Longitudinal distribution of fishes and habitat in Little Beaver Creek, Montana
by Craig Alan Barfoot

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University

Abstract:
The fish populations and habitat of Little Beaver Creek were inventoried to investigate longitudinal changes in fish communities and habitat. Additionally, relations between habitat variables and relative abundance of fish species were examined. Twenty-two species representing eight families were collected. The most abundant and species-rich family was Cyprinidae. Individual species showed distinct patterns of relative abundance between stream segments. The three study segments exhibited a weak longitudinal continuum. Community changes were reflected primarily by the downstream addition of species; replacement was of less importance. Two fish assemblages were identified: a midstream assemblage composed of species representing several families, and a downstream assemblage dominated by cyprinids. Major gradients in habitat involved changes in substrate composition, riparian zone characteristics, water clarity, and features related to stream size. Several habitat variables were significantly correlated with the relative abundance of fish species found in Little Beaver Creek. Generally, species typical of the downstream segment (goldeye, western silvery minnow, plains minnow, flathead chub, Iongnose dace, and sand shiner) were correlated with physical features characteristic of erosional habitats. Fishes characteristic of the upstream and midstream segments (shorthead redhorse, white sucker, creek chub, brassy minnow, black bullhead, brook stickleback, and green sunfish) were correlated with features associated with more Ientic-Iike or depositional environments.

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Craig Alan Barfoot

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

The fish populations and habitat of Little Beaver Creek were inventoried to investigate longitudinal changes in fish communities and habitat. Additionally, relations between habitat variables and relative abundance of fish species were examined. Twenty-two species representing eight families were collected. The most abundant and species-rich family was Cyprinidae. Individual species showed distinct patterns of relative abundance between stream segments. The three study segments exhibited a weak longitudinal continuum. Community changes were reflected primarily by the downstream addition of species; replacement was of less importance. Two fish assemblages were identified: a midstream assemblage composed of species representing several families, and a downstream assemblage dominated by cyprinids. Major gradients in habitat involved changes in substrate composition, riparian zone characteristics, water clarity, and features related to stream size. Several habitat variables were significantly correlated with the relative abundance of fish species found in Little Beaver Creek. Generally, species typical of the downstream segment (goldeye, western silvery minnow, plains minnow, flathead chub, longnose dace, and sand shiner) were correlated with physical features characteristic of erosional habitats. Fishes characteristic of the upstream and midstream segments (shorthead redhorse, white sucker, creek chub, brassy minnow, black bullhead, brook stickleback, and green sunfish) were correlated with features associated with more lentic-like or depositional environments.

INTRODUCTION

Longitudinal distribution of stream fishes is usually characterized by continual downstream addition of species (Sheldon 1968; Evans and Noble 1979). This increase in species richness has generally been attributed to the increased environmental stability and habitat complexity of downstream areas (Schlosser 1982; Harrel et al. 1967). Other studies (Moyle and Nichols 1973) have attributed changes in community composition to the process of zonation. This process results in relatively distinct communities due to fairly abrupt changes in stream geomorphology or temperature (Rahel and Hubert 1991; Platts 1979). Rahel and Hubert (1991) found that longitudinal changes in community composition in a Great Plains-Rocky Mountain stream reflected a combination of downstream addition and biotic zonation.

This study examined the hypothesis that fish communities reflect changes in stream geomorphology. Also, since little information is available on fish community composition and physicochemical characteristics of small, prairie streams in Montana (Clancey 1978; Elser et al. 1978), describing habitat characteristics which may influence fish distribution and abundance may be helpful to managers in evaluating future proposed land use changes.

In 1990 fish populations and physicochemical attributes of the Little Missouri River Basin were sampled. In 1991 the study was narrowed, focusing on Little Beaver Creek. The objectives of the study were to: (1) inventory the habitat and fish populations of Little Beaver Creek, (2) determine if there is a recognizable change in community composition and habitat along the stream gradient, and (3) determine the importance of habitat features upon the distribution, composition and relative abundance of fish species.

STUDY AREA

Little Beaver Creek is a second order prairie stream located in southeastern Montana (Figure 1). It originates in northeastern Carter County, near Ekalaka, and flows northeasterly for about 123 km before joining the Little Missouri River at Marmath, North Dakota. Elevations range from 1021 m at the source to 823 m at the mouth; the average gradient is 1.61 m/km. The predominant land use patterns in its watershed of approximately 1,550 km^2 are dryland farming and livestock grazing (Montana Statewide Mapping Program 1977). Average annual precipitation is about 41 cm, the majority falling as rain between April and July (U. S. Weather Bureau 1990).

