda and Cladocera were both positive. However, electivity for Plecoptera remained negative (L = -.052) despite the fact that they

Table 18. Frequency and relative frequency (percentage of total number) of various food items found in the diet of channel darters[1] collected in Glover Creek, Oklahoma from November 1978 to July 1980.

Food item	Frequency	Relative frequency
Arachinida	1	*
Copepoda	80	.22
Cladocera	52	.14
Ephemeroptera		
Pseudocloeon sp.	74	.20
Baetis sp.	5	.01
Plecoptera		
Nytiophylax sp.	1	*
Unidentified	2	*
Lepidoptera		
Paragyractis sp.	1	*
Diptera		
Chironomidae	117	.32
Simulium sp.	8	.02
Fish eggs	22	.06
Total	363	

[1]Number of stomachs containing food = 21 (TL = 34 mm to 59 mm).

*Constitutes less than .01.

Table 19. Relative frequency (percentage of total number) and index of electivity of various groups of food items in the diet of orangebelly darters for each season from October 1979 to July 1980 in Glover Creek, Oklahoma (summarized from Appendies G and H).

	Date							
	Oct. 1979		Jan. 1980		Mar. 1980		Jul. 1980	
Food item	R.F.	L	R.F.	L	R.F.	L	R.F.	L
Annelida	*		.006	-.119	*		.002	-.011
Gastropoda	.002	-.007	*		*		.005	+.005
Copepoda	.126	+.126	.092	+.092	.051	+.051	.002	+.002
Cladocera	.063	+.063	.055	+.055	.009	+.009	.002	+.002
Ostracoda	*		*		*		.024	+.024
Hydracarina	.004	+.004	.001	+.001	*		*	
Collembolla	.002	+.002	*		*		*	
Insecta								
Megaloptera	.004	-.005	*		*		.005	-.008
Odonata	.002	-.015	*		*		*	
Ephemeroptera	.002	-.165	.018	-.160	.311	+.160	.220	-.113
Plecoptera	.030	-.034	.231	-.052	.035	-.074	.010	-.067
Trichoptera	.028	-.166	.009	-.024	.039	-.014	.459	+.248
Diptera	.718	+.691	.573	+.476	.547	+.463	.256	+.240
Lepidoptera	*		*		*		.026	+.007
Coleoptera	.002	-.342	*		.005	-.405	.002	-.250

*Was not present in diet.

contributed a major proportion to the diet.

In March 1980, the diet was again composed primarily of Diptera (54.7%) which were again the most preferred item (L = +.463). In comparison to the January data, Plecoptera decreased in importance (3.5%) while Ephemeroptera increased (31.1%) and were highly selected for (L = +.160). Both Copepoda and Cladocera decreased in the diet but continued to be selected for.

Orangebelly darters showed the greatest change in diet during July 1980. Diptera, the most frequent item in the diet during previous seasons, contributed only 25.6% to the diet. Trichoptera were the most frequent items in the diet, contributing 45.9% (L = +.248) whereas these items were relatively infrequent during other seasons. Ephemeroptera decreased in the diet from 31.1% in March 1980 to 20% (L = -.113) during July 1980, but continued to be a major component of the diet. Copepods and Cladocera, previously frequent in the diet during other seasons, decreased to less than 1% of the diet, collectively.

Resource Partitioning

Habitat

Leopard darters and logperch generally utilized the same habitat. Measurements of niche breadth along the water depth, water velocity, and substrate axes were very similar (Table 20). Niche overlaps for all three parameters were essentially complete (>.950). The distribution of these two species did not differ significantly along the axes of water depth (P>.10)[1], water velocity (P>.25), or substrate (P>.25)

Table 20. Measures of habitat breadths and overlaps for adult logperch, channel darters, and leopard darters along the water depth, water velocity, and substrate type axes.

	Habitat breadth		
	P. caprodes	*P. pantherina*	*P. copelandi*
Water depth	.812	.777	.750
Water velocity	.217	.249	.443
Substrate type	.489	.462	.536
	Habitat overlaps		
	P. caprodes-*P. copelandi*	*P. pantherina*-*P. caprodes*	*P. copelandi*-*P. pantherina*
Water depth	.836	.963	.961
Water velocity	.934	.997	.952
Substrate type	.631	.970	.641

(Table 20).

Channel darters utilized somewhat different habitat than logperch or leopard darters. Measurements of niche breadth along the water depth axis was similar, but breadth values for water velocity and substrate type were wider for channel darters (Table 20). Niche overlaps between channel darters with logperch and leopard darters were essentially complete for the axes of water depth and water velocity, but was much lower along the substrate axis (Table 20). The distribution of channel darters was significantly different from logperch along all three habitat parameters ($P<.005$) and significantly different from leopard darters along the axes of water velocity ($P<.005$) and substrate ($P<.001$).

Orangebelly darters inhabited riffle habitats almost exclusively and, therefore, occupied a distinctly different habitat than the other principal darter species. However, within their preferred habitat, juveniles and adults preferred different subhabitats during every season.

In October 1979, juvenile and adult orangebelly darters inhabited significantly different habitats in relation to water depth ($P<.001$)[1] and water velocity ($P<.001$), but not substrate ($P<.10$). Juveniles preferred depths from 10 to 19 cm ($P<.005$) and water velocities $\leq$ 10 cm/s ($P<.001$) whereas adults preferred depths $\geq$ 20 cm ($P<.001$) and water velocities $\geq$ 10 cm/s ($P<.05$) (Table 21). Both juveniles and adults preferred rubble substrate ($P<.001$). In January 1980, juveniles and adults differed in habitat utilization only in relation to water velocity ($P<.001$). Juveniles preferred water velocities from 30 to 59 cm/s ($P<.001$) while adults preferred water velocities $\geq$ 60 cm/s

Table 21. Total area sampled, frequency of capture, and density of juvenile and adult orangebelly darters in various intervals of water depth, water velocity, and substrate types in Glover Creek, Oklahoma during October 1979.

Habitat variable	Area sampled (m^2)	Juveniles*		Adults**	
		N	N/m^2	N	N/m^2
Depth (cm)					
0 - 9	233.8	179	.765	106	.435
10 - 19	151.0	162	1.073	152	1.006
≥ 20	54.1	41	.758	75	1.386
		T = 11.00 P<.005		T = 69.14 P<.001	
Velocity (cm/s)					
0 - 9	385.4	364	.994	234	.607
≥ 10	53.5	19	.355	45	.841
		T = 18.57 P<.001		T = 4.04 P<.05	
Substrate					
5.5	22.7	20	.881	10	.440
6.0	83.7	129	1.541	81	.967
6.5	186.3	159	.853	146	.783
7.0-7.5	77.1	40	.519	20	.259
8.0	70.2	31	.441	22	.313
		T = 64.00 P<.001		T = 51.04 P<.001	

*≤ 41 mm (TL).

**> 41 mm (TL).

(P<.001) (Table 22). Juveniles and adults both preferred depths $\geq$ 40 cm (P<.001) and gravel-rubble substrate types (P<.001) (Table 22). In March 1980, juveniles and adults differed in habitat use in relation to water depth (P<.001), water velocity (P<.001), and substrate (P<.01), but both preferred depths from 20 to 29 cm (P<.001), water velocities $\geq$ 50 cm/s (P<.001), and boulder substrates (P<.001) (Table 23). In July 1980, juveniles and adults differed in habitat use in relation to depth (P<.001) and substrate (P<.001). Although juveniles did not prefer any particular depth (P<.25), they preferred boulder substrate almost exclusively (P<.001). Adults preferred depths $\geq$ 20 cm (P<.001) and substrates composed of rubble and boulder (P<.001) (Table 24).

The diversity of habitat used, as measured by niche breadth, was generally greater for juveniles than adults during every season for water depth and water velocity but not for substrate (Table 25). The relationship between seasonal diversity of habitat (Table 26) and niche breadth was highly variable. Niche breadths for juveniles were not related to diversity of depth (r = .06) or diversity of water velocity (r = .07). But were positively related to diversity of substrates (r = .86). Niche breadths of adults were negatively related to diversity of depth (r = -.77) and water velocity (r = -.30), but were somewhat positively related to diversity of substrate (r = .38). Overall, niche breadths of orangebelly darters (juveniles and adults combined) were somewhat negatively related to diversity of depth (r = -.20), somwhat positively related to water velocity (r = .11) and positively related to substrate (r = .70).

Niche overlaps between juveniles and adults along all three

Table 22. Total area sampled, frequency of capture, and density of juvenile and adult orangebelly darters in various intervals of water depth, water velocity, and substrate types in Glover Creek, Oklahoma during January 1980.

Habitat variable	sampled (m^2)	Juveniles* N	Juveniles* N/m^2	Adults** N	Adults** N/m^2
Depth (cm)					
0 - 9	114.2	3	.026	3	.026
10 - 19	166.2	49	.295	39	.234
20 - 29	254.8	124	.486	89	.349
30 - 39	89.9	43	.478	34	.378
≥ 40	6.1	4	.656	4	.656
		T = 54.71 P<.001		T = 39.56 P<.001	
Velocity (cm/s)					
0 - 9	206.5	63	.305	20	.097
10 - 19	145.7	61	.418	46	.316
20 - 29	135.8	49	.361	45	.331
30 - 39	46.0	27	.587	24	.522
40 - 49	67.3	6	.089	14	.208
50 - 59	21.9	13	.594	7	.319
60 - 69	2.3	1	.435	4	1.739
≥ 70	5.5	2	.363	8	1.454
		T = 27.38 P<.001		T = 88.65 P<.001	
Substrate					
5.0-5.5	4.5	16	3.555	13	2.888
6.0	160.3	92	.574	49	.305
6.5	316.4	79	.250	74	.234
7.0-7.5	95.6	34	.355	30	.314
8.0	54.4	2	.036	3	.055
		T = 187.29 P<.001		T = 128.16 P<.001	

*≤ 43 mm (TL).

**> 43 mm (TL).

Table 23. Total area sampled, frequency of capture, and density of juvenile and adult orangebelly darters in various intervals of water depth, water velocity, and substrate types in Glover Creek, Oklahoma during March 1980.

Habitat variable	sampled (m^2)	Juveniles*		Adults**	
		N	N/m^2	N	N/m^2
Depth (cm)					
0 - 9	175.7	20	.113	12	.068
10 - 19	225.1	178	.790	176	.782
20 - 29	121.8	189	1.551	99	.813
$\geq$ 30	36.6	38	1.038	10	.273
		T = 201.19		T = 120.42	
		P<.001		P<.001	
Velocity (cm/s)					
0 - 9	263.9	200	.758	133	.504
10 - 19	186.3	141	.757	77	.413
20 - 29	52.0	34	.653	42	.807
30 - 39	37.7	20	.530	14	.371
40 - 49	12.5	11	.880	14	1.120
$\geq$ 50	7.1	21	2.958	17	2.394
		T = 48.75		T = 70.57	
		P<.001		P<.001	
Substrate					
6.0	109.6	93	.848	50	.456
6.5	263.2	168	.638	139	.528
7.0	71.6	115	1.606	85	1.187
7.5	70.5	28	.397	7	.099
8.0	44.9	23	.512	7	.156
		T = 89.19		T = 98.16	
		P<.001		P<.001	

*$\leq$ 45 mm (TL).
**> 45 mm (TL).

Table 24. Total area sampled, frequency of capture, and density of juvenile and adult orangebelly darters in various intervals of water depth, water velocity, and substrate types in Glover Creek, Oklahoma during July 1980.

Habitat variable	sampled (m^2)	Juveniles*		Adults**	
		N	N/m^2	N	N/m^2
Depth (cm)					
0 - 9	277.7	213	.767	57	.205
10 - 19	71.2	43	.604	31	.435
≥ 20	6.1	5	.833	15	2.459
		T = 2.11 P<.25		T = 116.16 P<.001	
Velocity (cm/s)					
≥ 5	355.0	260	1.365	103	.290
Substrate					
6.0	20.7	12	.580	4	.193
6.5	239.6	99	.413	60	.250
7.0	6.8	127	18.676	25	3.676
7.5	34.3	10	.291	5	.146
8.0	53.6	12	.224	9	.168
		T = 3104.4 P<.001		T = 287.97 P<.001	

*≤ 34 mm (TL).

**> 34 mm (TL).

Table 25. Niche breadths and overlap values of water depth, water velocity, and substrate for juvenile and adult orangebelly darters.

	Niche Breadths			
	Oct. 1979	Jan. 1980	Mar. 1980	July 1980
Juveniles				
Depth	.811	.506	.652	.481
Velocity	.552	.558	.490	*
Substrate	.640	.614	.708	.514
Adults				
Depth	.925	.537	.537	.797
Velocity	.685	.648	.564	*
Substrate	.539	.638	.569	.488
Combined				
Depth	.882	.519	.616	.560
Velocity	.606	.619	.522	*
Substrate	.600	.637	.652	.534

	Niche overlaps			
	Oct. 1979	Jan. 1980	Mar. 1980	July 1980
Depth	.956	.998	.950	.942
Velocity	.991	.918	.988	*
Substrate	.982	.965	.985	.871

*Velocity was essentially unmeasurable and thus was not a critical factor affecting distribution in as far as it could be observed.

Table 26. Diversity of water depths, water velocities, and substrate types available to orangebelly darters each season from October 1979 to July 1980 in Glover Creek, Oklahoma.

	Date			
	Oct. 1979	Jan. 1980	Mar. 1980	July 1980
Depth	2.39	3.50	3.20	1.53
Velocity	1.27	4.45	2.88	*
Substrate	3.64	2.88	3.35	2.03

*Velocity was essentially unmeasurable and thus was not a critical factor affecting distribution in as far as it could be observed.

habitat parameters were more strongly related to habitat diversity than niche breadths. Overlaps along the axes of water depth and substrate were positively related to the diversity of those two parameters (r = .72 and .94, respectively), but were negatively related to the diversity of water velocity (r = -.88).

Food Habits

Juvenile and adult orangebelly darters differed significantly in diet during every season except March 1980 (Table 27). Although Diptera were the most common items in the diets of juveniles and adults (except July 1980), Diptera constituted a larger proportion of the diet in adults than in juveniles (except July 1980) and juveniles consumed larger numbers of Copepoda and Cladocera than did the adults. Overall diversity of diet, as measured by niche breadth, was greater for juveniles than adults during every season except March 1980 (Table 28).

The diversity of the diet of orangebelly darters was low (Table 28) compared to the diversity of food items in the environment (Table 13). Also, niche breadths were positively related to the diversity of food items in the environment for both juveniles (r = .96) and adults (r = .65), although juveniles exhibited a stronger relationship. The diversity of the diet of orangebelly darters overall (juveniles and adults combined) was strongly correlated to diversity of food items available (r = .98). However, niche overlaps had only a slight positive relationship to the diversity of food items available (r = .20).

Table 27. Relative frequency of various food items in the diets of juvenile and adult orangebelly darters for each season from October 1979 to July 1980 in Glover Creek, Oklahoma (summarized from Appendix G).

	Date							
	Oct. 1979[1]		Man. 1980[2]		Mar. 1980[3]		Jul. 1980[4]	
Food item	Juv.	Adult	Juv.	Adult	Juv.	Adult	Juv.	Adult
Annelida	*	*	.011	.001	*	*	.000	.009
Gastropoda	.000	.004	*	*	*	*	.003	.009
Copepoda	.235	.027	.150	.028	.067	.007	.003	.000
Cladocera	.107	.023	.090	.015	.010	.007	.003	.000
Ostracoda	*	*	*	*	*	*	.029	.009
Hydracarina	.008	.000	.003	.000	*	*	*	*
Collembolla	.004	.000	*	*	*	*	*	*
Insecta								
Megaloptera	.000	.008	*	*	*	*	.003	.009
Odonata	.004	.000	*	*	*	*	*	*
Ephemeroptera	.013	.019	.011	.025	.319	.292	.221	.145
Plecoptera	.038	.023	.274	.183	.032	.042	.011	.009
Trichoptera	.017	.040	.008	.009	.035	.050	.406	.602
Diptera	.472	.851	.440	.721	.527	.600	.284	.184
Lepidoptera	*	*	*	*	*	*	.029	.019
Coleoptera	.000	.004	*	*	.008	.000	.003	.000
	T=78.61	P<.001**	T=78.6	P<.001**	T=10.6	P<.25**	T-22.61	P<.025**

[1] N=24 (juveniles and I+ adults): $\leq$48 mm TL; N=27 (II+ and III+ adults): >48 mm TL

[2] N=30 (juveniles): $\leq$ 43 mm TL; N=26 (adults): >43 mm TL

[3] N=32 (juveniles): $\leq$ 45 mm TL; N=15 (adults): >45 mm TL

[4] N=41 (juveniles): $\leq$ 34 mm TL; N=26 (adults): >34 mm TL

*Not present in the diet.

**Statistical tests are included in Appendix I.

Table 28. Niche breadths and overlap values for the diets of juvenile and adult orangebelly darters for each season from October 1979 to July 1980 in Glover Creek, Oklahoma.

	Niche breadths			
	Oct. 1979	Jan. 1980	Mar. 1980	July 1980
Juveniles	.169	.284	.122	.228
Adults	.103	.158	.148	.217
Total	.137	.227	.130	.234
	Niche overlaps			
	.729	.858	.926	.911

CHAPTER V

DISCUSSION

General Community Structure

Numbers of fish species generally increase with increasing stream order (Shelford 1911; Thompson and Hunt 1930; Larimore et al. 1952; Hallam 1959; Kuehne 1962; Larimore and Smith 1963; Sheldon 1968; Deacon and Bradley 1972; Jenkins and Freeman 1972; Whiteside and McNatt 1972) with new species being added rather than headwater species being replaced. This phenomenon is generally attributed to increased physical heterogeneity (Sheldon 1968; Gorman and Karr 1978) and decreased environmental fluctuation in larger streams (Harrel and Dorris 1968).

