Smallmouth bass habitat and fish community relationships in central Iowa streams

by

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Signatures have been redacted for privacy

DEDICATION

In memory of Kelly Jean Falk, 1965-1990.

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INTRODUCTION

Iowa has suffered serious decline in the quality of its rivers and streams as a result of agricultural and urban development during the past 150 years (Meek 1892; Bulkley et al. 1976; Menzel 1981). Much of this degradation has occurred in north central Iowa, in the landform region known as the Des Moines Lobe (Figure 1). This area has been altered through channelization and extensive use of drainage tiles to aid row-cropping. Drainage tiles are underground pipes designed to drain water from fields and transport it elsewhere (usually road ditches and streams). In the drainage process, pesticides, fertilizers, and fine sediments are also transported. During heavy rains or rapid snow melt, movement of water and chemicals through the soil is accelerated. Water in receiving streams may rise quickly, becoming turbid with sediment removed from the banks or stream bed from higher than normal discharges. In Iowa and southern Minnesota, drainage tiles have contributed substantially to the decline of water quality in small streams (Luey and Adelman 1980; Menzel et al. 1984).

Agricultural land practices began to impact Iowa streams and their fishes shortly after the arrival of the prairie pioneers. By the late 1800's, Seth Meek recognized that plowing the native sod for agricultural purposes had changed the morphology of Iowa streams from "deep and narrow, and abounding in pickerel, bass, and catfishes" to wide and shallow (Meek 1892, p. 218). Of the about 140 native fish species in Iowa, it is estimated that 12 have been extirpated and others have suffered severe declines (Menzel 1984). Some were game fish species of rivers and streams in north central Iowa.

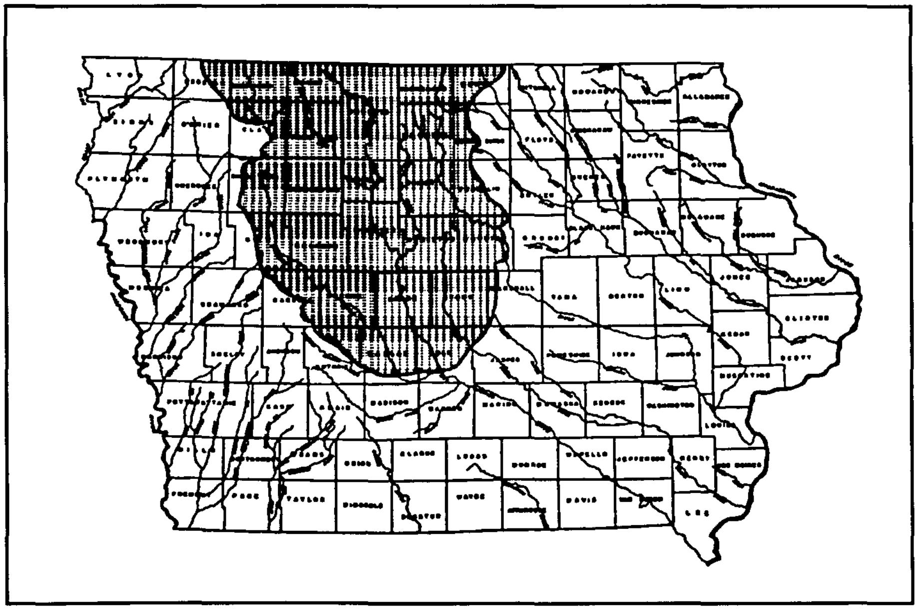

Figure 1. Location of the Des Moines Lobe landform in Iowa.

Kegley (1936, cited by Menzel 1981, p. 17) recalled that in the streams of Story County, "There were pike, pickerel, bass, redhorse suckers, large blue catfish, boolponts, sunfish, eels, etc."

Recent declines in populations of smallmouth bass *(Micropterus dolomieu)* have been attributed directly to loss of instream habitat due to agricultural practices in Iowa (Cleary 1956; Bulkley et al. 1976; Paragamian 1990) and adjacent states (Lyons et al. 1988; Roseboom et al. 1992; Waters et al. 1993; Sowa and Rabeni 1995). This is becoming a concern as the smallmouth bass is one of the most sought after gamefish by anglers in Iowa rivers and streams. It is estimated that over 60,000 anglers caught at least one smallmouth bass during 1994 (CSBR 1995). The natural range of this species in Iowa extends from the Mississippi River to about the western edge of the Des Moines Lobe (Figure 2). The smallmouth bass remains relatively abundant in the northeastern corner