The stream was divided into three segments based on area geology and channel morphology. The upstream-midstream boundary was established at a tributary entrance. The midstream-downstream boundary was determined by a major change in geologic and stream channel features.

The mid- and upstream study segments are underlain by the Fort Union Formation. These strata are coastal and alluvial deposits of the Paleocene Era (Vicke-Foster et al. 1986), and consist of relatively well-cemented, fine-grained sandstone and prominent coal beds. Depth of the deposits is variable, ranging up to 40 m (Vicke-Foster et al. 1986). The Fort Union Formation and alluvial beds of Little Beaver Creek store and release water throughout the year, resulting in permanent flow in the midstream segment (S. G. Custer, Earth Science Department, Montana State University, personal communication). The lentic-like environment of this reach is characterized by low, heavily vegetated banks, permanent flow, and abundant instream vegetation.

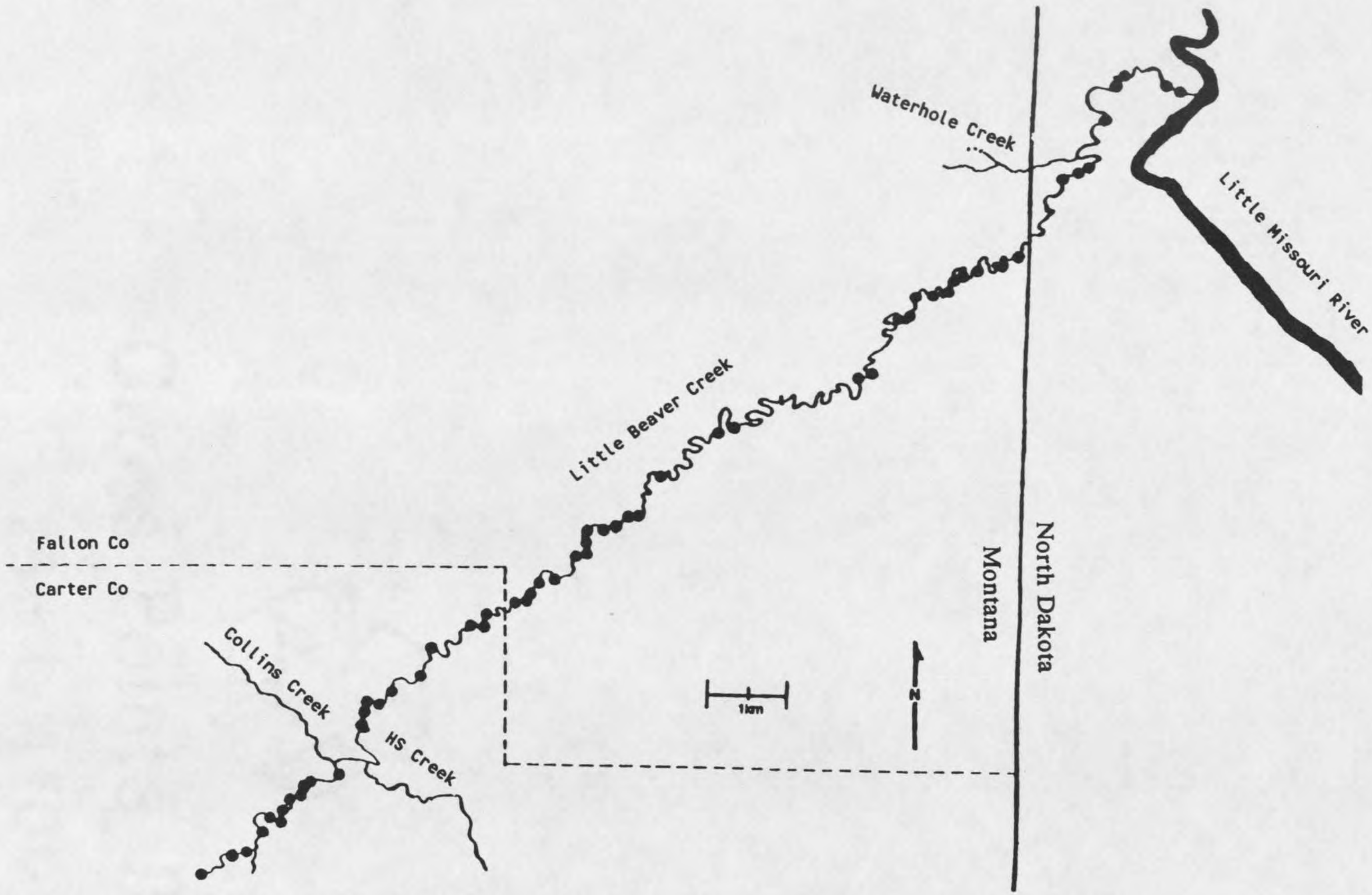

Figure 1. Little Beaver Creek study area in southeastern Montana. Circles indicate sample sites.