My data on the species composition of darters in Glover Creek agrees well with the literature. In contrast, Taylor and Wade (1972) collected the highest number of fish species in the lower reaches of Glover Creek, but reported the greatest number of darter species in the middle and upper reaches. However, Taylor and Wade typically sampled each of their sites only once during their survey of the Glover Creek drainage. I failed to collect several species reported by Taylor and Wade, the slough darter and slenderhead darter, and captured another, the orangethroat darter, only in the lower reaches. I did, however, capture one species, the dusky darter, not reported by Taylor and Wade.

Although Taylor and Wade (1972) collected a single slough darter above the confluence of the East and West Fork tributaries, the absence of this species from my collections is not surprising. The slough darter is usually associated with lowland rivers where they inhabit areas that 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 is virtually non-existent in the upper reaches of Glover Creek.

Taylor and Wade (1972) also collected a single slenderhead darter in the middle reaches of Glover Creek. Slenderhead darters prefer medium to fast currents over sand and gravel substrate (Page and Smith 1971) and are usually associated with larger streams and rivers (Smith 1979). The lack of smaller substrates throughout most of the upper reaches of Glover Creek probably restricts slenderhead darter distribution. This species is known to be very common in the lower Glover near the confluence of the Little River (James Randolph, per. com.).

I captured several dusky darters in the lower reaches of Glover Creek in areas close to shore that were characterized by relatively shallow water, little or no water current, sand and gravel substrates, and where vegetation and organic debris was present. This species is typically found in larger streams and rivers where it inhabits deeper riffles and runs with moderate to fast currents over gravel substrate (Page and Smith 1970; Miller and Robison 1973; Smith 1979). However, the dusky darter has also been observed to occur in quiet backwaters having silt-free bottoms (Pflieger 1975). As in the case of the slenderhead darter, the absence of smaller substrate types in the upper Glover probably limits the distribution of dusky darter.

Taylor and Wade (1972) captured the johnny darter in the upper and middle reaches of Glover Creek but failed to capture it in the lower reaches. I captured occasional specimens of johnny darters in these areas, although they were not abundant. The species is usually found in smaller streams (Trautman 1957; Flemer and Woolcott 1966; Scott and Crossman 1973; Lotrich 1973; Miller and Robison 1973; Pflieger 1975; Smith 1979) although they also inhabit larger streams and lakes. Johnny darters prefer quiet pools and sluggish riffles and almost exclusively prefer sand and gravel substrates. Quiet pool habitat is very abundant throughout the upper Glover, but sand and gravel substrates are uncommon. It may be that this lack of preferred substrate restricts johnny darter distribution.

Taylor and Wade (1972) captured one orangethroat darter in the middle reaches of Glover Creek, but we collected this species only from the lower reaches over sand and gravel in moderate currents. This species prefers riffles with slow to moderate current over sand and gravel substrates (Winn 1958a, 1958b; Cross 1967; Distler 1968; Miller and Robison 1973; Smith 1979), and tolerates intermittant and fluctuating discharges. The reasons for the scarcity and restricted distribution of this species in Glover Creek are unknown. However, competitive exclusion by the orangebelly darter may be involved. The orangethroat darter occurs sympatrically with the orangebelly darter and hybridization between these two species occurs in other Oklahoma streams (Linder 1955, 1959; Branson and Campbell 1969; Echelle et al. 1975). Where the two species occur in sympatry they tend to segregate (Echelle et al. 1974) with orangebelly darters inhabiting main channels and orangethroat darters predominating in the smaller tributaries. The lack of preferred substrate of the orangethroat darter in the smaller tributaries of the upper Glover in conjunction with probable competition with the orangebelly darter may restrict the former species to the lower reaches.

The darter community throught the upper reaches of Glover Creek is composed of four principal species: orangebelly darters, leopard darters, channel darters, and logperch, with the orangebelly darter being the dominant species. As compared to densities in other streams, these darters inhabit Glover Creek at extremely low densities. Density estimates for other darter species have ranged from $2.6/m^2$ to $9.6/m^2$, although estimates as low as $.03/m^2$ were recorded (Table 29). Scalet (1973a) estimated the density of orangebelly darters in the Blue River, Oklahoma, to be $2.6/m^2$ for adults, although he hypothesized that areas of preferred habitat probably harbored as many as $10/m^2$. Densities in Glover Creek were typically less than $1/m^2$ but in areas of preferred habitat, densities of 2 to $3/m^2$ were not uncommon (Tables 9, 10, 11, 12). Densities of leopard darters, channel darter, and logperch were considerably lower than those of orangebelly darters and were less than the lowest published densities.

The low densities of all darter species in Glover Creek suggest that density independent variables may have a significant effect on darter populations. Glover Creek experiences extreme variations in seasonal discharge (Orth 1980). Unpredictable spring flooding may affect reproductive success by interrupting spawning, disturbing already successful spawns or decreasing the survival of larvae. Low flows in summer and fall may also cause periods of stress.

Table 29. Species and location of density estimates published for other darter species.

Species	Location	Density	Author(s)
Etheostoma blennoides *E. zonale* *E. variatum* *E. maculatum* *E. flabellare* *E. camurum* *E. tippecanoe* *E. nigrum* *Percina maculata* *P. caprodes*	French Creek, Pa.	$1.19/m^2$ (total)	Lachner et al. 1950
E. caeruleum *E. blennoides* *E. flabellare* *E. zonale* *E. variatum* *E. nigrum* *E. maculatum* *P. maculata*	Deckart Run, Little Sugar Creek, and Conneaut Creek, Pa.	$3.2/m^2$	Reed 1968
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 *E. blennoides*	Osage River Basin, Mo. Osage River Basin, Mo.	1.15/100 m 7.28/100 m	Pflieger 1978

Habitat Preferences

There are several potential biases associated with the habitat preferences determined for the channel darter, logperch, and leopard darter. Collection methods were not efficient in deeper areas ($\geq$150 cm) or relative deep water ($\geq$80 cm) with fast current ($\geq$150 cm/s). Low numbers of captures required pooling of data over all age groups, seasons, and years. Such an approach precluded analysis of intraspecific differences and seasonal and yearly variations in preferred habitat. The last aspect probably introduces the greatest source of bias since some darter species are known to migrate into specific habitats to spawn. However, even given these biases, the data agrees well with published descriptions on the habitat of these species except leopard darters.

Channel Darter

The preferred habitat of channel darters in Glover Creek agrees quite well with other descriptions of this species habitat. Channel darters are typically stream dwellers although they are known to occur in lakes (Winn 1953, 1958a, 1958b; Trautman 1957; Hubbs and Lagler 1958; Scott and Crossman 1973). Generally, they inhabit areas of moderate current over bedrock substrate (Cross 1967), gravelly sections of slow flowing streams (Miller 1973; Miller and Robison 1973), and deeper water in larger streams (Blair 1959). During spring, channel darters tend to move out of these areas and into swift riffles and runs and establish a spawning territory over gravel and sand substrates with a larger rock near the center (Winn 1953; Cross 1967).

Logperch

In Glover Creek, logperch preferred deep pools with boulder substrate during most of the year but were collected occasionally in riffles in spring. Logperch are commonly found in clear streams with gravel and rocky bottoms (Cross 1967; Miller and Robison 1973), usually prefer deep water in or at the base of riffles near pools (Lachner et al. 1950; Thomas 1970), but are known to occur along gravelly, waveswept shorelines in lakes (Winn 1958a, 1958b; Pflieger 1975) and reservoirs (Mullan et al. 1968). Similar to channel darters, logperch migrate into other habitats to spawn (Winn 1958a, 1958b) and in streams, spawn in swift riffles with gravel bottoms (Cross 1967).

Leopard Darter

Previous descriptions of leopard darter habitat describe the species as a riffle dweller (Moore and Reeves 1955; Oklahoma Biological Survey 1972; Miller and Robison 1973; Cloutman and Olmsted 1974; Eley et al. 1975; Robison 1978). In contrast, data from this study and similar work on the Cossatot River in Arkansas (Jones and Maughan 1980) demonstrate that leopard darters prefer pools during most seasons. Nothing is known about the reproductive behavior or habitat of leopard darters and no observations of spawning were made in Glover Creek. However, the occurrence of leopard darters in riffle areas during spring suggest that this habitat may be used for spawning.

The reason for the difference between previous descriptions of leopard darter habitat and my data may be related to differences in collecting methods. Most of the previous authors usually collected with seines whereas I collected with electroshocking equipment. Seines do not sample the deeper, boulder and bedrock bottomed pools as efficiently as electroshocking techniques (Jones and Maughan 1980).

Orangebelly Darter

My data on orangebelly darter habitat agrees with previous work but, in addition, shows seasonal variation in habitat utilization in response to changes in habitat availability. The orangebelly darter usually inhabits shallow riffles and raceways having moderate to swift current over gravel and rubble substrates (Miller and Robison 1973; Scalet 1973a). Orth (1980) used methods identical to those used in this study to examine orangebelly darter preferred habitat and estimated that highest densities occurred at depths from 10 to 19 cm, water velocities from 40 to 49 cm/s, and gravel and rubble substrates. However, Orth combined data over all seasons and did not attempt to compare seasonal variation in habitat utilization. I observed that, as the availability of depth, velocities, and substrates changed between seasons, orangebelly darters tended to prefer the deeper, faster waters in the riffles. Substrate preferences did not appear to vary much between seasons, however, which would indicate that depth and velocity are the more important habitat variables influencing orangebelly darters.

Food Habits

Data on the food habits of logperch and channel darters are based on specimens collected from all sampling locations and the data were pooled over all seasons and years. This approach precluded analysis of diets seasonally but was necessitated by the small sample size. Also, comparisons of diet with food availability could not be made since benthic invertebrates were sampled at only one location and longitudinal variation in diversity was not measured throughout the Glover Creek drainage. However, the data are representative of the overall diets of these two species.

Logperch

Logperch in Glover Creek ate mostly chironomids as the major food item in their diet although ephemeropterans and trichopterans were also taken. Microcrustaceans were taken less frequently. Microcrustaceans are the predominant food items taken in lakes (Turner 1921; Ewers 1933, 1935) while chironomids and other immature aquatic insects constitute the greatest proportion of the diet of logperch in streams (Turner 1921; Dobie 1959; Mullan et al. 1968; Thomas 1970).

Channel Darter

In Glover Creek, chironomids were the most frequent items taken by channel darters, followed by ephemeropterans, copepods, and cladocerans. The principal foods of channel darters were chironomids and microcrustaceans (Winn 1953; Cross 1967; Miller and Robison 1973) although trichopteran larvae and other small aquatic insects are also eaten.

Orangebelly Darter

Orangebelly darters consumed a wide variety of organisms in Glover Creek but tended to select for dipteran larvae (primarily Simuliidae and Chironomidae, Appendices G, H, and I). At the same time, the orangebelly darter appeared to remain relatively opportunistic. For example, Plecoptera, Trichoptera, and Ephemeroptera were utilized to some degree throughout the year, but the proportion of these items in the diet was greatest during seasons of increased abundance.

The only previous food habit study of the orangebelly darter was conducted by Scalet (1972) on the Blue River subspecies, E. r. cyanorum. Scalet collected darters and benthic samples every two months over a one year period and observed distinct changes in the numbers, volumes, and kinds of food items consumed as the darters increased in size. Younger fish ate copepods, cladocerans, and smaller ephemeropterans and dipteran larvae while older aged fish consumed larger ephemeropteran, dipteran, and trichopteran larvae. After comparing benthic samples with stomach contents, Scalet concluded that the orangebelly darter was selective in feeding.

In general, the food habits of the Glover River subspecies, E. r. radiosum, appear to be very similar to those of the Blue River subspecies. However, Plecoptera were not utilized in the Blue River whereas this food item contributed significantly to the diet of orangebelly darters in Glover Creek. This difference probably results from differences in availability, since Scalet did not find Plecoptera in his benthic samples. Scalet also observed that riffle bettle larvae were utilized by fish of all ages in the Blue River while this species was rarely consumed by orangebelly darters in Glover Creek.

Several inconsistencies were found in the food habit data and difficulties were also encountered in quantification of the relative importance of various food items. Larimore (1957) demonstrated that no single measure can adequately describe fish diets. But, limitations of time and the quality and quantity data often preclude multiple measures. The percentage that each food category contributed to the total number of food items in all stomachs (relative frequency) was used to assess diets of darters in Glover Creek. Wallace (1981) correctly points out, however, that this measure is biased toward small food items which contribute little to total volume (weight). Other measures, such as the percentage of all stomachs (containing food) in which each food category occurred, the percentage that each food category contributed to the total volume of food in all stomachs, or a combination of methods that give a relative index of importance (George and Hadley 1979) are also biased. In addition, volume or biomass measures were not made because food items removed from darter stomachs in Glover Creek were usually digested with only the head capsules present for identification and enumeration. This limitation could be overcome by developing a relationship between the head capsule size and body size from specimens in the benthic samples. However, such a relationship does not exist in the published literature. Since the range in food size was relatively narrow, the use of numbers, rather than other measures, was deemed the most appropriate approach.

Another bias encountered was the occurrence of particular food items in the diet (principally copepods, cladocerans and other microcrustaceans) that were absent in benthic samples. Assessment of the abundance of these organisms and other uncollected species in riffle habitats presents a unique sampling problem. In the first case, occurrence is probably the result of drift and could be evaluated by some type of drift sampling. In the second case, specific sampling techniques would need to be developed to capture rare species or those with low catchability. However, rarer species or those with lower catchabilities may not significantly contribute to the diet and the absence of these species is probably not a serious bias.

Resource Partitioning

Current ecological theory predicts that similar species must differ in their utilization of limited resources in order to coexist (Schoener 1974; Pianka 1976). Therefore, a comparison of resource utilization patterns between coexisting species that are closely related should reveal observable differences along one or more resource dimensions. There are three general dimensions along which organisms typically partition resources: space, food, and time (Pianka 1973; Schoener 1974). However, different communities vary as to which particular dimension is most important. For example, terrestrial mammals tend to partition macrohabitat (Schoener 1974). In deep-sea benthic communities, food is generally considered more important than habitat (space) or time (Sanders and Hessler 1969; Dayton and Hessler 1972). In stream communities, darters tend to partition habitat (Balesic 1971; Smart 1979; Smart and Gee 1979; Wynes 1979; O'Neil 1980).

In Glover Creek, most darter species exhibited distinct differences in resource utilization. Orangebelly darters occurred primarily in shallow riffles, leopard darters and logperch preferred pools, and channel darters inhabited deeper riffles and runs. Differences in diet were less obvious. Diets were similar in terms of kinds of items but differed in either the proportional importance of each item or in the overall diversity of food items consumed. Thus, most darters partitioned resources primarily by habitat and secondly by food habit.

However, no statistical differences were observed in habitat preferences between leopard darters and logperch and overlap values were essentially complete along the parameters measured. Although overlap values have been used as coefficients of competition (Schoener 1968; Orions and Horn 1969; Pianka 1969; Culver 1970; Brown and Lieberman 1973; May 1975) equating overlap with competition may be misleading since niches can overlap completely if resources are not limiting or are partitioned along another dimension (Colwell and Futuyma 1971). Some authors have hypothesized that high overlap may be correlated with reduced competition (Pianka 1976).

There are several possible explanations for the high overlap in habitat between leopard darters and logperch. Habitat may be partitioned along another parameter than those measured in this study. For example, Smart and Gee (1979) found that johnny darters and blackside darters (<u>Percina maculata</u>) inhabited the same general habitat but were vertically separated. Our methods precluded analysis of vertical separation and detailed studies on other habitat aspects of the leopard darter and logperch are needed to evaluate this hypothesis. The most probable explanation for high overlap in habitat between leopard darters and logperch is that habitat is not limiting for adults. The fact that density estimates for both these species were exceptionally low and a great deal of adult habitat in Glover Creek appears to be unused (Jones and Maughan 1980) lends support for this hypothesis.

If adult populations are not limited by physical habitat, then they may be limited by some other resource such as food. The tendency for fish species that overlap in habitat to discriminate in diet has been reported previously (Zaret and Rand 1971). Leopard darters and logperch appear to have different feeding strategies. Logperch in Glover Creek preyed mostly on chironomids, a variety of ephemeropterans, and a host of other aquatic insects and invertebrates including gastropods. Leopard darters were not examined for stomach contents because of restrictions imposed by the threatened status of the species. However, Robison (1978) examined seven museum specimens which contained primarily Simulium sp. pupae and larvae, Pseudocloeon sp., and chironomids. Given the limits of the data, there appears to be differences in diet between the two species. Also, basic morphological differences in mouth form suggest different feeding habits and behavior. Logperch are characterized by a ventro-terminal mouth and a blunt, rounded, and bony snout which is often used to turn over debris on the bottom in search of food (Keast and Webb 1966). Leopard darters possess a more terminal mouth and lack the modified snout. Such differences in morphology have been used by other authors to infer different resource utilization strategies (Findley 1976; Roughgarden 1974; Keast and Webb 1966). Logperch apparently have adapted a more benthic mode of feeding while that of leopard darters is that of either moving temporarily into riffles to feed (Robison 1978) or utilizing drift organisms.

I have no direct data indicating that food might be limiting leopard darters and logperch in Glover Creek, but the standing crop of benthos in pool habitat with larger boulder and bedrock substrate is usually much less than in the highly productive riffles having smaller rubble and gravel substrate (Pennak and Van Gerpen 1947). If food were limiting adult populations of leopard darters and logperch, differences in feeding strategies appear to be great enough to allow ecological segregation and avoidance of competitive interaction.