The upstream segment consists of a series of isolated pools, which are apparently connected only in years of substantial runoff. Some pools are sustained by groundwater input and hold fish throughout the year. Others recede during spring and early summer and are replaced by a sedge meadow.

Riparian vegetation of the upstream and midstream segments consists largely of grasses, sedges, sweet clover, *Melilotus* spp., and wild rose, *Rosa* spp. Common genera of submerged vegetation in the midstream segment include *Potamogeton, Ceratophyllum, Myriophyllum* and *Ranunculus.* One species of emergent vegetation, water speedwell *Veronica catenata* (Penn.), was found only in this segment. This species is characteristic of slow, permanently flowing streams (Hitchcock et al. 1959).

The demarcation between the midstream and downstream segments lies in a region where the Cedar Creek anticline bisects the stream. This is also a region of complex faulting (Vicke-Foster et al. 1986). The downstream segment is underlain by the Hell Creek and Pierre Shale Formations. These sediments were deposited in marine offshore and prodeltal environments of the upper Cretaceous, and were subsequently exposed during a period of uplift (Vicke-Foster et al. 1986).

The Hell Creek Formation consists primarily of medium-grained sandstone and bentonitic silty shale (Vicke-Foster et al. 1986) and is a known aquifer (Fetter 1988). The area of complex faulting at the contact between the Fort Union and Hell Creek Formations is probably a recharge zone for the Hell Creek Formation (S. G. Custer, Earth Science Department, Montana State University, personal communication).

The Pierre Shale Formation is composed of dark-gray and black, bentonitic mudstone and shale (Vicke-Foster et al. 1986; Fetter 1988), resulting in very limited porosity and poor water storage (Fetter 1988). These features contribute to the shifting substrate, fluctuating flow and high turbidity of the downstream segment. In both 1990 and 1991, flow became intermittent by mid to late July.

The downstream segment drains an area located in the heavily eroded badlands topography of western North Dakota and has channel characteristics similar to those of the nearby Little Missouri River. The Little Missouri River is an intermittent prairie stream with frequent fluctuations in flow, high suspended sediment loads, and shifting bed materials; there is virtually no aquatic vegetation (Van Eekhout 1974).

There is a general paucity of streamside vegetation in the lower segment of Little Beaver Creek. The walls of the deeply incised channel are relatively bare. Bankside plants are more characteristic of upland vegetation and include big sagebrush *Artemesia tridentata* (Nutt.), silver sagebrush *A. cana* (Pursh), and broom snakeweed *Gutierrezia sarathrae* (Pursh).

In summary, Little Beaver Creek possess three relatively distinct segments: an upstream segment consisting of a series of isolated pools, a midstream segment characterized by clear, stable conditions provided by groundwater input, and a downstream segment having turbid, fluctuating conditions more characteristic of a western, Great Plains stream.

METHODS

Sampling Sites

The 123 km study area was subdivided into three segments (Figure 1): I) an 18 km segment, extending from the upper reaches of Little Beaver Creek to the entrance of HS and Collins Creeks; II) a 52.5 km midstream segment terminating at an area of abrupt change in geological features and stream channel morphology; and III) the lower 52 km of Little Beaver Creek to the confluence with the Little Missouri River at Marmath, North Dakota.

Sampling sites were limited to areas accessible by road since nearly all land along the stream is privately owned. U. S. Geological Survey topographic maps (7.5 minute series; scale 1:24,000) were utilized to determine access points and stream order. Stream length and the distance from each site to the confluence with the Little Missouri River were measured with a cartometer.

Fifty-eight study sites were sampled in 1991: 12 in the upstream segment, 25 in the midstream segment, and 21 in the downstream segment. Legal descriptions of all sites appear in the appendix (Table12). A site consisted of a pool-riffle sequence, with the exception of sites occurring in regions where flow was intermittent and the stream was a series of isolated pools. To reduce sampling bias and avoid measuring stream characteristics that had been influenced by low water crossings and bridges, the third pool-riffle sequence downstream of access points was sampled.