If adult populations are not at carrying capacity (resource limited) as the data suggests, then adult population densities are probably determined during some period prior to the adult stage, such as spawning or larval stages. Factors associated with fluctuating environmental conditions in Glover Creek, i.e., seasonal variation in flow, and their potential influence on the success of darter reproduction and survival of young have previously been discussed. Interspecific interactions between the adult leopard darter, logperch, and orangebelly darters during spawning and the young during early life could potentially contribute to the low densities of leopard darters and logperch. Logperch usually spawn in riffles and runs during spring (Winn 1958a, 1958b; Cross 1967; Miller and Robison 1973; Pflieger 1975) and indirect evidence suggests that leopard darters also reproduce in riffles during spring (Jones and Maughan 1980). Orangebelly darters may interfere with the ability of these other darters to successfully reproduce through competition for space, egg predation, or other interspecific interactions. In addition, orangebelly darter larvae drift passively downstream and inhabit pools and quiet areas after hatching in riffles in spring (Scalet 1973b). If all the darters in Glover Creek have similar early life histories, interspecific competition between larvae and young juveniles for similar resources in rearing areas might affect survival. Other factors, such as predation on larvae by other fish species, may also affect survival of larval darters.

Of the factors discussed, survival and mortality during periods prior to the adult stage, whatever the causes, is probably the most likely. If this is true, then more extensive research would need to be conducted on the early life histories of these fishes in order to determine at what particular period population density is determined and what factors are the most responsible.

The major emphasis of the resource partitioning study in this thesis was on the evaluation of intraspecific differences between juvenile and adult orangebelly darters. According to theory, the degree or intensity of competition should be correlated with species similarity (Hardin 1960; Haussman 1972; Jaeger 1974). Adults and juveniles of the orangebelly darter preferred different microhabitats in riffles throughout the year. However, niche overlaps were essentially complete during every season along the habitat parameters measured. In general, adults tended to use deeper portions of the riffle having faster currents, while juveniles inhabited the shallower areas providing slower currents. Patterns of habitat utilization were, however, not always consistent from one season to the next. For example, juveniles and adults differed in their use of depth and velocity in October 1979, but only in their use of velocity in

January 1980. Based on these data, I must conclude that adults and juveniles partitioned habitat although they did not consistantly discriminate along any particular parameter, or combination of parameters.

Juveniles and adults also differed significantly in diets every season except March 1980. Similar kinds of food items were preferred by both groups but the proportions of each kind differed in the diet. Microcrustaceans were consistantly more important in the diet of juveniles whereas adults consumed larger proportions of dipteran larvae. This diet difference may be related to the habitat differences between adults and juveniles, the size of food items most efficiently handled, or both.

Niche breadth is a quantitative measure of the distribution of a species along the resources exploited by that species (Pianka 1969; Colwell and Futuyma 1971; Pielou 1972; Pianka 1973) and should reflect the degree of ecological specialization by that species for a particular resource (Pianka 1976). A narrow niche breadth indicates that the species is utilizing some portion of the range of the available resource disproportionately. Conversely, a wide niche breadth indicates more uniform utilization of a greater range of the available resource. Adult orangebelly darters tended to have greater habitat niche breadths than juveniles along all habitat axes except substrate. These differences may possibly be related to differences in physiological tolerances between juveniles and adults. For example, juveniles may not be able to maintain their position in deep, fast waters, whereas the adults can occupy these areas as well as the shallow areas with slow currents. Alternatively, adults may preclude juveniles from inhabiting deeper, faster habitats. The present data do not allow discrimination between these two alternatives.

Both juveniles and adults had relatively narrow dietary niche breadths throughout the year. However, juveniles tended to have greater breadths than adults during every season except March 1980. The narrower dietary niche breadth of adults may be the result of their use of a wider range of habitat which allows them to be somewhat more selective. Conversely, juveniles may be forced to utilize a wider range of food items as a result of utilizing narrower habitat limits. This interpretation seems to correspond with the present theory since niche breadths should be inversely related to resource availability (MacArthur and Pianka 1966; Emlen 1968; Schoener 1971). As generally stated, the theory holds that as resources become less available, organisms are forced to utilize a wider range of resources (generalization) and niche breadth should increase. Conversely, during periods of resource abundance, organisms can afford to utilize a narrower range of resources (specialization) and niche breadth should decrease.

In Glover Creek, diversity of both habitat and benthic macroinvertebrates varied seasonally. However, correlation between niche breadths and resource diversity were not consistent and results were not always what theory would predict. For example, habitat niche breadths of juveniles were not correlated with the diversity of depths or velocities. Adults, on the other hand, had habitat niche breadths that were negatively correlated with the diversity of depths and velocities. For both groups, niche breadths were positively correlated with diversity of substrates. The dietary niche breadths of both the juveniles and adults were positively correlated with the diversity of food items.

Theoretically, overlap values should be positively correlated with the diversity of resources in the environment. That is to state that, as resources become less available, separation between competitors should become greater in order to avoid competitive interaction and overlap should decrease. Conversely, as resources become more abundant, the need for avoidance is reduced and overlap should increase (Pianka 1976). Niche overlaps between adults and juveniles were positively correlated with the diversity of depth and substrate but negatively correlated with the diversity of velocity. Niche overlaps in diet were positively correlated with food diversity only slightly.

Overall, there is considerable disparity between what should have been observed based on theory, the actual data on the niche relationships between juvenile and adult orangebelly darters, and the dynamics of the resources in the environment. One of the basic assumptions made in resource partitioning studies is that populations are resource limited and always at carrying capacity (Schoener 1974; Wiens 1977). If this theory is not true, competition would not be a significant factor and resource partitioning would not be necessary. High overlap values in resource utilization throughout the year, the lack of correlation, and in some cases, positive correlation between niche breadths and resource diversity suggests that the resources measured are not limiting for orangebelly darters in Glover Creek except for possibly short periods of time. Thus, intraspecific competition for resources may not be an important factor influencing orangebelly darter populations in Glover Creek during most of the year. However, significant differences in resource utilization were measured and would probably insure that intraspecific competition for resources would probably be minimized during the short periods when resources might become limited.

Many limitations exist in the evaluation of the theory of competition, and several of these were encountered in this study. No measure has been developed to statistically test niche values obtained by Pianka's (1973) equations. Conventional statistical tests can be applied to the data but the results must be interpreted independently. For example, niche overlaps for adult and juvenile orangebelly darters were always consistently high but statistical tests indicated significant differences in a majority of instances. However, one must also recognize that statistical tests may or may not reflect real biological differences (or similarities) and the results are still open to interpretation.

Resource dimensions are often assumed to be independent in their effect on populations and are treated as such in the data analysis. However, biologists have long recognized that independence may not always be the case. For example, several habitat variables of darters in this study were shown to be dependent. The need for multidimensional analyses of resource utilization patterns have long been recognized by leading ecologists (May 1975; Pianka 1976). Various other problems with the theory have been pointed out and discussed at length by previous authors (Schoener 1974; Peters 1976; Pianka 1976; Wiens 1977). This study cannot address these questions but do point out the difficulty of interpreting these types of data. Despite these problems, it is very evident that differences in resource utilization exist among sympatic darter species, both at the interspecific and intraspecific levels. More detailed experiments would be required to evaluate the relationships between these differences and the resulting population structures observed.

LITERATURE CITED

Balesic, H. 1971. Comparative ecology of four species of darters (Etheostominae) in Lake Dauphin and its tributary, the Valley River. Masters thesis, University of Manitoba, Winnipeg, Manitoba, Canada.

Blair, A. P. 1959. Distribution of the darters (Percidae, Etheostomatinae) of northeastern Oklahoma. Southwestern Naturalist 4:1-13.

Blair, A. P., and J. Windle. 1961. Darter associates of Etheostoma cragini (Percidae). Southwestern Naturalist 6:201-202.

Bovee, K. D., and T. Cochnauer. 1977. Development and evaluation of weighted criteria, probability-of-use-curves for instream flow assessment: Fisheries. United States Fish and Wildlife Service, Instream Flow Information Paper 3, FWS/OBS-77/63, Fort Collins, Colorado, USA.

Bovee, K. D., and R. T. Milhous. 1978. Hydraulic simulation in instream flow studies: Theory and techniques. United States Fish and Wildlife Service, Instream Flow Information Paper 5, FWS/OBS-78/33, Fort Collins, Colorado, USA.

Braasch, M. E., and P. W. Smith. 1967. The life history of the slough darter, Etheostoma gracile (Pisces; Percidae). Illinois Natural History Survey, Biological Notes 58, Urbana, Illinois, USA.

Branson, B. A. 1967. Fishes of the Neosho River system in Oklahoma. American Midland Naturalist 78:126-154.

Branson, B. A., and J. B. Campbell. 1969. Hybridization in the darters Etheostoma spectabile and Etheostoma radiosum cyanorum. Copeia 1969:70-75.

Brown, J. H., and G. A. Lieberman. 1973. Resource utilization and coexistence of seed-eating desert rodents in sand dune habitats. Ecology 54:788-797.

Burr, B. M., and L. M. Page. 1978. The life history of the cypress darter, Etheostoma proeliare, in Max Creek, Illinois. Illinois Natural History Survey, Biological Notes 106, Urbana, Illinois, USA.

Carle, F. L., and O. E. Maughan. 1980. Accurate and efficient estimation of benthic populations: A comparison of removal estimation and conventional sampling techniques. Hydrobiologia 70:181-182.

Carle, F. L., and M. R. Strubb. 1978. A new method for estimating population size from removal data. Biometrics 34:621-630.

Cloutman, D. G., and L. L. Olmsted. 1974. A survey of the fishes of the Cossatot River in southwestern Arkansas. Southwestern Naturalist 19:257-266.

Colwell, R. K., and D. J. Futuyma. 1971. On the measurement of niche breadth and overlap. Ecology 52:567-576.

Conover, W. J. 1971. Practical non-parametric statistics. John Wiley and Sons, New York, New York, USA.

Coutant, C. C. 1977. Compilation of temperature preference data. Journal of Fisheries Research Board of Canada 34:739-761.

Cross, F. B. 1967. Handbook of the fishes of Kansas. University of Kansas, Museum of Natural History Miscellaneous Publication 45: 1-357.

Culver, D. C. 1970. Analysis of simple cave communities: Niche separation and species packing. Ecology 51:949-958.

Dayton, R. K., and R. R. Hessler. 1972. Role of biological disturbance in maintaining diversity in the deep sea. Deep-Sea Research 19:199-208.

Deacon, J. E., and W. G. Bradley. 1972. Ecological distribution of fishes of the Moapa River in Clark County, Nevada. Transactions of the American Fisheries Society 101:408-409.

Distler, D. A. 1968. Distribution and variation of Etheostoma spectabile (Agassiz) (Percidae; Teleostei). University of Kansas Science Bulletin 48:143-208.

Dobie, J. 1959. Note on food of northern logperch. Transections of the American Fisheries Society 88:213.

Echelle, A. A., A. F. Echelle, and M. H. Smith. 1975. Analysis of genic continuity in a headwater fish, Etheostoma radiosum (Percidae). Copeia 1975:197-204.

Echelle, A. A., J. R. Schenck, and L. G. Hill. 1974. Etheostoma spectabile-Etheostoma radiosum hybridization in the Blue River. American Midland Naturalist 91:182-194.

Echelle, A. A., and G. D. Schnell. 1976. Factor analysis of species associations among fishes of the Kiamichi River, Oklahoma. Transections of the American Fisheries Society 105:17-31.

Edmunds, G. F., Jr., S. L. Jensen, and L. Berner. 1976. The mayflies of North and Central America. University of Minnesota Press, Minneapolis, Minnesota, USA.

Eley, R. L., J. C. Randolph, and R. J. Miller. 1975. Current status of the leopard darter, Percina pantherina. Southwestern Naturalist 29:343-354.

Emlen, J. M. 1968. Optimal choice in animals. American Naturalist 102:385-390.

Ewers, L. A. 1933. Summary report of crustacea used as food by fishes of the western end of Lake Erie. Transactions of the American Fisheries Society 63:379-390.

Ewers, L. A., and M. W. Boesel. 1935. The food of some Buckeye Lake fishes. Transactions of the American Fisheries Society 65:57-90.

Findley, J. S. 1976. The structure of bat communities. American Naturalist 110:129-139.

Flemer, D. A., and W. S. Woolcott. 1966. Food habits and distribution of the fishes of Tuckahoe Creek, Virginia, with special emphasis on the bluegill, Lepomis macrochirus Rafinesque. Chesapeake Science 7:75-89.

Gause, G. F. 1934. The struggle for existence. Baltimore, Williams, and Wilkins. Reprinted, 1964, by Hafner, New York, New York, USA.

Gee, J. H., and T. G. Northcote. 1963. Comparative ecology of two sympatric species of dace (Rhinichthys) in the Fraser River system, British Columbia. Journal of Fisheries Research Board of Canada 20:105-118.

George, E. L., and W. F. Hadley. 1979. Food and habitat partitioning between rock bass (Ambloplites rupestris) and smallmouth bass (Micropterus dolomieui) young of the year. Transactions of the American Fisheries Society 108:253-261.

Gorman, O. T., and J. R. Karr. 1978. Habitat structure and stream fish communities. Ecology 59:507-515.

Hallam, J. C. 1959. Habitat and associated fauna of four species of fish in Ontario streams. Journal of Fisheries Research Board of Canada 16:147-173.

Hardin, G. 1960. The competitive exclusion principal. Science 131: 1292-1297.

Harrel, R. C., and T. C. Dorris. 1968. Stream order, morphometry, physio-chemical conditions, and community structure of benthic macroinvertebrates in an intermittent stream system. American Midland Naturalist 80:220-251.

Haussmann, U. G. 1973. On the principal of competitive exclusion. Theoretical Population Biology 4:31-41.

Hubbs, C. L., and K. F. Lagler. 1958. Fishes of the Great Lakes Region. University of Michigan Press, Ann Arbor, Michigan, USA.

Jaeger, R. G. 1974. Competitive exclusion: Comments on survival and extinction of species. Biological Science 24:33-39.

Jenkins, R. M. 1956. The fishery resources of the Little River System, McCurtain County, Oklahoma. Oklahoma Department of Widlife Conservation, Oklahoma Fisheries Research Laboratory Report 55, Norman, Oklahoma, USA.

Jenkins, R. M., and C. A. Freeman. 1972. Logitudinal distribution and habitat of the fishes of Mason Creek, an upper Roanoke River drainage tributary, Virginia. Virginia Journal of Science 23: 193-202.

Jones, R. N., and O. E. Maughan. 1980. Some aspects of the biology and ecology of the leopard darter, Percina pantherina: Status of populations in Glover Creek, McCurtain County, Oklhaoma. United States Fish and Wildlife Service, PN82220-0005, Albuquerque, New Mexico, USA.

Keast, A. 1977. Diet overlaps and feeding relationships between the year classes in the yellow perch (Perca flavescens). Environmental Biology of Fishes 2:53-70.

Keast, A., and D. Webb. 1966. Mouth and body form relative to feeding ecology in the fish fauna of a small lake, Lake Opinicon, Ontario. Journal of Fisheries Research Board of Canada 23:1845-1874.

Kuehne, R. A. 1962. A classification of streams, illustrated by fish distribution in an eastern Kentucky creek. Ecology 43:608-614.

Lachner, E. A., E. F. Westlake, and P. S. Handwerk. 1950. Studies on the biology of some percid fishes from western Pennsylvania. American Midland Naturalist 43:92-111.

Larimore, R. W. 1957. Ecological life history of the warmouth (Centrarchidae). Illinois Natural History Survey Bulletin 27, Urbana, Illinois, USA.

Larimore, R. W., Q. H. Pickering, and R. Durham. 1952. An inventory of the fishes of Jordan Creek, Vermillion County, Illinois. Illinois Natural History Survey, Biological Notes 29, Urbana, Illinois, USA.

Larimore, R. W. and P. W. Smith. 1963. The fishes of Champaign County, Illinois, as affected by 60 years of stream changes. Bulletin of the Illinois Natural History Survey 28:299-382.

Linder, A. D. 1955. The fishes of the Blue River in Oklahoma with descriptions of two new percid hybrid combinations. American Midland Naturalist 54:173-191.

Linder, A. D. 1959. Behavior and hybridization of two species of Etheostoma (Percidae). Transactions of the Kansas Academy of Science 61:195-212.

Lotka, A. J. 1925. Elements of physical biology. Baltimore, Williams, and Wilkins, New York, New York, USA.

Lotrich, V. A. 1973. Growth, production, and community composition of fishes inhabiting a first-, second-, and third-order stream of eastern Kentucky. Ecological Monographs 43:377-397.

MacArthur, R. H., and E. R. Pianka. 1968. On optimal use of a patchy environment. American Naturalist 100:603-609.

Main, R. B. 1978. IFG4 program user manual. United States Fish and Wildlife Service, Unpublished Manuscript, Fort Collins, Colorado, USA.

Matthews, W. J., and L. G. Hill. 1979. Age-specific differences in the distribution of red shiners, Notropis lutrensis, over physiochemical ranges. American Midland Naturalist 101:366-372.

May, R. M. 1975. Some notes on estimating the competition matrix, α. Ecology 56:737-744.

Merritt, R. W., and K. W. Cummins. 1978. An introduction to the aquatic insects of North America. Kendall/Hunt Publishing Company, Dubuque, Iowa, USA.

Miller, R. J. 1973. An analysis of the fish populations in Salt Creek, Osage County, Oklahoma. Final report, Department of the Army, Corp of Engineers, Tulsa District, Contract Number DACW 56-73-C-0127, Tulsa, Oklahoma, USA.

Miller, R. J., and H. W. Robison. 1973. The fishes of Oklahoma. Oklahoma State University Press, Stillwater, Oklahoma, USA.

Moore, G. A., and J. D. Reeves. 1955. Hadropterus pantherinus, a new percid fish from Oklahoma and Arkansas. Copeia 1955:89-92.

Moore, G. A., and C. C. Rigney. 1952. Taxonomic status of the percid fish Poecilichthys radiosus in Oklahoma and Arkansas, with descriptions of two new subspecies. Copeia 1952:7-15.

Mullan, J. W., R. Applegate, and W. C. Rainwater. 1968. Food of logperch (Percia caprodes) and brook silverside (Labidesthes sicculus) in a new and old Ozark reservoir. Transactions of the American Fisheries Society 97:300-305.

Odum, E. P. 1971. Fundamentals of ecology. W. B. Saunders Company, Philadelphia, Pennsyvania, USA.

Oklahoma Biological Survey. 1972. Pre- and post-impoundment analysis of fish populations in the Mountain Fork River, McCurtain County, Oklahoma. Report prepared under Contract DAC 256-73-C-0023 with the United States Army Corps of Engineers, Tulsa District, Tulsa, Oklahoma, USA.

O'Neil, P. E. 1980. Life histories and resource partitioning patterns of three species of fishes (Percidae: Etheostoma). Master's thesis, University of Alabama, University, Alabama, USA.

Orions, G. H., and H. S. Horn. 1969. Overlap in foods and foraging of four species of blackbirds in the potholes of central Washington. Ecology 50:930-938.

Orth, D. J. 1980. Evaluation of a methodology for recommending instream flows for fishes. Doctoral thesis, Oklahoma State University, Stillwater, Oklahoma, USA.

Orth, D. J., and R. N. Jones. 1980. Range extensions of the orange-throat darter (Etheostoma spectabile) and the freckled madtom (Noturus nocturnus) into western Oklahoma. Proceeding of the Oklahoma Academy of Science 60:98-99.

Paden, J. M. 1948. Notes on four species of fishes in Oklahoma. Proceedings of the Oklahoma Academy of Science 28:38-39.

Page, L. M. 1972. An analysis of diversity in the darter genus Percina (Osteichthyes, Percidae: Etheostoma). Doctoral thesis, University of Illinois, Urbana, Illinois, USA.

Page, L. M. 1974. The life history of the spottail darter, Etheostoma squamiceps, in Big Creek, Illinois, and Fergeson Creek, Kentucky. Illinois Natural History Survey, Biological Notes 89, Urbana, Illinois, USA.

Page, L. M. 1975. The life history of the stripetail darter, Etheostoma kennicotti, in Big Creek, Illinois. Illinois Natural History Survey, Biological Notes 93, Urbana, Illinois, USA.

Page, L. M., and D. W. Schemske. 1978. The effect of interspecific competition on the distribution and size of darters of the subgenus Catonotus (Percidae: Etheostoma). Copeia 1978:406-412.

Page, L. M., and P. W. Smith. 1970. The life history of the dusky darter, Percina sciera, in the Embarras River, Illinois. Illinois Natural History Survey, Biological Notes 69, Urbana, Illinois, USA.

Pennak, R. W. 1953. Freshwater invertebrates of the United States. Ronald Press, New York, New York, USA.

Pennak, R. W., and E. D. Van Gerden. 1947. Bottom fauna production and physical nature of the substrate in a northern Colorado trout stream. Ecology 28:42-48.

Peters, R. H. 1976. Tautology in evolution and ecology. American Naturalist 110:1-12.

Pflieger, W. L. 1975. The fishes of Missouri. Missouri Department of Conservation, Jefferson City, Missouri, USA.

Pianka, E. R. 1969. Sympatry of desert lizards (Ctenotus) in western Austrailia. Ecology 50:1012-1030.

Pianka, E. R. 1973. The structure of lizard communities. Annual Review of Ecology and Systematics 4:53-74.

Pianka, E. R. 1976. Competition and niche theory. Pages 114-141 in R. M. May, editor. Theoretical ecology: Principals and applications, W. B. Saunders Company, Philadelphia, Pennsylvania, USA.

Pielou, E. C. 1972. Niche width and niche overlap: a method of measuring them. Ecology 53:687-692.

Reed, R. J. 1968. Mark and recapture studies of eight species of darters (Pisces: Percidae) in three streams of northwestern Pennslyvania. Copeia 1968:172-175.

Reeves, J. D. 1953. The fishes of the Little River System in Oklahoma. Doctoral thesis, Oklahoma State University, Stillwater, Oklahoma, USA.

Riggs, C. D., and W. F. Wade. 1964. Percina shumardi in the Illinois River of Oklahoma. Proceedings of the Oklahoma Academy of Science 44:65-66.

Robison, H. W. 1978. The leopard darter (a status report). Endangered Species Report 3, United States Fish and Wildlife Service, Albuquerque, New Mexico, USA.

Roughgarden, J. 1974. Niche width: biogeographic patterns among Anolis lizard populations. American Naturalist 108:429-442.

Sanders, H. L., and R. R. Hessler. 1969. Ecology of the deep-sea benthos. Science 163:1419-1424.

Scalet, C. G. 1971. Parasites of the orangebelly darter, Etheostoma radiosum (Pisces: Percidae). Journal of Parasitology 57:900.

Scalet, C. G. 1972. Food habits of the orangebelly darter, Etheostoma radiosum cyanorum (Osteichthys: Percidae). American Midland Naturalist 87:515-522.

Scalet, C. G. 1973a. Stream movement and population density of the orangebelly darter, Etheostoma radiosum cyanorum (Osteichthyes: Percidae). Southwestern Naturalist 17:381-387.

Scalet, C. G. 1973b. Reproduction of the orangebelly darter, Etheostoma radiosum cyanorum (Osteichthys: Percidae). American Midland Naturalist 89:156-165.

Scalet, C. G. 1974. Lack of piscine predation on the orangebelly darter, Etheostoma radiosum cyanorum. American Midland Naturalist 92:510-512.

Schoener, T. W. 1968. The Andlis lizards of Bimini: Resource partitioning in a complex fauna. Ecology 49:704-726.

Schoener, T. W. 1971. Theory of feeding strategies. Annual Review of Ecology and Systematics 2:369-404.

Schoener, T. W. 1974. Resource partitioning in ecological communities. Science 185:27-39.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184:1-966.

Sheldon, A. L. 1968. Species diversity and logitudinal succession in stream fishes. Ecology 49:193-198.

Shelford, V. E. 1911. Ecological succession: Stream fishes and the method of physiographic analysis. Biological Bulletin 21:9-35.

Smart, H. 1979. Coexistence and resource partitioning in two species of darters (Percidae), Etheostoma nigrum and Percina maculata. Master's thesis, University of Manitoba, Winnipeg, Manitoba, Canada.

Smart, H., and J. H. Gee. 1979. Coexistence and resource partitioning in two species of darters (Percidae), Etheostoma nigrum and Percina maculata. Canadian Journal of Zoology 57:2061-2071.

Smith, P. W. 1979. The fishes of Illinois. University of Illinois Press, Urbana, Illinois, USA.

Strauss, R. E. 1979. Reliability estimates for Ivlev's electivity index, the forage ratio, and a proposed linear index of food selection. Transactions of the American Fisheries Society 108: 344-352.

Taylor, J., and F. Wade. 1972. Biological inventory of the Glover Creek Basin, Oklahoma. Southeastern Oklahoma State College, Final report, Contract DAGW56-72-C-0086, Durant, Oklahoma, USA.

Thomas, D. L. 1970. An ecological study of four darters of the genus Percina (Percidae) in the Kaskaskia River, Illinois. Illinois Natural History Survey, Biological Notes 70, Urbana, Illinois, USA.

Thompson, D. H., and F. D. Hunt. 1930. The fishes of Champaign County: A study of the distribution and abundance of fishes in a small stream. Illinois Natural History Survey Bulletin 19:1-101.

Trautman, M. B. 1957. The fishes of Ohio. Ohio State University Press, Columbus, Ohio, USA.

Turner, C. L. 1921. Food of the common Ohio darters. Ohio Journal of Science 22:41-62.

Usinger, R. L. 1956. Aquatic insects of California. University of California Press, Berkeley, California, USA.

U.S. Army Corps of Engineers. 1975. Draft of environmental statement, Lukfata Lake, Glover Creek, Oklahoma. United States Army Corps of Engineers, Tulsa District, Tulsa, Oklahoma, USA.

U.S. Fish and Wildlife Service. 1978. Final threatened status and critical habitat for the leopard darter. Federal Register 43: 3711-3716.

Volterra, V. 1926. Variations and fluctuations of the number of individuals in animal species living together. Pages 412-414, 432-433 _in_ R. N. Chapman, editor. Animal ecology, McGraw-Hill, New York, New York, USA.

Wallace, R. K., Jr. 1981. An assessment of diet-overlap indexes. Transaction of the American Fisheries Society 110:72-76.

Whiteside, B. G., and R. M. McNatt. 1972. Fish species diversity in relation to stream order and physiochemical conditions in the Plum Creek drainage basin. American Midland Naturalist 88:92-101.

Wiens, J. A. 1977. On competition and variable environments. American Scientist 65:590-597.

Wiggins, G. B. 1977. Larvae of the North American caddisfly genera. University of Toronto Press, Toronto, Canada.

Winn, H. E. 1953. Breeding habits of the Percid fish _Hadropterus copelandi_ in Michigan. Copeia 1953:26-30.

Winn, H. E. 1958a. Comparative reproductive behavior and ecology of fourteen species of darters. Ecological Monographs 28:155-191.

Winn, H. E. 1958b. Observations on the reproductive habits of darters (Pisces, Percidae). American Midland Naturalist 59:186-192.

Wynes, D. L. 1979. Predator-prey relationship in riffle--fish communities of the Little Miami River, Ohio. Doctoral thesis, Miami University, Miami, Ohio, USA.

Zaret, T. M., and A. S. Rand. 1971. Competition in tropical stream Fishes: support for the competitive exclusion principle. Ecology 52:336-342.

APPENDICES

APPENDIX A

LEGAL LOCATIONS AND DESCRIPTIONS OF SAMPLING LOCATIONS ON GLOVER CREEK

Decription of Sampling Sites

Site 1

Site 1 is located where state highway 3 and 7 crosses Glover Creek, about 19 km west of Broken Bow, Oklahoma; the northwest corner of the northeast quarter-section in Section 28, T5S, R23E. The sampling area extends downstream from the bridge for approximately 160 m. The creek channel is about 55 m wide at this point but the actual creek width varies considerably with discharge level. This area of Glover Creek is characterized by large pools separated by shallow riffles and runs. The substrate is predominantly rubble and gravel with scattered boulders. During low summer flows, large areas of rubble become exposed forming several smaller channels and isolated pools. Dense growths of water willow (*Justica sp.*) typically invade areas of shallow flow during summer.

Site 2

Site 2 is located on the main stem of Glover Creek upstream from the 3 and 7 bridge; the southwest corner of the northeast quarter-section in Section 9, T5S, R23E, on access road 71000-51000. This area of Glover Creek consists of large reaches of wide pool separated by short riffles and runs. Sampling is conducted above and below a low water concrete bridge. The area above the bridge is primarily pool habitat with rubble and gravel substrate. Except for the deeper main channel of flow, much of this area is shallow and becomes exposed during low summer flows. Backwaters and sloughs form along the western shoreline during low water and this area becomes isolated from the main channel. The area below the bridge typically has turbulent eddys along either shore but widens out into a relatively shallow run about 30 m long at normal flow. Below the run, a deep wide pool is formed. During low flows, a short riffle is present below the bridge followed by wide, shallow, slow flowing areas along either shore for approximately 40 m. The substrate is almost entirely rubble and large gravel. Average width of the channel is about 50 m. The surrounding terrain is low rolling hills used for commercial timber harvesting and cattle grazing in some areas.

Site 3

Site 3 is located on the main stem upstream from Site 2; the northwest corner of the northwest quarter-section in Section 32, T4S, R23E, on access road 71300-51300. This area of Glover Creek is much the same as Site 2. Sampling is conducted above and below a low water concrete bridge. The area above the bridge is pool habitat with rubble and gravel substrate. Below the bridge, a small turbulent pool is formed that flows into a narrow, fast flowing run averaging 10 m in width. Substrate in this area is predominantly large boulders and bedrock with gravel and rubble along one shore. The banks are steep along the eastern shoreline with outcroppings of slabrock and boulders. The other shoreline is bounded by a large area of shrub covered rubble that forms an island at high flows. During high flows, water levels are frequently over the bridge forming shallow fast flowing riffles and channels along the western shoreline. A long wide pool is formed below this area that averages 45 m in width. The surrounding terrain is steep with virtually no flood plain. Commercial timber harvesting is the principal economic activity in the area.

Site 4

Site 4 is located on Cedar Creek about 8 km upstream from Glover Creek; the southwest corner of the northeast quarter-section in Section 27, T4S, R23E, on access road 51155. The area is characterized by long narrow pools and runs separated by shallow riffles. The sampling area is approximately 100 m long and 10 m wide. The upstream area is a pool about 50 m long with large boulder and bedrock substrate. A shallow riffle about 15 m long is formed below the pool. Substrate is rubble and gravel with scattered boulder. Below the riffle, about 35 m of shallow run is formed with large rubble and gravel substrate scattered over bedrock. The steep surrounding terrain confines the creek at high flows which becomes relatively deep and fast flowing in this area.

Site 5

This site is located on the main stem of Glover Creek, above Site 3; the northeast corner of the southwest quarter section in Section 8, T4S, R23E, at Dierk's Boy Scout Camp. The sampling area is best described as a run. At low flows during summer and fall, the area forms a series of shallow riffles and small, slow flowing pools. Substrate is quite varied with rubble, gravel, and small boulders in areas of flow and bedrock and large boulders predominant in pool areas. The surrounding terrain is steep and hilly. The channel averages about 45 m in width.

Site 6

This site is located on Carter Creek approximately 5 km upstream from Glover Creek; the southeast corner of the northwest quarter section in Section 4, T4S, R23E, on access road 51750. The area is characterized by long wide pools separated by short riffles, narrow runs, and small pools. The sampling area is about 100 m long consisting of mostly pool habitat. One area of backwater, forming a slough is present along one shore. About 10 m of shallow riffle and narrow run is sampled below the pool. Substrate in the pool is scattered boulders over bedrock. Rubble and gravel is the predominant substrate in the riffles. Commercial timber harvesting is the main economic activity in the area.

Site 7

This site is located on the main stem of Glover Creek, upstream from Site 5; the northwest corner of the northeast quarter-section in Section 32, T3S, R23E, on access road 72000-52000. The sampling area is approximately 20 m downstream from a low water concrete bridge. The area is approximately 35 m long and averages 23 m wide. The upstream 25% of the site is a narrow riffle with large rubble and gravel substrate. Several small islands are usually exposed in the riffle during low flows of summer. The area widens out into a pool below the riffle with the main channel running along the immediate western shoreline. Substrate in the main channel is predominantly large boulder and rubble scattered over bedrock. During low flows of summer and early fall, this area is usually exposed and has extensive growths of water willow. The area below the study site is a wide pool approximately

200 m long. The surrounding terrain along the shorelines is steep with relatively no flood plain.

Site 8

Site 8 is located on Pine Creek approximately 9 km upstream from Glover Creek; the northwest corner of the northwest quarter-section in Section 11, T3S, R23E, on access road 52500. The area is characterized by small pools with boulder and bedrock substrate separated by short riffles and runs having gravel and rubble substrate. The creek averages 8 m in width. Approximately 100 m of stream is sampled, consisting of several small pools and riffles. The surrounding terrain is steep and hilly with commercial timber harvesting the main economic activity. During high flows, the cleek is generally confined to the channel forming a fast flowing and turbulent run.

Site 9

Site 9 is located on the main stem of Glover Creek, upstream from Site 7, several river kilometers below the confluence of the East and West Forks; the northeast corner of the southwest quarter-section in Section 13, T3S, R22E. Access is by county road. The sampling area is located above and below a low water crossing. A large island divides the channel above the crossing with the creek flowing along both sides of the island except at extremely low flows. The area is best described as a series of short, shallow, interconnecting riffles, narrow flowing runs and small pools. Large wide pools are formed above and below the site. Substrate is predominantly rubble with scattered boulders and areas of gravel. Although the surrounding terrain is fairly steep and hilly, the channel is very wide, averaging 100 m, and forms a semi-flood plain. Commercial timber harvesting is the principal economic activity in the area.

Site 10

Site 10 is located on the main stem about 200 m below the confluence of the East and West Forks; the northeast corner of the southwest quarter section in Section 7, T3S, R23E, on access road 53000. The sampling area is located below a low water concrete bridge. A turbulent pool is formed immediately below the bridge that widens out along the eastern shore creating a large area of backwater and eddy. A narrow shallow run, approximately 30 m long and 15 m wide is formed below the pool. The run ends in a deep wide pool. During low flow, a large portion of the backwater area is exposed and the run becomes a shallow flowing riffle. Substrate in this area is predominantly rubble and gravel with scattered boulder. At low flows, shallow areas become overgrown with water willow. The surrounding terrain is fairly steep and has little or no flood plain.