Measurement of Habitat

Habitat features of each pool and riffle were sampled separately. Length of each pool and riffle was measured on the right bank when facing downstream. Each pool or riffle was then divided into 10 equally spaced transects which were placed perpendicular to flow. A measuring tape was stretched across the stream and wetted width was recorded. Physical characteristics along each transect were measured at seven equally spaced points (Hubert and Rahel 1989). If a habitat feature (pool or riffle) was less than 10 m in length, five equally spaced transects were used.

At each sampling point, water depth was measured to the nearest centimeter using a meter stick. A marked wooden dowel was used to measure depths that exceeded 1 m. The dominant substrate type was visually identified and placed into one of six categories (Table 1).

Table 1. Substrate types and codes used in channel substrate classification (modified from Platts et al. 1983).

Substrate type	Size (mm)	Code
Fine sediment	<4.7	1
Gravel	4.8-76.0	2
Cobble	76.1-304.0	3
Small boulder	305.0-609.0	4
Large boulder	>609.0	5
Bedrock		6

Percent of instream cover along each transect in the form of submergent and emergent aquatic vegetation was visually estimated and assigned to one of five categories. Bankside measures recorded at each end of each transect included undercut bank, overhanging vegetation, streamside vegetative cover rating (Table 3) and shoreline water depth (Platts et al. 1983). Current velocities were measured at 0.6 of the water depth at three evenly spaced points along each transect using a model 201 Marsh-Mcbirney current meter.

Table 2. Categories of instream cover based on estimated percent of stream bottom covered by aquatic vegetation along transects.

Percent cover	Category
0	0
<25%	1
25-50%	2
50-75%	3
75-100%	4

Table 3. Streamside cover types and categories recorded at both ends of each transect.

Streamside cover type	Category
Over 50% bare ground	1
Dominated by grasses and forbs	2
Dominated by trees	3
Dominated by shrubs	4

Water Quality

At each site, surface temperature and dissolved oxygen were measured using an Otterbine-Barebo Sentry III oxygen/temperature monitor. Monthly maximum-minimum temperatures were recorded from one site within each reach for the months of May through August using Taylor maximum-minimum thermometers.

Fish

Pulsed direct-current electroshocking was used to sample fish communities. Each pool and riffle was blocked at both ends with 6-mm mesh seines. Two passes were then made with a Coffelt model Bp-1c backpack electroshocking unit. Fish samples from both passes were combined. Larvae and young-of-the-year fish were excluded. Fish were enumerated and identified to species except for plains minnows *Hybognathus placitus* Girard, and western silvery minnows *H. argyritis* Girard, which were combined into a single category and labeled as ws/plns minnow because of difficulty in separating them in the field. Sample specimens were preserved and later identified to ensure that both species occurred in Little Beaver Creek. These species are often found in association with one another (Pflieger 1975).

Catch-per-unit-effort (CPUE) was used as a measure of relative abundance. Catch-per-unit-effort for each species was calculated by dividing the number of fish captured by the electroshocking time. To eliminate fractions, fish/minute calculations were multiplied by 100.

Data Analysis

The following features were determined for pools and riffles at each sample site.

1. Elevation (m).
2. Distance from the mouth of the Little Missouri River (km).
3. Length (m).
4. Water surface area (m^2).
5. Mean wetted width (m).
6. Mean depth (cm).
7. Coefficient of variation (SD/mean) in depth.
8. Mean shoreline depth (cm).
9. Width-to-depth ratio.
10. Pool-riffle ratio.
11. Mean velocity (cm/sec).
12. Coefficient of variation in velocity.
13. Substrate type (in %).
14. Streamside vegetative cover rating (in %) calculated from transect intercept points.
15. Mean undercut bank calculated at transect intercept points (cm).
16. Mean overhanging vegetation calculated at transect intercept points (cm).
17. Overall instream cover rating (emergent and submerged vegetation).
18. Secchi depth.
19. Dissolved oxygen.
20. Temperature.

Statistical analyses were performed using STATVIEW software on a Macintosh SE 30 and on an IBM PC AT using programs written by Daniel Gustafson, Montana State University. Catch-per-unit-effort data were analyzed with a Chi-square test to determine if individual species were selecting for pools or riffles and to determine if individual species were selecting for a particular stream segment.

Principal components analysis was used to identify species assemblages. This analysis reveals sites where species are behaving in similar fashions (Gustafson 1990). Principal components analysis allows the investigator to identify sites with similar communities and assists in determining which species are having the greatest influence (Carpenter et al. 1981).

A Kruskal-Wallis test was used to determine if habitat features differed significantly among stream segments. Correlations of habitat variables with individual fish species were computed using a non-parametric Spearman-Rank analysis. Habitat variables were assessed for intercorrelation using Spearman-Rank analysis to reduce redundancy reported in fish-habitat associations. If two variables were highly multicolinear ($R \geq 0.75$), one was excluded (Lanka et al. 1987).

RESULTS

Fish

A total of 4924 individuals representing 22 species in eight families was collected in Little Beaver Creek. Taxonomic names of these species and families are listed in Table 4. Five species were non-native and the status of a sixth was undetermined (Holton 1990). The most abundant and species-rich family was Cyprinidae. Green sunfish, creek chub, white sucker, fathead minnow, and sand shiner were the five most abundant species; of these, only the green sunfish is introduced.

The three study segments exhibited a weak longitudinal continuum in fish species composition with considerable overlap between segments (Figure 2). Community changes were reflected primarily by the downstream addition of species; replacement was of less importance.

Ten species (white sucker, common carp, creek chub, fathead minnow, brassy minnow, black bullhead, brook stickleback, green sunfish, yellow perch, and Iowa darter) occurred in the upstream segment. Five species (northern pike, shorthead redhorse, longnose dace, sand shiner, and stonecat) were added in the midstream segment and one species (yellow perch) was lost. Five additional species (goldeye, golden shiner, flathead chub, western silvery minnow, and plains minnow) were added in the downstream segment, while two species (brassy minnow and Iowa darter) were lost (Table 5).

Table 4. Fish species collected in Little Beaver Creek, Montana, March-August 1990 and 1991.

Family and species	Common name
Esocidae	
Esox lucius[b]	Northern pike
Hiodontidae	
Hiodon alosoides	Goldeye
Catostomidae	
Moxostoma macrolepidotum	Shorthead redhorse
Catostomas commersoni	White sucker
Carpoides carpio[a]	River carpsucker
Cyprinidae	
Cyprinus carpio[b]	Common carp
Notemigonus crysoleucas[c]	Golden shiner
Phoxinus eos[a]	Northern redbelly dace
Semotilus atromaculatus	Creek chub
Platygobio gracilus	Flathead chub
Rhinichthys cataractae	Longnose dace
Pimaphales promelas	Fathead minnow
Hybognathus hankinsoni	Brassy minnow
Hybognathus argyritis	Western silvery minnow
Hybognathus placitus	Plains minnow
Notropis stramineus	Sand shiner
Ictaluridae	
Ameiurus melas[b]	Black bullhead
Noturus flavus	Stonecat
Gasterostidae	
Culaea inconstans	Brook stickleback
Centrarchidae	
Lepomis cyanellus[b]	Green sunfish
Percidae	
Perca flavescens[b]	Yellow perch
Etheostoma exile	Iowa darter

[a] These species were each collected at only one site duing the 1990 stream inventory and were represented by only a few individuals.

[b] Introduced species.

[c] May be native to eastern Montana, native to the Dakotas.