Site 11

Site 11 is located on the West Fork of Glover Creek, approximately .5 km above its confluence with the East Fork; the southeast corner of the northwest quarter section in Section 7, T3S, R23E, on access road 74100. The sampling area is about 60 m downstream from a low water concrete bridge. The upstream 50% of the stie is a riffle about 48 m long and 16 m wide. Substrate in the riffle is predominantly large boulder with small areas of rubble and gravel. During low flows of summer and early fall, much of the riffle is exposed forming several small channels. The remainder of the site, immediately downstream from the riffle, is a wide pool approximately 45 m long and 21 m wide with primarily bedrock and large boulder substrate. The surrounding terrain is characterized by low rolling hills with moderately dense stands of pine-oak forest. This area is used for commercial timber harvesting and cattle grazing in some areas.

Site 12

Site 12 is located on the East Fork of Glover Creek, about 1 km northwest of Bethel, Oklahoma; the northeast corner of the southwest quarter section in Section 24, T2S, R23E. Access is by county road. The sampling area is immediately downstream from a concrete bridge and is approximately 31 m long and 10 m wide. The upstream 35% of the area is a riffle with rubble, gravel, and scattered boulder substrate. During low summer flows most of the riffle is exposed and several shallow channels with extensive growths of water willow are formed. The area below the riffle is characteristic of a narrow flowing run that forms a small shallow pool during low summer flows. The substrate in this area is predominantly bedrock and large boulder with a small area of rubble and gravel along one shoreline. The surrounding terrain is low, flat, and is used primarily for agriculture. During high flows after spring rains, much of the surrounding croplands become flooded.

Site 13

Site 13 is located in the headwaters of the East Fort of Glover Creek, about 7 km northeast of Bethel, Oklahoma; the northeast corner of the southeast quarter section in Section 5, T2S, R24E, on access road 61000. This area is characterized by long narrow pools separated by shallow riffles and short runs. The sampling area is approximately 80 m long with a pool in the upstream portion that averages 12 m in width. Substrate in this area is primarily scattered boulder and large rubble over bedrock. The pool narrows down to form a riffle about 10 m wide and 20 m long. Substrate in the riffle is large rubble and boulder. The surrounding terrain is steep, hilly, and has dense stands of pine-oak forest.

Site 14

Site 14 is located in the headwaters of the West Fork of Glover Creek, about 8 km northwest of Battiest, Oklahoma; the southeast corner of the southeast quarter section in Section 24, T1S, R22E, on access road 61200. The upstream 50% of the site is a riffle approximately 30 m long and 7 m wide. Substrate is mostly rubble and gravel with scattered large boulders. Bluff Creek enters the West Fork about 10 m upstream from the tail of the riffle but is usually dry during summer and early fall. The downstream area is a pool approximately 40 m long and 11 m wide. Substrate is mostly bedrock and large boulder. The surrounding terrain is steep, forming little flood plain, and is used for commercial harvesting of dense stands of pine-oak timber. This area of the West Fork is characteristically narrow forming small pools and short runs separated by frequent riffle areas of larger substrates.

APPENDIX B

MODIFIED WENTWORTH PARTICAL SIZE SCALE

Table 30. 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 C

CAPTURE LOCATIONS AND HABITAT DATA OF DARTERS COLLECTED IN GLOVER CREEK

Table 31. Dates, locations, total lengths, and habitat data for leopard darters in Glover Creek, Oklahoma.

Sampling period	Date	Site	Total length (mm)	Habitat data: Water depth (cm)	Water velocity (cm/s)	Substrate type	Habitat
Summer 1977*	13 Aug.	11	-	41	-	6.0	Pool
Fall 1977*	16 Nov.	11(P)	73	-	-	-	Pool
			75	-	-	-	Pool
	10 Dec.	3	58	-	-	-	Riffle
Winter 1978*	10 Jan.	11(P)	74	-	-	-	Pool
			77	-	-	-	Pool
			75	-	-	-	Pool
			75	-	-	-	Pool
Spring 1978*	10 Apr.	11(P)	67	30	4.6	6.5	Pool
			70	-	-	-	Pool
	16 Apr.	11(R)	72	28	96.0	7.0	Riffle
			70	24	38.9	7.0	Riffle
			50	18	38.9	6.0	Riffle
Summer 1978*	25 May	14	-	42	2.3	6.0	Pool
	8 Jun.	11	92	61	0	7.0	Pool
	21 Jul.	14(P)	78	68	0	7.5	Pool
			77	49	0	7.5	Pool
			73	25	0	5.5	Pool
			45	48	0	7.0	Pool
			70	52	0	7.5	Pool

Table 31. Continued.

Sampling period	Date	Site	Total length (mm)	Habitat data: Water depth (cm)	Water velocity (cm/s)	Substrate type	Habitat
Fall 1978	15 Oct.**	11(P)	63	64	0	7.5	Pool
			56	67	0	7.5	Pool
	18 Nov.	3	53	31	9.6	5.5	Run
	18 Nov.	10	86	50	6.9	5.5	Pool
Winter 1979	29 Dec.	1	63	41	2.3	5.5	Pool
	2 Jan.	6	71	83	0	5.5	Pool
	7 Jan.	12	81	29	0	5.5	Pool
			54	50	22.8	8.0	Run
	10 Jan.**	11(R)	70	32	25.2	5.5	Riffle
	12 Jan.**	14(P)	55	99	0	6.5	Pool
			55	108	0	6.5	Pool
	13 Jan.	9	70	48	36.6	6.0	Run
Spring 1979	28 Apr.**	12(R)	53	31	27.4	5.5	Riffle
	29 Apr.**	12(P)	78	63	0	7.0	Pool
	13 Jun.	2	69	38	0	6.0	Pool
Summer 1979	18 Jul.	13	73	40	0	6.0	Pool
	21 Aug.	7	64	33	0	7.5	Pool
	1 Sept.**	14(P)	72	78	0	6.5	Pool
	2 Sept.**	11(P)	67	20	0	7.0	Pool
			64	48	0	6.5	Pool
			64	57	0	6.5	Pool
			63	36	0	5.5	Pool
			65	62	0	5.5	Pool

Table 31. Continued.

Sampling period	Date	Site	Total length (mm)	Habitat data: Water depth (cm)	Water velocity (cm/s)	Substrate type	Habitat
Summer 1979	2 Sept.**	11(P)	66	62	0	5.5	Pool
			71	26	0	6.5	Pool
			64	44	0	7.0	Pool
			62	45	0	7.0	Pool
			68	33	0	6.5	Pool
			70	29	0	6.5	Pool
Fall 1979	20 Oct.	7	68	46	0	6.5	Pool
			69	9	0	6.5	Pool
	21 Oct.	1	65	20	0	5.5	Pool
	22 Oct.	11(P)	73	28	0	6.5	Pool
			70	38	0	6.5	Pool
			71	25	0	6.5	Pool
			71	34	0	6.5	Pool
			67	37	0	6.5	Pool
	23 Oct.	2	70	26	0	6.5	Pool
			67	18	0	6.0	Pool
	10 Nov.	13	92	46	0	6.5	Pool
Winter 1980	4 Jan.	12	81	43	41	8.0	Pool
			77	43	0	6.5	Pool
	5 Jan.	14(P)	68	74	4	6.5	Pool
			71	66	4	5.5	Pool
			82	60	6	6.0	Pool
			81	80	1	6.5	Pool
			67	84	0	6.5	Pool
			81	84	0	7.0	Pool

Table 31. Continued.

Sampling period	Date	Site	Total length (mm)	Habitat data: Water depth (cm)	Water velocity (cm/s)	Substrate type	Habitat
Winter 1980	5 Jan.	14(P)	77	67	5	6.5	Pool
			63	70	0	5.5	Pool
			67	94	7	6.5	Pool
			66	78	0	6.0	Pool
			84	100	11	6.5	Pool
	8 Jan.	7	70	42	3	6.5	Pool
			69	34	7	5.5	Pool
			67	42	8	6.5	Pool
			74	42	8	6.5	Pool
			67	30	26	6.5	Pool
			76	48	0	6.5	Pool
			71	30	15	6.5	Pool
			75	55	5	7.0	Pool
			69	54	5	7.0	Pool
			68	44	4	6.0	Pool
			70	55	7	6.5	Pool
	9 Jan.	3	65	61	15	6.0	Run
			63	49	18	6.5	Run
			61	54	5	7.0	Run
			66	68	0	5.5	Run
		6	81	38	7	6.0	Pool
			68	70	0	6.5	Pool
	10 Jan.	2	68	18	14	6.5	Run
			65	36	16	6.0	Run
			63	20	9	6.0	Pool
		5	64	60	5	7.0	Pool

Table 31. Continued.

Sampling period	Date	Site	Total length (mm)	Habitat data: Water depth (cm)	Water velocity (cm/s)	Substrate type	Habitat
Winter 1980	23 Feb.	14(R)	81	25	41	6.0	Riffle
			73	32	26	7.0	Riffle
			85	39	14	7.0	Riffle
			71	32	34	7.0	Riffle
	8 Mar.	12	55	20	50	6.0	Riffle
	9 Mar.	14(R)	76	20	1	6.5	Riffle
			82	22	19	6.0	Riffle
			92	21	12	5.5	Riffle
			90	27	5	7.0	Riffle
			82	18	9	5.5	Riffle
			86	32	4	6.5	Riffle
	10 Mar.	14(P)	85	78	2	6.5	Pool
			77	80	0	7.0	Pool
			74	70	0	7.0	Pool
			85	47	8	6.0	Pool
			65	84	0	7.0	Pool
	11 Mar.	11(P)	63	72	0	7.0	Pool
			64	70	0	7.5	Pool
			68	88	0	8.0	Pool
			70	50	1	7.0	Pool
			71	76	6	8.0	Pool
			60	56	0	7.0	Pool
	12 Mar.	7	63	30	0	6.5	Pool
			74	18	25	6.5	Riffle
			70	60	7	6.5	Pool
		3	61	60	15	6.5	Pool

Table 31. Continued.

Sampling period	Date	Site	Total length (mm)	Habitat data: Water depth (cm)	Water velocity (cm/s)	Substrate type	Habitat
Winter 1980	12 Mar.	3	63	50	17	6.0	Pool
			56	30	1	6.0	Pool
			58	28	0	5.5	Run
			57	62	0	5.5	Pool
		8	80	14	18	7.0	Riffle
	13 Mar.	10	65	36	0	8.0	Pool
			63	8	0	6.0	Pool
		9	66	18	0	6.0	Pool
			68	24	0	6.5	Pool
	14 Mar.	2	64	28	0	6.0	Pool
			62	30	18	6.0	Run
		5	66	36	1	5.5	Pool
Summer 1980	15 Jul.	14(P)	84	122	0	7.0	Pool
			83	110	0	7.0	Pool
			87	120	0	7.0	Pool
	16 Jul.	13	85	35	0	7.0	Pool
			66	43	0	7.0	Pool
			85	38	0	6.5	Pool
	23 Jul.	1	71	43	0	6.5	Pool

*Conducted by Orth.

**Conducted in conjunction with Orth.

Table 32. Dates, locations, total lengths, and habitat data for logperch in Glover Creek, Oklahoma.

Sampling period	Date	Site	Length	Depth	Velocity	Substrate
Fall 1978	15 Nov.	1	107	52	0	5.5
Winter 1978–1979	29 Dec.	1	87	48	16	5.5
			114	60	5	5.5
Spring 1979	12 Jun.	4	110	49	18	8.0
	11 Jun.	3	129	32	0	6.0
			103	40	24	6.0
Summer 1979	21 Aug.	7	140	20	6	6.5
			135	42	4	7.5
			125	–	–	–
			125	–	–	–
	20 Aug.	3	128	38	6	6.0
	10 Aug.	2	124	26	43	5.5
Fall 1979	20 Oct.	7	89	28	0	6.5
	22 Oct.	11	125	34	0	6.5
	21 Oct.	1	130	95	0	5.0
			134	45	4	5.5
	21 Oct.	3	115	22	0	5.5
	23 Oct.	2	133	60	0	6.5
			112	39	0	6.5
			121	63	0	6.5
			105	30	0	6.5
Winter 1980	5 Jan.	14(P)	115	95	5	7.0
			108	94	0	6.5
			125	78	0	6.5
			109	72	0	6.5
			121	82	0	7.0
			116	81	0	6.5
			113	74	0	7.0
			151	92	8	6.5
	23 Feb.	14(R)	120	37	14	6.5
	24 Feb.	11(P)	131	90	13	6.5
Spring 1980	8 Mar.	12	135	50	16	8.0
			120	36	13	8.0
	10 Mar.	14(P)	115	73	0	7.0
			122	65	0	6.5
			115	81	0	7.0
			126	70	0	7.0
			120	74	1	7.0

Table 32. Continued.

Sampling period	Date	Site	Length	Depth	Velocity	Substrate
Spring 1980	10 Mar.	14(P)	142	82	0	7.0
	12 Mar.	3	75	38	12	6.5
	14 Mar.	2	109	46	3	6.0
Summer 1980	15 Jul.	14(P)	99	106	0	7.0
			141	106	0	7.0
	19 Jul.	11(P)	141	52	0	7.5
	23 Jul.	5	116	50	0	7.5
		2	120	17	0	6.0
			-	57	0	7.0
			117	41	0	7.0
			109	41	0	7.0
			98	51	0	7.0
			106	41	0	5.5

Table 33. Dates, locations, total lengths, and habitat data for johnny darter in Glover Creek, Oklahoma.

Sampling period	Date	Site	Length	Depth	Velocity	Substrate
Fall 1978	-	-	-	-	-	-
Winter 1978-1979	29 Dec.	1	40	72	0	5.5
	3 Jan.	2	42	29	37	5.0
Spring	-	-	-	-	-	-
Summer 1979	-	-	-	-	-	-
Fall 1979	-	-	-	-	-	-
Winter 1980	10 Jan.	2	53	46	0	5.5
			49	54	0	7.0
Spring 1980	12 Mar.	7	-	20	48	7.0
		3	43	28	4	6.0
			48	62	0	5.5
			42	50	0	7.0
	14 Mar.	2	45	29	30	5.5
			52	60	0	8.0
			41	26	0	5.5
			45	35	0	5.5
Summer 1980	21 Jul.	1	-	39	0	5.5

Table 34. Dates, locations, total lengths, and habitat data for orangethroat darter in Glover Creek, Oklahoma.

Sampling period	Date	Site	Length	Depth	Velocity	Substrate
Fall 1978	-	-	-	-	-	-
Winter 1978-1979	29 Dec.	1	37	32	7	5.0
			39	22	23	5.0
			41	65	9	5.5
Spring 1979	-	-	-	-	-	-
Summer 1979	-	-	-	-	-	-
Fall 1979	21 Oct.	1	41	7	92	4.0
Winter 1980	8 Jan.	1	41	18	54	5.0
			38	32	18	5.0
			33	50	9	5.5
			33	52	12	5.5
			36	30	0	5.5
			43	30	0	5.5
			33	67	13	5.5
			31	22	0	6.0
			36	15	0	6.0
Spring 1980	12 Mar.	1	36	18	60	5.0
			47	10	26	5.0
			32	18	56	5.0
			43	26	10	5.0
Summer 1980	23 Jul.	1	-	15	11	5.5
			-	9	6	5.0
			-	11	32	5.5
			-	12	0	5.5
			-	13	16	5.5
			-	13	19	5.5
			-	6	19	5.5
			-	10	12	5.5
			-	18	11	5.5
			-	10	28	5.5
			-	12	0	6.0

Table 35. Dates, locations, total lengths, and habitat data for dusky darter in Glover Creek, Oklahoma.

Sampling period	Date	Site	Length	Depth	Velocity	Substrate
Fall 1978	-	-	-	-	-	-
Winter 1978-1979	-	-	-	-	-	-
Spring 1979	-	-	-	-	-	-
Summer 1979	16 Jul.	1	-	24	18	4.5
Fall 1979	21 Oct.	1	58	24	9	4.0
			64	8	0	4.5
			100	20	27	4.0
			80	8	20	4.0
			82	8	30	4.0
Winter 1980	8 Jan.	1	57	40	23	5.0
Spring 1980	12 Mar.	1	89	36	9	3.0
			63	32	30	3.0

Table 36. Dates, locations, total lengths, and habitat data for channel darter in Glover Creek, Oklahoma.

Sampling period	Date	Site	Length	Depth	Velocity	Substrate
Fall 1978	19 Nov.	2	47	35	0	5.0
			47	43	16	5.0
Winter 1978–1979	29 Dec.	1	45	65	9	5.5
			48	60	2	5.5
			50	70	0	5.5
			52	72	0	5.5
	13 Jan.	9	52	32	43	6.0
Spring 1979	22 Apr.	10	62	19	41	5.5
			53	7	0	5.5
	11 Jun.	1	52	20	12	5.5
			45	20	29	5.5
	12 Jun.	9	54	38	30	6.0
		10	56	5	30	6.0
	13 Jun.	2	50	19	44	5.0
			52	18	28	4.5
			48	14	42	4.5
			52	34	33	4.5
Fall 1979	21 Oct.	1	46	40	0	5.5
	22 Oct.	11	45	24	0	8.0
	11 Nov.	5	48	53	0	-
Winter 1979–1980	10 Jan.	5	54	62	5	8.0
	24 Feb.	11(P)	52	48	13	7.0
Spring 1980	8 Mar.	12	44	28	11	6.5
	9 Mar.	14(R)	63	22	18	6.5
			49	25	11	6.5
	10 Mar.	14(P)	57	90	0	7.0
	11 Mar.	11(P)	45	64	0	7.0
	12 Mar.	3	46	20	8	5.5
			47	48	0	8.0
			50	42	0	8.0
			56	32	40	5.5
			44	30	24	5.5
			54	20	73	5.5
			53	10	50	5.5
	13 Mar.	9	61	48	30	8.0
			58	50	31	8.0
	14 Mar.	2	51	25	30	5.5
			44	28	28	6.0
			44	38	35	5.5

Table 36. Continued.

Sampling period	Date	Site	Length	Depth	Velocity	Substrate
Spring 1980	14 Mar.	2	43	30	13	6.0
			52	26	0	5.5
		5	50	50	0	8.0
			55	54	0	7.5
			48	68	0	8.0
			53	64	0	6.5
			47	12	8	6.5
Summer 1980	15 Jul.	14(P)	53	111	0	7.0

APPENDIX D

CATCH PER UNIT OF EFFORT OF DARTERS

COLLECTED IN GLOVER CREEK

Table 37. 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	1	*E. radiosum*		.415	
		P. caprodes	1	.415	2.4
	2	*E. radiosum*		.169	
		P. copelandi	2	.169	11.8
	3	*E. radiosum*		.386	
		P. pantherina	1	.386	2.6
	4	*E. radiosum*		.341	
	6	*E. radiosum*		.279	
	8	*E. radiosum*		.211	
	9	*E. radiosum*		.288	
	10	*E. radiosum*	34	.192	177.0
		P. pantherina	1	.192	5.2
	13	*E. radiosum*		.245	
Winter 1979	1	*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
	2	*E. radiosum*	30	.362	82.8
		E. nigrum	1	.362	2.7
	3	*E. radiosum*	3	.396	7.5
	4	*E. radiosum*	22	.356	62.0
	5	*E. radiosum*	4	.379	10.5
	6	*E. radiosum*	9	.274	33.3
		P. pantherina	1	.274	3.6
	8	*E. radiosum*	31	.418	74.1
	9	*E. radiosum*	6	.511	11.7
		P. pantherina	1	.511	1.9
		P. copelandi	1	.511	1.9
	10	*E. radiosum*	49	.926	52.9
	13	*E. radiosum*	22	.488	45.0

Table 37. Continued.

Season and year	Sampling location	Species	C	F(hrs)	c/f
Spring 1979	1	*E. radiosum*	52	.381	136.4
		P. copelandi	2	.381	5.2
	2	*E. radiosum*	45	.325	138.4
		P. copelandi	4	.325	12.3
		P. pantherina	1	.325	3.0
	3	*E. radiosum*		.397	
		P. caprodes	2	.397	5.0
	4	*E. radiosum*	42	.450	93.0
		P. caprodes	1	.450	2.0
	5	*E. radiosum*	13	.515	26.0
	6	*E. radiosum*	9	.283	31.8
	7	*E. radiosum*	47	.552	85.1
	8	*E. radiosum*	31	.265	116.9
	9	*E. radiosum*	24	.340	70.6
		P. copelandi	1	.340	2.9
	10	*E. radiosum*	79	.806	98.0
		P. copelandi	3	.806	3.7
	13	*E. radiosum*	27	.283	95.0
Summer 1979	1	*E. radiosum*	13	.594	21.8
		P. sciera	1	.594	1.7
	2	*E. radiosum*	45	.423	106.4
		P. caprodes	1	.423	2.3
	3	*E. radiosum*	34	.428	89.4
	4	*E. radiosum*	58	.461	126.0
	5	*E. radiosum*	30	.558	53.7
	6	*E. radiosum*	32	.613	52.5
	8	*E. radiosum*	45	.577	77.9
	9	*E. radiosum*	25	.448	55.8
	10	*E. radiosum*	65	.590	110.0
	13	*E. radiosum*		.658	
		P. pantherina	1	.658	1.5

Table 37. Continued.

Season and year	Sampling location	Species	C	F(hrs)	c/f
Fall 1979	1	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
	2	E. radiosum	300	.533	563.0
		P. caprodes	4	.533	7.5
		P. pantherina	2	.533	3.7
	3	E. radiosum	51	.489	104.3
		P. caprodes	1	.489	2.0
	4	E. radiosum	118	.420	281.0
	5	E. radiosum	27	.827	32.6
		P. copelandi	2	.827	2.4
	6	E. radiosum	31	.489	63.4
	7	E. radiosum	60	.558	107.5
	9	E. radiosum	36	.504	71.4
	10	E. radiosum	51	.424	120.2
	13	E. radiosum	23	.335	68.6
		P. pantherina	1	.335	3.0
Winter 1980	1	E. radiosum		.600	
		E. spectabile	9	.600	15.0
		P. sciera	1	.600	1.6
	2	E. radiosum	78	.336	232.0
		P. pantherina	3	.336	8.9
		E. nigrum	2	.336	5.9
	3	E. radiosum		.420	
		P. pantherina	4	.420	9.5
	4	E. radiosum	54	.531	102.0
	5	E. radiosum	50	.377	132.6
		P. pantherina	1	.377	2.6
		P. copelandi	1	.377	2.6
	6	E. radiosum	38	.485	78.3
		P. pantherina	2	.485	4.1
	7	E. radiosum		.508	
		P. pantherina	11	.508	21.0
	8	E. radiosum	40	.505	79.2

Table 37. Continued.

Season and year	Sampling location	Species	C	F(hrs)	c/f
Winter 1980	9	E. radiosum	20	.552	36.2
	10	E. radiosum	56	.540	103.7
	13	E. radiosum	27	.580	46.5
Spring 1980	1	E. radiosum	41	.496	82.6
		E. spectabile	4	.496	8.0
		P. sciera	2	.496	4.0
	2	E. radiosum	74	.411	180.1
		E. nigrum	4	.411	9.7
		P. caprodes	1	.411	2.4
		P. pantherina	2	.411	4.8
		P. copelandi	5	.411	12.1
	3	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
	4	E. radiosum	81	.327	247.0
	7	E. radiosum	60	.425	141.2
		P. pantherina	3	.425	7.0
		E. nigrum	1	.425	2.3
	6	E. radiosum	62	.338	183.4
		P. pantherina	1	.338	2.9
	9	E. radiosum	79	.417	189.4
		P. copelandi	2	.417	4.8
		P. pantherina	2	.417	4.8
	10	E. radiosum	47	.774	60.7
		P. pantherina	2	.774	2.5
	13	E. radiosum	29	.140	157.0
Summer 1980	1	E. radiosum	170	.571	297.7
		E. spectabile	11	.571	19.3
		E. nigrum	1	.571	1.7
		P. pantherina	1	.571	1.7
	2	E. radiosum	317	.638	496.8
		P. caprodes	6	.638	9.4
	3	E. radiosum	68	.487	139.6
	4	E. radiosum	129	.401	322.0

Table 37. Continued.

Season and year	Sampling location	Species	C	F(hrs)	c/f
Summer 1980	5	*E. radiosum*	65	.393	165.3
		P. caprodes	1	.393	2.5
	6	*E. radiosum*	46	.383	120.0
	7	*E. radiosum*	31	.165	187.8
	8	*E. radiosum*	35	.232	150.8
	9	*E. radiosum*	26	.418	62.2
	10	*E. radiosum*	67	.519	129.1
	13	*E. radiosum*	22	.140	157.0
		P. pantherina	3	.140	21.4

APPENDIX E

POPULATION ESTIMATES AND DENSITIES OF DARTERS

COLLECTED IN GLOVER CREEK

Table 38. 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 (m^2)	Density m^2	Density ha	Density N/100 m
Fall 1978*											
15 Nov.	14(P)	*P. caprodes*	1	1	1-3	1.2	45.3	631	.0016	16	2.2
16 Nov.	11(P)	*P. pantherina*	2	2	2-4	1.1	44.5	892	.0022	22	4.5
10 Dec.	3	*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
	11(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.	11(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.	11(R)	*E. radiosum*	57	187	52-691	257.1	42.3	545	.3431	3,431	442.0
12 Jan.	3	*E. radiosum*	57	66	57-81	7.4	41.3	344	.1918	1,918	159.0
13 Jan.	14(P)	-	-	-	-	-	45.3	675	-	-	-
Spring 1978*											
9 Apr.	14(R)	-	-	-	-	-	45.3	664	-	-	-
10 Apr.	11(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.	11(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.	14(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

Table 38. 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
Summer 1978*											
12 Jul.	14(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.	11(R)	E. radiosum	46	74	46-127	27.1	42.3	269	.2751	2,751	175.0
20 Jul.	11(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.	14(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.**	11(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.**	14(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.II	11(R)	E. radiosum	146	225	148-302	39.3	42.3	185	1.2200	12,200	532.0
23 Oct.**	14(R)	E. radiosum	118	145	118-172	13.7	41.0	97	1.4948	14,948	353.0
Winter 1979											
4 Jan.**	14(R)	E. radiosum	65	109	65-179	35.7	41.0	488	.2233	2,233	266.0
7 Jan.	12	P. pantherina	2	2	2-2	0.0	31.0	322	.0062	62	6.4
9 Jan.**	11(P)	E. radiosum	4	4	4-4	0.0	44.5	947	.0042	42	9.0
10 Jan.**	11(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

Table 38. 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
Winter 1979											
12 Jan.	14(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
Spring 1979											
28 Apr.**	14(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.**	14(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.**	11(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.**	11(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.	12	*E. radiosum*	167	216	174-257	21.1	31.0	265	.8150	8,150	696.0
Summer 1979											
18 Jul.	12	*E. radiosum*	170	199	175-223	12.2	31.0	210	.9476	9,476	644.0
20 Aug.	3	*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	30.	.0033	33	2.4
21 Aug.	7	*E. radiosum*	355	489	410-568	40.3	34.6	743	.6581	6,581	141.0
		P. pantherina	1	1	1-1	2.0	34.6	743	.0013	13	3.0
23 Aug.**	11(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

Table 38. 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
Summer 1979											
24 Aug.**	14(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
1 Sept.**	14(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.**	11(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.	7	*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.	3	-	-	-	-	-	41.3	-	-	-	-
22 Oct.	11(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.	14(R)	*E. radiosum*	269	406	310-502	49.1	41.0	233	1.7424	17,424	990.0
28 Oct.	14(P)	*P. copelandi*	1	1	1-1	0.0	45.3	654	.0015	15	2.2
10 Nov.	12	*E. radiosum*	231	258	238-278	10.2	31.0	205	1.2585	12,585	832.0
Winter 1980											
4 Jan.	12	*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

Table 38. Continued.

Sampling period/date	Site	Species	C	N	95% C.I.	Std. err.	Site length (m)	Site area (m)	Density m^2	Density ha	Density N/100 m
Winter 1980											
5 Jan.	14(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.	14(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
24 Feb.	11(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.	12	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.	14(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.	14(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.	11(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.	14(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

Table 38. Continued.

Sampling period/date	Site	Species	C	N	95% C.I.	Std. err.	Site length (m)	Site area (m)	Density m²	Density ha	Density N/100 m
Summer 1980											
16 Jul.	14(R)	_E. radiosum_	32	40	32-56	8.3	41.0	205	.1951	1,951	97.5
17 Jul.	12	_E. radiosum_	234	323	254-388	33.1	31.0	149	2.1678	21,678	1041.0
18 Jul.	3	_E. radiosum_	210	305	231-378	37.6	41.3	202	1.5099	15,099	738.0
19 Jul.	11(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.	7	_E. radiosum_	80	144	80-243	50.5	34.6	.9290		9,290	416.0

*Population estimates conducted by Orth (1980).

**Population estimates conducted in conjunction with Orth.

APPENDIX F

STATISTICAL TESTS OF HABITAT PREFERENCES OF DARTERS

Table 39. Observed frequencies and expected frequencies (calculated assuming a uniform distribution) of logperch captured in various water depth, water velocity, and substrate type intervals in Glover Creek, Oklahoma from November 1978 to July 1980.

	Depth interval				
	0-19	20-39	40-59	60-79	≥80
Observed	1	12	15	10	11
Expected	14	15	9	5	6

T = 25.8 (d.f. = 4) P<.001

	Velocity intervals				
	0-19	20-39	40-59	60-79	≥80
Observed	47	1	1	0	0
Expected	39	5	3	1	1

T = 8.9 (d.f. = 4) P<.10

	Substrates								
	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0
Observed	0	0	1	7	5	16	14	3	3
Expected	1	1	1	10	7	15	8	2	4

T = 8.8 (d.f. = 8) P<.10

Table 40. Observed frequencies and expected frequencies (in parenthesis) for chi-square tests of independence between: A) water depth and water velocity; B) substrate type and water velocity; C) substrate type and water depth, for logperch captured in Glover Creek, Oklahoma, from November 1978 to July 1980.

A.

Velocity	Depth 0-39	40-59	60-79	≥80	Total
0-19	12 (12)	14 (14)	10 (10)	11 (11)	47
≥20	1 (1)	1 (1)	0 (0)	0 (0)	2
Total	13	15	10	11	49

T = 1.58 (d.f. = 3) P>.25

B.

Velocity	Substrate 5.0 + 5.5	6.0	6.5	7.0	7.5 + 8.0	Total
0-19	7 (8)	4 (5)	16 (15)	14 (13)	6 (6)	47
≥20	1 (0)	1 (0)	0 (0)	0 (1)	0 (0)	2
Total	8	5	16	14	6	49

T = 6.37 (d.f. = 4) P<.25

C.

Depth	Substrate 5.0 + 5.5	6.0	6.5	7.0	7.5 + 8.0	Total
0-39	2 (2)	3 (1)	7 (4)	0 (4)	1 (2)	13
40-59	4 (2)	2 (2)	0 (5)	4 (4)	5 (2)	15
60-79	1 (2)	0 (1)	5 (3)	4 (3)	0 (1)	10
≥80	1 (2)	0 (1)	4 (4)	6 (3)	0 (1)	11
Total	8	5	16	14	6	49

T = 25.47 (d.f. = 12) P<.025

Table 41. Observed frequencies and expected frequencies (calculated assuming a uniform distribution) of channel darters captured in various water depth, water velocity, and substrate type intervals in Glover Creek, Oklahoma, from November 1978 to July 1980.

	Depth (cm)				
	0-19	20-39	40-59	60-79	≥80
Observed	8	19	11	8	2
Expected	14	14	9	5	5

T = 7.35 (d.f. = 4) P<.25

	Velocity (cm/s)				
	0-19	20-39	40-59	60-79	≥80
Observed	30	11	6	1	0
Expected	38	5	2	1	1

T = 13.16 (d.f. = 4) P<.025

	Substrate								
	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0
Observed	0	3	3	17	5	5	4	1	8
Expected	1	1	1	10	7	15	7	2	4

T = 22.9 (d.f. = 8) P<.005

Table 42. Observed frequencies and expected frequencies (in parenthesis) of chi-square tests of independence between: A) water depth and water velocity; B) water depth and substrate type; and C) water velocity and substrate type, for channel darters collected in Glover Creek, Oklahoma, from November 1978 to July 1980.

A.

Velocity (cm/s)	Depth (cm) 0-19	20-39	40-59	>60	Total
0-19	2 (5)	9 (12)	9 (7)	10 (6)	30
20-39	2 (2)	7 (4)	2 (3)	0 (2)	11
>40	4 (1)	3 (3)	0 (2)	0 (1)	7
Total	8	19	11	10	48

T = 19.43 (d.f. = 6) P<.05

B.

Depth (cm)	Substrate 4.5 + 5.0	5.5	6.0	6.5	7.0	7.5 + 8.0	Total
0-19	3 (1)	9 (10)	1 (3)	5 (3)	4 (2)	0 (2)	8
20-39	2 (2)	9 (7)	4 (2)	3 (2)	0 (2)	1 (4)	19
40-59	1 (1)	1 (3)	0 (1)	0 (1)	1 (1)	6 (2)	9
>60	0 (1)	4 (4)	0 (1)	1 (1)	3 (1)	2 (2)	10
Total	6	17	5	5	4	9	46

T = 32.82 (d.f. = 15) P<.005

C.

Velocity (cm/s)	Substrate 4.5 + 5.0	5.5	6.0	6.5	7.0	7.5 + 8.0	Total
0-19	2 (4)	9 (10)	1 (3)	5 (3)	4 (2)	7 (5)	28
20-39	2 (1)	4 (4)	3 (1)	0 (1)	0 (1)	2 (2)	11
>40	2 (1)	4 (3)	1 (1)	0 (1)	0 (1)	0 (1)	7
Total	6	17	5	5	4	9	46

T = 15.00 (d.f. = 10) P<.25

Table 43. Observed and expected frequencies of leopard darters over all depth, velocity, and substrate intervals.

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

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

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

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

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

T = 15.00 (d.f. = 8) P<.10

Table 44. Observed frequencies and expected frequencies (in parenthesis) of chi-square tests of independence between: A) water depth and water velocity; B) water depth and substrate type; and C) water velocity and substrate type, for leopard darters collected in Glover Creek, Oklahoma, from August 1977 to July 1980.

A.

Velocity (cm/s)	Depth (cm) 0-19	20-39	40-59	60-79	≥80	Total
0-19	7 (8)	39 (43)	30 (29)	26 (23)	14 (12)	116
20-39	2 (1)	6 (4)	2 (3)	0 (2)	0 (1)	10
≥40	0 (0)	3 (1)	1 (1)	0 (1)	0 (0)	4
Total	9	48	33	26	14	130

T = 11.20 (d.f. = 8) P<.25)

B.

Substrate	Depth (cm) 0-19	20-39	40-59	60-79	≥80	Total
5.5	1 (1)	11 (7)	2 (5)	6 (4)	1 (2)	20
6.0	4 (4)	10 (9)	7 (6)	3 (5)	0 (3)	25
6.5	3 (3)	17 (17)	14 (12)	7 (9)	6 (5)	47
7.0	1 (2)	8 (10)	9 (7)	5 (6)	6 (3)	29
7.5	0 (0)	1 (2)	0 (1)	4 (1)	0 (1)	5
8.0	0 (0)	1 (2)	2 (1)	1 (1)	1 (1)	5
Total	9	48	34	26	14	131

T = 30.74 (d.f. = 16) P<.025

C.