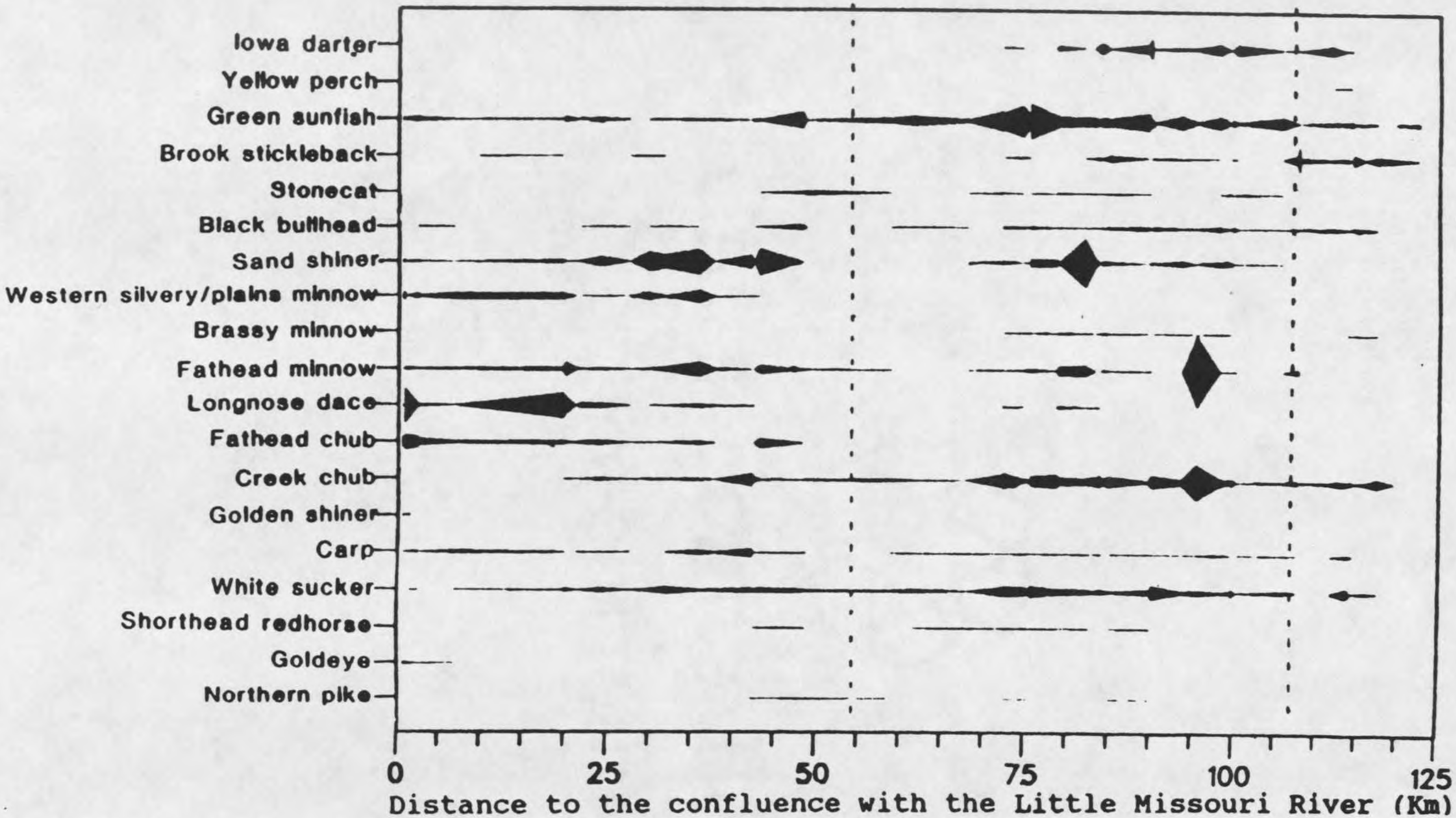

Figure 2. Longitudinal distribution and relative abundance of fishes collected in Little Beaver Creek, Montana, April-August 1991. Width of kite is proportional to relative abundance (CPUE) of individual species along the stream gradient. Dashed lines indicate stream study segments.

Table 5. Addition and replacement of fish species occurring in Little Beaver Creek.

Stream reach	Upper	Middle	Lower
Number of sites	12	25	21
Number of species	10	14	17
Number of unique species	1	1	5
Number of species added	10	5	5
Number of species lost	---	1	2

The species added in the downstream segment, with the exception of the golden shiner, are characteristic of turbid, Great Plains streams. The golden shiner was found at only one site. Six species (white sucker, common carp, creek chub, fathead minnow, black bullhead, brook stickleback, and green sunfish) were widespread and found in all three stream segments. Brook stickleback, however, were found at only two downstream sites in very limited numbers and, in both cases, were sampled following storm events.

Based on catch-per-unit-effort data, significant differences in the abundance of individual species occurred between stream segments (Table 6). Two species (brook stickleback and yellow perch) attained their greatest abundance in the upstream segment. Nine species (shorthead redhorse, white sucker, creek chub, fathead minnow, brassy minnow, black bullhead, stonecat, green sunfish, and Iowa darter) dominated the midstream segment, and nine species (northern pike, goldeye, carp, golden shiner, flathead chub, longnose dace, plains minnow, western silvery minnow, and sand shiner) reached their greatest abundance in the downstream segment.

Table 6. Chi-square analysis of fish species abundance (CPUE) between segments (1=upper) in Little Beaver Creek, Montana, 1991. Riffle and pool data are combined.

	Stream segment				
	1	2	3		
	Sample size				
Species	16	48	41	Chi^2	P
Northern pike	0	5	14	10.3	0.01
Goldeye	0	0	56	87.4	0.00
Shorthead redhorse	0	55	11	39.0	0.00
White sucker	229	1796	530	622.9	0.00
Carp	63	63	332	234.2	0.00
Golden shiner	0	0	8	12.5	0.00
Creek chub	426	2940	408	1664.6	0.00
Flathead chub	0	0	1135	1771.7	0.00
Longnose dace	0	62	1462	2073.3	0.00
Fathead minnow	72	1385	868	324.3	0.00
Brassy minnow	19	101	0	85.7	0.00
Ws/plns minnow	0	0	898	1401.8	0.00
Sand shiner	0	1684	1795	675.9	0.00
Black bullhead	138	526	96	231.9	0.00
Stonecat	0	157	95	53.7	0.00
Brook stickleback	979	242	13	3967.2	0.00
Green sunfish	432	3735	635	2023.0	0.00
Yellow perch	8	0	0	44.5	0.00
Iowa darter	144	1089	0	981.3	0.00

Fish data for both pools and riffles were examined using principal components analysis. Goldeye, golden shiner, northern pike and yellow perch were excluded from analysis, since they occurred at less than 10% of the sites and probably contributed very little to assemblage behavior.

Principal components analysis identified two species assemblages in pools (Figure 3) but none in riffles. The first two principal components explained 44.3% of the total variance in the pool data (Table 7). Most of the variation in the data occurred between downstream and midstream sites. Principal component 1 explained 25.6% of the total variance in the fish data, and separated midstream sites from downstream sites. Downstream sites 1-10 had similar communities and midstream sites 25-40 (except site 33) had similar communities. The midstream assemblage was composed of species representing several families, while downstream sites (1-10) were dominated by cyprinids.

Generally, species characteristic of the downstream segment received negative weightings on PC 1, while species characteristic of the midstream segment were weighted positively (Table 7). Those species most important in downstream sites 1-10 include ws/plns minnow, flathead chub, longnose dace, fathead minnow and carp. The white sucker, green sunfish, creek chub, black bullhead, shorthead redhorse, and stonecat were most important in the midstream assemblage.

Upstream sites and sites that could be interpreted as being transitional areas between segments tended to cluster around zero on the first principal component. Upstream sites generally had low species diversity and supported very few fish. Transitional sites occurred in regions of species overlap; no well defined assemblages were present.