Velocity (cm/s)	Substrate 5.5	6.0	6.5	7.0	7.5	8.0	Total
0-19	19 (18)	19 (21)	45 (42)	25 (26)	5 (4)	3 (4)	116
20-39	2 (2)	2 (2)	2 (4)	2 (2)	0 (0)	1 (0)	10
≥40	0 (1)	2 (1)	0 (1)	1 (1)	0 (0)	1 (0)	4
Total	20	24	47	29	5	5	130

T = 12.71 (d.f. = 10) P<.25

Table 45. Observed frequencies and expected frequencies (calculated assuming a uniform distribution) of orangebelly darters (juveniles and adults combined) collected in various water depth, water velocity, and substrate type intervals in Glover Creek, Oklahoma during October 1979.

	Depth (cm)		
	0-9	10-19	≥20
Observed	285	314	116
Expected	381	246	88

T = 51.79 (d.f. = 2) P<.001

	Velocity (cm/s)	
	0-9	≥10
Observed	598	64
Expected	581	81

T = 3.89 (d.f. = 1) P<.05

	Substrate				
	5.5	6.0	6.5	7.0 + 7.5	8.0
Observed	30	210	305	60	53
Expected	34	125	279	115	105

T = 112.69 (d.f. = 4) P<.001

Table 46. Observed frequencies and expected frequencies (calculated assuming a uniform distribution) of orange-belly darters (juveniles and adults combined) collected in various water depth, water velocity, and substrate type intervals in Glover Creek, Oklahoma during January 1980.

	Depth (cm)				
	0-9	10-19	20-29	30-39	≥40
Observed	6	88	213	77	8
Expected	71	72	158	56	4

T = 94.94 (d.f. = 4) P<.001

	Velocity (cm/s)							
	0-9	10-19	20-29	30-39	40-49	50-59	60-69	≥70
Observed	83	107	94	51	20	20	5	10
Expected	128	90	84	28	42	18	1	3

T = 75.07 (d.f. = 7) P<.001

	Substrate				
	4.0 + 5.5	6.0	6.6	7.0 + 7.5	8.0
Observed	29	141	153	64	5
Expected	3	99	196	59	34

T = 307.89 (d.f. = 4) P<.001

Table 47. Observed frequencies and expected frequencies (calculated assuming a uniform distribution) of orange-belly darters (juveniles and adults combined) collected in various water depth, water velocity, and substrate type intervals in Glover Creek, Oklahoma during March 1980.

	Depth (cm)			
	0-9	10-19	20-29	≥30
Observed	32	354	288	48
Expected	227	291	157	47

T = 289.99 (d.f. = 3) P<.001

	Velocity (cm/s)					
	0-9	10-19	20-29	30-39	40-49	≥50
Observed	333	218	76	34	25	38
Expected	341	241	67	49	16	9

T = 103.08 (d.f. = 5) P<.001

	Substrate				
	6.0	6.5	7.0	7.5	8.0
Observed	143	307	200	35	30
Expected	140	336	91	90	57

T = 178.24 (d.f. = 4) P<.001

Table 48. Observed frequencies and expected frequencies (calculated assuming a uniform distribution) of orangebelly darters (juveniles and adults combined) collected in various water depth and substrate type intervals in Glover Creek, Oklahoma during July 1980.

	Depth (cm)		
	0-9	10-19	≥20
Observed	270	74	20
Expected	285	73	6

T = 31.48 (d.f. = 2) P<.001

	Substrate				
	6.0	6.5	7.0	7.5	8.0
Observed	16	159	152	15	21
Expected	21	245	7	35	55

T = 3114.94 (d.f. = 4) P<.001

Table 49. Observed frequencies and expected frequencies (in parenthesis) for chi-square tests of differences in distribution of logperch and leopard darters in various intervals of water depth, water velocity, and substrate types in Glover Creek, Oklahoma, from November 1978 to July 1980.

Species	Depth 0-19	20-39	40-59	60-79	≥80	Total
Logperch	1 (3)	12 (16)	15 (13)	10 (10)	11 (7)	49
Leopard darter	9 (7)	48 (44)	34 (36)	26 (26)	14 (18)	131
Total	10	60	49	36	25	180

T = 6.95 (d.f. = 4) P>.10

Species	Velocity 0-19	20-39	40-59	60-79	≥80	Total
Logperch	47 (45)	1 (3)	1 (1)	0 (0)	0 (0)	49
Leopard darter	116 (118)	10 (8)	3 (3)	0 (0)	1 (1)	130
Total	163	11	4	0	1	179

T = 1.95 (d.f. = 4) P>.25

Species	Substrate 5.0	5.5	6.0	6.5	7.0	7.5	8.0	Total
Logperch	1(0)	7(7)	5(8)	16(17)	14(12)	3(2)	3(2)	49
Leopard darter	0(1)	20(20)	25(22)	47(46)	29(31)	5(6)	5(6)	131
Total	1	27	30	63	43	8	8	180

T = 5.41 (d.f. = 6) P>.25

Table 50. Observed frequencies and expected frequencies (in parenthesis) for chi-square tests of differences in distributions of logperch and channel darters in various intervals of water depth, water velocity, and substrate types in Glover Creek, Oklahoma, from November 1978 to July 1980.

Species	Depth 0-19	20-39	40-59	60-79	≥80	Total
Logperch	1 (4)	12 (16)	15 (13)	10 (9)	11 (6)	49
Channel darter	8 (4)	19 (15)	11 (13)	8 (9)	2 (6)	48
Total	9	31	26	18	13	97

T = 15.98 (d.f. = 4) P<.005.

Species	Velocity 0-19	20-39	40-59	60-79	≥80	Total
Logperch	47 (39)	1 (6)	1 (3)	0 (1)	0 (0)	49
Channel darter	30 (38)	11 (6)	6 (3)	1 (0)	0 (0)	48
Total	77	12	7	1	0	97

T = 17.99 (d.f. = 4) P<.005

Species	Substrate 4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	Total
Logperch	0(1)	1(2)	7(12)	5(5)	16(11)	14(9)	3(2)	3(5)	49
Channel darter	3(1)	3(2)	17(12)	5(5)	5(10)	4(9)	1(2)	8(5)	48
Total	3	4	24	10	21	18	4	11	97

T = 22.09 (d.f. = 7) P<.005

Table 51. Observed frequencies and expected frequencies (in parenthesis) for chi-square tests of differences in distributions of leopard darters and channel darters in various intervals of water depth, water velocity, and substrate types in Glover Creek, Oklahoma, from November 1978 to July 1980.

Species	Depth 0-19	20-39	40-59	60-79	≥80	Total
Leopard darter	9 (12)	48 (49)	34 (33)	26 (25)	14 (12)	131
Channel darter	8 (4)	19 (18)	11 (12)	8 (9)	2 (4)	48
Total	17	67	45	34	16	179

T = 6.42 (d.f. = 4) P>.10

Species	Velocity 0-19	20-39	40-59	60-79	≥80	Total
Leopard darter	116 (106)	10 (15)	3 (7)	0 (1)	1 (1)	130
Channel darter	30 (39)	11 (6)	6 (2)	1 (0)	0 (0)	48
Total	146	21	9	1	1	178

T = 21.13 (d.f. = 4) P<.005

Species	Substrate 4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	Total
Leopard darter	0(2)	0(2)	20(27)	25(22)	47(38)	29(24)	5(4)	4(9)	131
Channel darter	3(1)	3(1)	17(10)	5(8)	5(14)	4(9)	1(2)	8(3)	48
Total	3	3	37	30	52	33	6	13	179

T = 42.84 (d.f. = 7) P<.001

Table 52. Observed frequencies and expected frequencies (in parenthesis) of chi-square tests of independence between total length and: A) water depth, B) water velocity, and C) substrate type, for orangebelly darters collected in Glover Creek, Oklahoma during October 1979.

A.

Length	Depth (cm) 0-9	10-19	$\geq$20	Total
$\leq$41 mm	179 (152)	162 (168)	41 (62)	382
>41 mm	106 (133)	152 (146)	75 (54)	333
Total	285	314	116	715

T = 25.74 (d.f. =2) P<.001

B.

Length	Velocity (cm/s) 0-9	$\geq$10	Total
$\leq$41 mm	364 (346)	19 (37)	383
>41 mm	234 (252)	45 (27)	279
Total	598	64	662

T = 23.05 (d.f. = 1) P<.001

C.

Length	Substrate 5.5	6.0	6.5	7.0 + 7.5	8.0	Total
$\leq$41 mm	20 (17)	129 (121)	159 (176)	40 (35)	31 (31)	379
>41 mm	10 (13)	81 (89)	146 (129)	20 (25)	22 (22)	279
Total	30	210	305	60	53	658

T = 8.04 (d.f. = 4) P<.10

Table 53. Observed frequencies and expected frequencies (calculated assuming a uniform distribution) of juvenile (TL = $\leq$ 41 mm) orangebelly darters collected in various water depth, water velocity, and substrate type intervals in Glover Creek, Oklahoma during October 1979.

	Depth (cm)		
	0-9	10-19	$\geq$20
Observed	179	162	41
Expected	203	131	47

T = 11.00 (d.f. = 2) P<.005

	Velocity (cm/s)	
	0-9	$\geq$10
Observed	364	19
Expected	336	47

T = 18.57 (d.f. = 1) P<.0001

	Substrate				
	5.5	6.0	6.5	7.0 + 7.5	8.0
Observed	20	129	159	40	31
Expected	19	72	160	56	60

T = 64.00 (d.f. = 4) P<.001

Table 54. Observed frequencies and expected frequencies (calculated assuming a uniform distribution) of adult (TL = > 41 mm) orangebelly darters collected in various water depth, water velocity, and substrate type intervals in Glover Creek, Oklahoma during October 1979.

	Depth (cm)		
	0-9	10-19	$\geq$20
Observed	106	152	75
Expected	177	114	41

T = 69.14 (d.f. = 2) P<.001

	Velocity (cm/s)	
	0-9	$\geq$10
Observed	234	45
Expected	245	34

T = 4.04 (d.f. = 1) P<.05

	Substrate				
	5.5	6.0	6.5	7.0 + 7.5	8.0
Observed	10	81	146	20	22
Expected	14	53	118	49	44

T = 51.04 (d.f. = 4) P<.001

Table 55. Observed frequencies and expected frequencies (in parenthesis) of chi-square tests of independence between total length and: A) water depth, B) water velocity, and C) substrate type, for orangebelly darters collected in Glover Creek, Oklahoma during January 1980.

A.

Length	Depth (cm) 0-9	10-19	20-29	30-39	≥40	Total
≤43 mm	3 (3)	49 (50)	124 (121)	43 (44)	4 (5)	223
>43 mm	3 (3)	39 (38)	89 (92)	34 (33)	4 (3)	169
Total	6	88	213	77	8	392

T = .51 (d.f. = 5) P>.25

B.

Length	Velocity (cm/s) 0-9	10-19	20-29	30-39	40-49	50-59	60-69	≥70	Total
≤43 mm	63 (47)	61 (61)	49 (53)	27 (29)	6 (11)	13 (11)	1 (3)	2 (6)	222
>43 mm	20 (36)	46 (46)	45 (40)	24 (22)	14 (9)	7 (9)	4 (2)	8 (4)	168
Total	83	107	94	51	20	20	5	10	390

T = 28.18 (d.f. = 7) P<.001

C.

Length	Substrate 5.0 + 5.5	6.0	6.5	7.0 + 7.5	8.0	Total
≤43 mm	16 (16)	92 (81)	79 (87)	34 (36)	2 (3)	223
>43 mm	13 (12)	49 (61)	74 (66)	30 (28)	3 (2)	169
Total	29	141	153	64	5	392

T = 6.64 (d.f. = 4) P<.25

Table 56. Observed frequencies and expected frequencies (calculated assuming a uniform distribution) of juvenile (TL = ≤ 43 mm) orangebelly darters collected in various water depth, water velocity, and substrate type intervals in Glover Creek, Oklahoma during January 1980.

	Depth (cm)				
	0-9	10-19	20-29	30-39	≥40
Observed	3	49	124	43	4
Expected	40	59	90	32	2

T = 54.71 (d.f. = 4) P<.001

	Velocity (cm/s)							
	0-9	10-19	20-29	30-39	40-49	50-59	60-69	≥70
Observed	63	61	49	27	6	13	1	2
Expected	73	51	48	16	24	8	1	2

T = 27.38 (d.f. = 7) P<.001

	Substrate				
	5.0 + 5.5	6.0	6.6	7.0 + 7.5	8.0
Observed	16	92	79	34	2
Expected	1	57	112	34	19

T = 187.29 (d.f. = 4) P<.001

Table 57. Observed frequencies and expected frequencies (calculated assuming a uniform distribution) of adult (TL = > 43 mm) orangebelly darters in various water depth, water velocity, and substrate type intervals in Glover Creek, Oklahoma during January 1980.

	Depth (cm)				
	0-9	10-19	20-29	30-39	≥40
Observed	3	39	89	34	4
Expected	30	44	68	24	2

T = 39.56 (d.f. = 4) P<.001

	Velocity (cm/s)							
	0-9	10-19	20-29	30-39	40-49	50-59	60-69	≥70
Observed	20	46	45	24	14	7	4	8
Expected	55	39	36	12	18	6	1	1

T = 88.65 (d.f. = 7) P<.001

	Substrate				
	5.0 + 5.5	6.0	6.5	7.0 + 7.5	8.0
Observed	13	49	74	30	3
Expected	1	43	85	25	14

T = 128.16 (d.f. = 4) P<.001

Table 58. Observed frequencies and expected frequencies (in parenthesis) of chi-square tests of independence between total length and: A) water depth, B) water velocity, and C) substrate type, for orangebelly darters collected in Glover Creek, Oklahoma during March 1980.

A.

length	Depth (cm)				Total
	0-9	10-19	20-29	≥30	
≤45	20 (19)	178 (208)	189 (169)	38 (28)	425
>45	12 (13)	176 (145)	99 (118)	10 (20)	297
Total	32	354	288	48	722

T = 24.56 (d.f. = 3) P<.001

B.

Length	Velocity (cm/s)						Total
	0-9	10-19	20-29	30-39	40-49	≥50	
≤45	200 (196)	141 (128)	34 (45)	20 (20)	11 (15)	21 (22)	427
>45	133 (137)	77 (119)	42 (31)	14 (14)	14 (10)	17 (15)	297
Total	333	218	76	34	25	38	724

T = 25.44 (d.f. = 5) P<.001

C.

Length	Substrate					Total
	6.0	6.5	7.0	7.5	8.0	
≤45	93 (85)	168 (183)	115 (119)	28 (21)	23 (18)	427
>45	50 (58)	139 (124)	85 (80)	7 (14)	7 (12)	288
Total	143	307	200	35	30	715

T = 14.8 (d.f. = 4) P<.01

Table 59. Observed frequencies and expected frequencies (calculated assuming a uniform distribution) of juvenile (TL = $\leq$ 45 mm) orangebelly darters collected in various water depth, water velocity, and substrate type intervals in Glover Creek, Oklahoma during March 1980.

	Depth (cm)			
	0-9	10-19	20-29	$\geq$30
Observed	20	178	189	38
Expected	133	171	92	28

T = 201.19 (d.f. = 3) P<.001

	Velocity (cm/s)					
	0-9	10-19	20-29	30-39	40-49	$\geq$50
Observed	200	141	34	20	11	38
Expected	201	142	40	29	9	5

T = 48.75 (d.f. = 5) P<.001

	Substrate				
	6.0	6.5	7.0	7.5	8.0
Observed	93	168	115	28	23
Expected	83	201	55	54	34

T = 89.19 (d.f. = 4) P<.001

Table 60. Observed frequencies and expected frequencies (calculated assuming a uniform distribution) of adult (TL = > 45 mm) orangebelly darters collected in various water depth, water velocity, and substrate type intervals in Glover Creek, Oklahoma during March 1980.

	Depth (cm)			
	0-9	10-19	20-29	≥30
Observed	12	176	99	10
Expected	93	119	65	19

T = 120.42 (d.f. = 3) P<.001

	Velocity (cm/s)					
	0-9	10-19	20-29	30-39	40-49	≥50
Observed	113	77	42	14	14	17
Expected	140	99	28	20	7	4

T = 70.57 (d.f. = 5) P<.001

	Substrate				
	6.0	6.5	7.0	7.5	8.0
Observed	50	139	85	7	7
Expected	56	135	37	36	23

T = 98.61 (d.f. = 4) P<.001

Table 61. Observed frequencies and expected frequencies (in parenthesis) of chi-square tests of independence between total length and: A) water depth, and B) substrate type, for orange-belly darters collected in Glover Creek, Oklahoma during July 1980.

A.

Length	Depth (cm) 0-9	10-19	≥20	Total
≤34 mm	213 (193)	43 (53)	5 (14)	261
>34 mm	57 (76)	31 (21)	15 (6)	103
Total	270	74	20	364

T = 35.23 (d.f. = 2) P<.001

B.

Length	Substrate 6.0	6.5	7.0	7.5	8.0	Total
≤34 mm	12 (11)	99 (114)	127 (109)	10 (11)	12 (15)	260
>34 mm	4 (4)	60 (45)	25 (43)	5 (4)	9 (6)	103
Total	16	159	152	15	21	363

T = 19.94 (d.f. = 4) P<.001

Table 62. Observed frequencies and expected frequencies (calculated assuming a uniform distribution) of juvenile (TL = ≤ 34 mm) orangebelly darters collected in various water depth and substrate type intervals in Glover Creek, Oklahoma during July 1980.

	Depth (cm)		
	0-9	10-19	≥20
Observed	213	43	5
Expected	204	52	4

T = 2.11 (d.f. =) P<.25

	Substrate				
	6.0	6.5	7.0	7.5	8.0
Observed	12	99	127	10	12
Expected	15	175	5	25	39

T = 3104.40 (d.f. = 4) P<.0001

Table 63. Observed frequencies and expected frequencies (calculated assuming a uniform distribution) of adult (TL = > 34 mm) orangebelly darters collected in various water depth and substrate type intervals in Glover Creek, Oklahoma during July 1980.

	Depth (cm)		
	0-9	10-19	≥20
Observed	57	31	15
Expected	80	21	2

T = 116.16 (d.f. = 2) P<.001

	Substrate				
	6.0	6.5	7.0	7.5	8.0
Observed	4	60	25	5	9
Expected	6	69	2	10	15

T = 287.96 (d.f. = 4) P<.001

APPENDIX G

SEASONAL FOOD HABITS OF ORANGEBELLY DARTERS

Table 64. Total numbers and frequency of occurrence of various food items found in the diet of juvenile and adult orangebelly darters collected in Glover Creek during October 1979.

Food item	Juveniles*		Adults**		Total	
	Number	Freq.	Number	Freq.	Number	Freq.
Gastropoda	0	.000	1	.004	1	.002
Copepoda	55	.235	7	.027	62	.126
Cladocera	25	.107	6	.023	31	.063
Hydracarina	2	.008	0	.000	2	.004
Collembolla						
Smynthuridae	1	.004	0	.000	1	.002
Odonata						
Coenagrionidae	1	.004	0	.000	1	.002
Megaloptera						
Corydalus sp.	0	.000	2	.008	2	.004
Ephemeroptera	3	.013	5	.019	8	.016
Isonychia sp.	0	.000	1	.004	1	.002
Stenonema sp.	2	.008	2	.008	4	.008
Leptophlebia sp.	1	.004	2	.008	3	.006
Plecoptera						
Taeniopteryx sp.	0	.000	2	.008	2	.004
Unidentified	9	.038	4	.015	13	.026
Trichoptera	4	.017	10	.040	14	.028
Hydropsychidae	0	.000	1	.004	1	.002
Wormaldia sp.	0	.000	3	.011	3	.006
Chimarra sp.	0	.000	1	.004	1	.002
Hydroptilia sp.	3	.012	0	.000	3	.006
Unidentified	1	.004	5	.020	6	.012
Diptera	134	.572	217	.851	351	.718
Chironomidae	47	.201	73	.286	120	.245
Simulium sp.	87	.371	144	.564	231	.472
Coleoptera						
Stenelmis sp.	0	.000	1	.004	1	.002
Total	234		255		489	

*N = 30 Juveniles (≤43 mm TL): 1 empty

**N = 26 Adults (<43 mm TL): 2 empty

Table 65. Total numbers and frequency of occurrence of various food items in the diet of orangebelly darters collected in Glover Creek during January 1980.

Food item	Juveniles*		Adults**		Total	
	Number	Freq.	Number	Freq.	Number	Freq.
Annelida						
Lumbriculidae	4	.011	0	.000	4	.006
Copepoda	53	.150	9	.028	62	.092
Cladocera	32	.090	5	.015	37	.055
Hydracarina	1	.003	0	.000	1	.001
Ephemeroptera	4	.011	8	.025	12	.018
Pseudocloeon sp.	2	.005	6	.018	8	.012
Baetis sp.	2	.005	0	.000	2	.003
Unidentified	0	.000	1	.003	1	.001
Heptagenia sp.	0	.000	1	.003	1	.001
Plecoptera	97	.274	58	.183	155	.231
Taeniopteryx sp.	9	.025	13	.041	22	.032
Strophopteryx sp.	21	.060	12	.038	33	.049
Allocapnia sp.	60	.170	25	.079	85	.126
Hydroperca sp.	0	.000	1	.003	1	.001
Unidentified	7	.020	7	.022	14	.020
Trichoptera	3	.008	3	.009	6	.009
Hydropsychidae	2	.005	2	.006	4	.006
Philopotamidae						
Wormaldia sp.	1	.003	0	.000	1	.001
Unidentified	0	.000	1	.003	1	.001
Hydroptilidae						
Dibusa sp.	1	.003	2	.006	3	.004
Unidentified	0	.000	1	.003	1	.001
Unidentified	3	.008	2	.006	5	.007
Diptera	156	.440	228	.721	384	.573
Chironomidae	68	.192	85	.269	153	.228
Simulium sp.	86	.242	143	.453	229	.341
Unidentified	2	.005	0	.000	2	.003
Total	354		316		670	

*N = 30 Juveniles (≤43 mm TL): 1 empty

**N = 26 Adults (<43 mm TL): 2 empty

Table 66. Total numbers and frequency of occurrence of various food items in the diet of orangebelly darters collected in Glover Creek during March 1980.

Food item	Juveniles*		Adults**		Total	
	Number	Freq.	Number	Freq.	Number	Freq.
Copepoda	25	.067	1	.007	26	.051
Cladocera	4	.010	1	.007	5	.009
Ephemeroptera	118	.319	41	.292	159	.311
Pseudocloeon sp.	105	.283	38	.271	143	.280
Baetis sp.	9	.024	1	.007	10	.019
Rithrogenia sp.	1	.002	0	.000	1	.002
Stenonema sp.	1	.002	2	.014	3	.005
Isonychia sp.	2	.005	0	.000	2	.004
Plecoptera	12	.032	6	.042	18	.035
Perlesta sp.	2	.005	1	.007	3	.005
Neoperla sp.	1	.002	0	.000	1	.002
Hydroperla sp.	0	.000	3	.021	3	.005
Isoperla sp.	2	.005	0	.000	2	.004
Chloroperlidae	0	.000	1	.007	1	.002
Nemura sp.	1	.002	1	.007	2	.004
Unidentified	6	.016	0	.000	6	.011
Trichoptera	13	.035	7	.050	20	.039
Hydroptilia sp.	6	.016	6	.042	12	.023
Stactobiella sp.	1	.002	0	.000	1	.002
Hydropsychidae	1	.002	1	.007	2	.004
Agapetus sp.	1	.002	0	.000	1	.002
Chimarra sp.	4	.010	0	.000	1	.002
Diptera	195	.527	84	.600	279	.547
Chironomidae	192	.519	63	.450	255	.500
Simulium sp.	3	.008	17	.121	20	.039
Empididae	0	.000	4	.028	4	.007
Coleoptera						
Stenelmis sp.	3	.008	0	.000	3	.005
Total	370		140		510	

*N = 32 Juveniles (≤45 mm TL).

**N = 15 Adults (>45 mm TL).

Table 67. Total numbers and frequency of occurrence of various food items in the diet of juvenile and adult orangebelly darters collected in Glover Creek during July 1980.

Food item	Juveniles*		Adults**		Total	
	Number	Freq.	Number	Freq.	Number	Freq.
Annelida						
Lumbriculidae	0	.000	1	.009	1	.002
Gastropoda						
Ferrissia sp.	1	.003	1	.009	2	.005
Copepoda	1	.003	0	.000	1	.002
Cladocera	1	.003	0	.000	1	.002
Ostracoda	8	.029	1	.009	9	.024
Megaloptera						
Corydalus sp.	1	.003	1	.009	2	.005
Ephemeroptera	60	.221	15	.145	75	.200
Stenonema sp.	3	.011	2	.019	5	.013
Stenacron sp.	1	.003	0	.000	1	.002
Heptagenia sp.	6	.022	3	.029	9	.024
Ephron sp.	0	.000	2	.019	2	.005
Choroterpes sp.	2	.007	2	.019	4	.010
Isonychia sp.	4	.014	0	.000	4	.010
Baetis sp.	44	.162	6	.058	50	.133
Plecoptera						
Neoperla sp.	3	.011	1	.009	4	.010
Trichoptera	110	.406	62	.602	172	.459
Hydroptilia sp.	0	.000	3	.029	3	.008
Chimarra sp.	71	.262	38	.369	109	.291
Polycentropus sp.	0	.000	1	.009	1	.002
Hydropsyche sp.	0	.000	1	.009	1	.002
Unidentified	39	.144	19	.180	58	.155
Diptera						
Chironomidae	77	.284	19	.184	96	.256
Lepidoptera						
Paragyractis sp.	8	.029	2	.019	10	.026
Coleoptera						
Stenelmis sp.	1	.003	0	.000	1	.002
Total	271		103		374	

*N = 41 Juveniles (≤34 mm TL).

**N = 26 Adults (>34 mm TL): 4 empty.

APPENDIX H

SEASONAL ELECTIVITY INDICES OF VARIOUS FOOD ITEMS OF JUVENILE AND ADULT ORANGEBELLY DARTERS

Table 68. Electivity indices (L) for various food items in the diet of juvenile and adult orangebelly darters collected during October 1979.

Food item	Juveniles	Adults	Total
Gastropoda	-.009	-.005	-.007
Copepoda	+.235	+.027	_.126
Cladacera	+.107	+.023	+.063
Collembolla			
Smynthuridae	+.004	.000	+.002
Odonata			
Coenagrionidae	-.013	-.017	-.015
Megaloptera			
Corydalus sp.	-.009	-.001	-.005
Ephemeroptera	-.168	-.162	-.165
Isonychia sp.	-.025	-.025	-.023
Stenonema sp.	-.080	-.080	-.080
Leptophlebia sp.	-.035	-.031	-.033
Plecoptera	-.026	-.041	-.034
Taeniopteryx sp.	-.008	.008	-.004
Unidentified	-	-	-
Trichoptera	-.177	-.154	-.166
Hydropsychidae	.000	+.004	+.002
Wormaldi sp.	.000	+.011	+.006
Chimarra sp.	-.167	-.163	-.165
Hydroptilia sp.	+.012	.000	+.006
Unidentified	-	-	-
Diptera	+.493	+.824	+.691
Chironomidae	+.193	+.278	+.237
Simulium sp.	+.362	+.555	+.463
Coleoptera			
Stenelmis sp.	-.344	-.340	-.342
Hydracarina	+.008	.000	+.004

Table 69. Electivity indices for various food items in the diet of juvenile and adult orange-belly darters collected in Glover Creek during January 1980.

Food item	Juveniles	Adults	Total
Lumbriculidae	-.114	-.125	-.119
Copepoda	+.150	+.028	+.092
Cladocera	+.090	+.015	+.055
Hydracarina	+.003	.000	+.001
Ephemeroptera	-.167	-.153	-.160
Pseudocloeon sp.	-.027	-.014	-.020
Baetis sp.	+.001	-.004	-.001
Heptagenia sp.	-.005	-.002	-.004
Unidentified	-	-	-
Plecoptera	-.009	-.100	-.052
Taeniopteryx sp.	+.008	+.024	+.015
Strophopteryx sp.	-.006	-.028	-.017
Allocapnia sp.	+.009	-.082	-.035
Hydroperla sp.	-.011	-.008	-.010
Unidentified	-	-	-
Trichoptera	-.025	-.024	-.024
Hydropsychidae	+.005	+.006	+.006
Philopotamidae			
Wormaldia sp.	-.003	-.014	-.013
Unidentified	-	-	-
Hydroptilidae			
Dibusa sp.	-.008	-.005	-.007
Unidentified	-	-	-
Unidentified	-	-	-
Diptera	+.343	+.624	+.476
Chironomidae	+.192	+.206	+.165
Simulium sp.	+.212	+.431	+.320
Unidentified	-	-	-

Table 70. Electivity indices of food items in the diet of juvenile and adult orangebelly darters collected in Glover Creek during July 1980.

Food item	Juveniles	Adults	Total
Lumbriculidae	-.013	-.004	-.011
Gastropoda			
Ferrissia sp.	+.003	+.009	+.005
Copepoda	+.003	.000	+.002
Cladocera	+.003	.000	+.002
Ostracoda	+.029	+.009	+.024
Megaloptera			
Corydallus sp.	-.010	-.004	-.008
Ephemeroptera	-.092	-.168	-.113
Stenonema sp.	-.065	-.041	-.063
Stenacron sp.	-.017	-.020	-.018
Heptagenia sp.	-.011	-.004	-.009
Ephron sp.	-.021	-.002	-.016
Choroterpes sp.	-.058	-.039	-.048
Isonychia sp.	-.020	-.034	-.024
Baetis sp.	+.159	+.055	+.130
Plecoptera			
Neoperla sp.	-.066	-.068	-.067
Trichoptera	+.195	+.391	+.248
Hydroptilia sp.	.000	+.029	+.008
Chimarra sp.	-.254	+.361	+.283
Polycentropus sp.	.000	+.009	+.002
Hydropsyche sp.	-.003	+.006	-.001
Unidentified	-	-	-
Diptera			
Chironomidae	+.268	+.168	+.240
Lepidoptera			
Paragyractis sp.	+.010	.000	+.007
Coleoptera			
Stenelmis sp.	-.249	-.252	-.250

Table 71. Electivity indices of food items in the diet of juvenile and adult orangebelly darters collected in Glover Creek during March 1980.

Food item	Juveniles	Adults	Total
Copepoda	+.067	+.007	+.051
Cladocera	+.010	+.007	+.009
Ephemeroptera	+.168	+.141	+.160
Pseudocloeon sp.	+.224	+.212	+.221
Baetis sp.	+.001	-.016	-.004
Rithogenia sp.	.000	-.002	.000
Stenonema sp.	-.045	+.010	-.042
Isonychia sp.	+.002	-.003	+.001
Plecoptera	-.077	-.067	-.074
Perlesta sp.	-.037	-.035	-.037
Neoperla sp.	-.048	-.050	-.048
Hydroperla sp.	.000	+.021	+.005
Isoperla sp.	-.002	-.007	-.003
Chloroperlidae	.000	+.007	+.002
Nemura sp.	-.002	+.003	.000
Unidentified	-	-	-
Trichoptera	-.018	-.003	-.014
Hydroptilia sp.	+.011	+.037	+.018
Stactobiellia sp.	+.002	.000	+.002
Hydropsychidae	+.002	+.007	+.004
Agapetus sp.	-.005	-.007	-.005
Chimarra sp.	-.043	-.026	-.019
Diptera	+.443	+.516	+.463
Chironomidae	+.458	+.389	+.439
Simulium sp.	+.001	+.114	+.032
Empididae	-.004	+.024	+.003
Coleoptera			
Stenelmis sp.	-.402	-.410	-.405

APPENDIX I

STATISTICAL TESTS OF INDEPENDENCE BETWEEN JUVENILE AND ADULT ORANGEBELLY DARTER FOOD HABITS

Table 72. Observed frequencies and expected frequencies (assuming independence between length and diet) of juvenile and adult orangebelly darters collected during October 1979.

Food item	Juveniles Observed	Juveniles Expected	Adults Observed	Adults Expected	Total
Gastropoda	0	.48	1	.52	1
Copepoda	55	29.66	7	32.33	62
Cladocera	25	14.83	6	16.16	31
Hydracarina	2	.95	0	1.04	2
Collembolla	1	.48	0	.52	1
Odonata	1	.48	0	.52	1
Megaloptera	0	.95	2	1.04	2
Ephemeroptera	3	3.82	5	4.14	8
Plecoptera	9	7.17	6	7.82	15
Trichoptera	4	6.70	10	7.30	14
Diptera	134	167.96	217	183.03	351
Coleoptera	0	.48	1	.52	1
Totals	234		255		489

T = 78.61 (d.f. = 11) P<.001

Table 73. Observed frequencies and expected frequencies (assuming independence of length and diet) of juvenile and adult orangebelly darters collected in Glover Creek during January 1980.

Food item	Juveniles		Adults		Total
	Observed	Expected	Observed	Expected	
Lumbriculidae	4	2.11	0	1.88	4
Copepoda	53	32.75	9	29.24	62
Cladocera	32	19.54	5	17.45	37
Hydracarina	1	.52	0	.47	1
Ephemeroptera	4	6.34	8	5.65	12
Plecoptera	97	81.89	58	73.10	155
Trichoptera	3	3.17	3	2.82	6
Diptera	156	202.88	228	181.11	384
Totals	354		316		670

T = 78.60 (d.f. = 7) P<.001

Table 74. Observed and expected frequencies (assuming independence of length and diet) of juvenile and adult orangebelly darters collected in Glover Creek during March 1980.

Food item	Juveniles		Adults		Total
	Observed	Expected	Observed	Expected	
Copepoda	25	18.86	1	7.13	26
Cladocera	4	3.62	1	1.37	5
Ephemeroptera	118	115.35	41	43.64	159
Plecoptera	12	13.05	6	4.94	18
Trichoptera	13	14.50	7	5.49	20
Diptera	195	202.41	84	76.58	279
Coleoptera	3	2.17	0	.82	3
Totals	370		140		510

T = 10.63 (d.f. = 6) P<.25

Table 75. Observed and expected frequencies (assuming independence of length and diet) of juvenile and adult orangebelly darters collected in Glover Creek during July 1980.

Food item	Juveniles		Adults		Total
	Observed	Expected	Observed	Expected	
Lumbriculidae	0	.72	1	.27	1
Ferrissia sp.	1	1.44	1	.55	2
Copepoda	1	.72	0	.27	1
Cladocera	1	.72	0	.27	1
Ostracoda	8	6.52	1	2.47	9
Corydalus sp.	1	1.44	1	.55	2
Ephemeroptera	60	75.00	15	20.65	75
Plecoptera	3	2.89	1	1.10	4
Trichoptera	110	124.63	62	47.36	172
Diptera	77	96.00	19	26.43	96
Lepidoptera	8	7.24	2	2.75	10
Coleoptera	1	.72	0	.27	1
Total	271		103		374

T = 22.61 (d.f. = 11) P<.025

VITA[2]

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