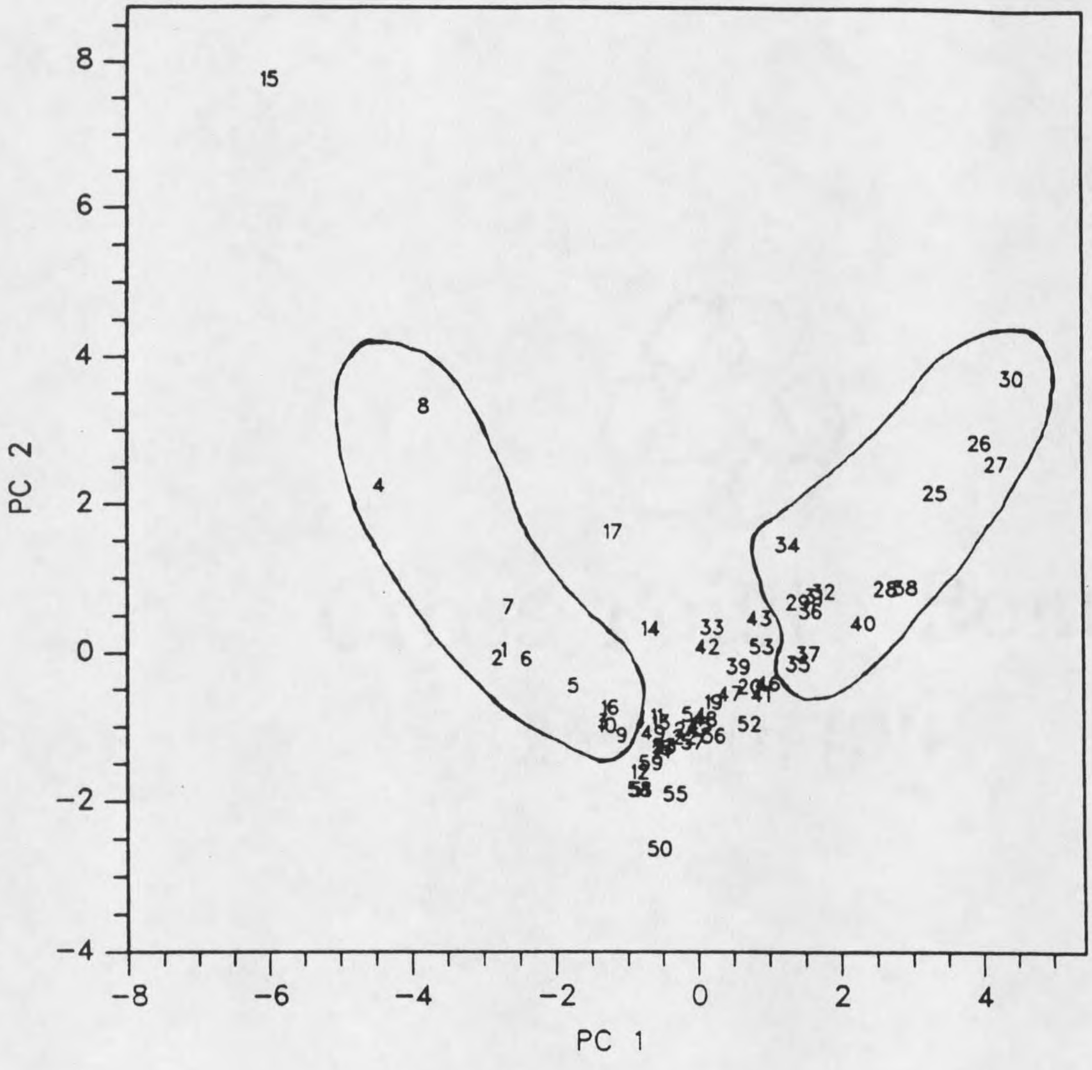

Figure 3. Study site groupings based on principal components analysis of species abundances (CPUE) in pools of Little Beaver Creek, Montana. Sites are plotted against the first and second principal component (PC) scores. Sites 1-21 downstream segment; sites 22-46 midstream segment; sites 47-58 upstream segment.

Table 7. Principal components analysis of fish data for pools, Little Beaver Creek, Montana 1991.

Species	Principal component loadings 1	2
Shorthead redhorse	0.26	0.19
White sucker	0.35	0.28
Carp	-0.18	0.21
Creek chub	0.35	0.25
Flathead chub	-0.29	0.14
Longnose dace	-0.28	0.36
Fathead minnow	-0.24	0.36
Brassy minnow	0.15	0.05
Ws/plns minnow	-0.34	0.33
Sand shiner	-0.06	0.47
Black bullhead	0.30	0.09
Stonecat	0.24	0.21
Brook stickleback	-0.01	-0.19
Green sunfish	0.35	0.29
Iowa darter	0.12	-0.04
Eigen values	3.84	2.81
Percent of variance	25.56	18.73
Cummulative percent	25.56	44.29

The second principal component accounted for 18.7% of the variance and is a measure of species diversity in pool habitats. Species often found in association with several other species received positive weightings on this component, while those that occurred alone or in conjunction with few other species received negative weightings. Brook sticklebacks had the largest negative weighting. Sticklebacks were most abundant in the heavily vegetated, isolated pools of the upstream segment and generally occurred at species poor sites. Generally, midstream sites scored higher on PC 2 and tended to have higher numbers of species per site than did either of the other segments.

Habitat

In Little Beaver Creek the major longitudinal gradients in habitat involved changes in substrate composition, riparian zone characteristics, water clarity and features related to stream size (Figures 4 and 5; Appendix Tables 13 and 14). The general trend in bottom materials was a downstream decrease in the mean percentages of smaller substrate particles. Fine sediment in pools decreased from a mean of 87% in the upstream segment to 36% in the downstream segment. Fine sediments in riffles showed a similar trend with mean percentages of 73%, 30% and 7% in the upstream, midstream and downstream segments, respectively.

Streamside vegetative cover was heavier along upstream and midstream pools, and the percentage of bare ground (mean=6% and 12%) was less than along pools of the downstream segment (mean=28%). Additionally, midstream sites tended to have greater amounts of overhanging vegetation and undercut banks.

Mean Secchi depths of pools decreased from the upstream segment (64.8 cm) to the downstream segment (24.0 cm) (Figure 4). Lengths of pools and riffles increased with distance downstream (Figures 4 and 5). The same trend was true for other size-related features such as stream surface area, mean width, and mean depth.