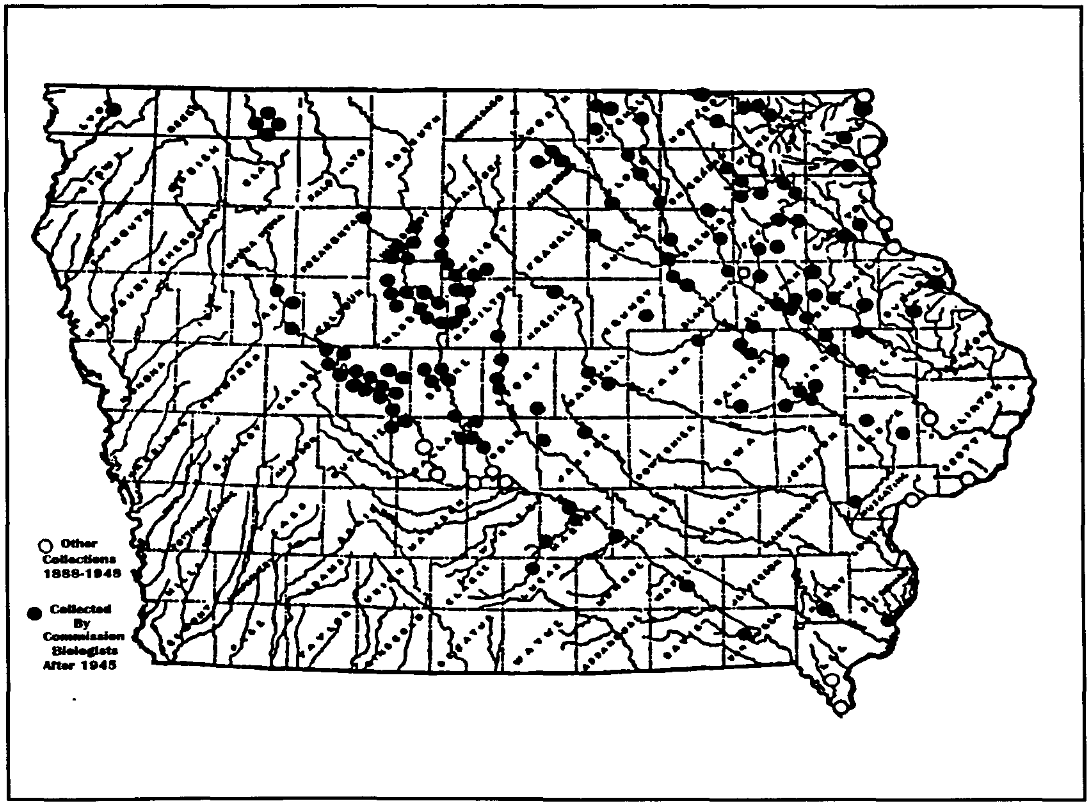

Figure 2. Historical distribution of smallmouth bass in Iowa (from Harlan and Speaker 1956).

of the state, however, only remnant smallmouth bass fisheries within agricultural land are found to the west. These populations continue to support themselves without supplemental stocking in a region in which physical habitat is believed to be only marginally acceptable for this species (Reynolds 1965).

Despite the recognition that tributaries of Iowa's interior rivers may be important spawning and nursery areas for game fish, comprehensive studies addressing habitat characteristics of fish communities in most streams have not been attempted. Paragamian (1990) sampled scattered river locations throughout all regions of Iowa but did not sample tributaries of these rivers. Elsewhere, Fausch et al. (1990) stressed the importance of using entire fish communities as indicators of stream degradation instead of using a single species approach. Lyons et al. (1988) studied fish assemblages occurring with smallmouth bass in Wisconsin streams as a community level approach in order to better understand smallmouth bass distribution. Previously in Iowa, Paragamian (1986) collected overall fish community and water chemistry data from scattered river and tributary locations but did not measure physical habitat features.

Trautman (1942) determined that the most important factor involved in the distribution and abundance of smallmouth bass in streams of Ohio is stream gradient or slope. Gradient is generally thought to be linked to other physical stream attributes critical to smallmouth bass such as amount of rocky substrate, width, depth, velocity, and cover (Lyons 1991; Barrett and Maughan 1994). Researchers in Iowa have hypothesized that stream gradient is important to the distribution of smallmouth bass and other fishes (Bulkley et al. 1976; Paragamian 1980, 1986, 1987b). Bulkley et al. (1976) concluded that fish abundance may be better correlated with stream gradient than sinuosity in streams with rocky substrate throughout Iowa. According to Sowa and Rabeni (1995), however, comparisons should not be made between geographical regions (i.e., landforms) because of potential influences due to climate, geology, topography, soils, and vegetation. Furthermore, factors affecting fish distribution and abundance in streams are determined by watershed or landscape wide factors within a region in addition to local or site-specific factors. Both spatial scales need to be addressed to ascertain the relative importance of the factors acting at each level.

In this study I addressed the importance of stream gradient and physical habitat features to fish communities in agriculturally impacted watersheds within the Des Moines Lobe. I hypothesized that smallmouth bass distribution in central Iowa tributary streams is influenced primarily by channel gradient. The major objectives of this study were to: (1) determine if relative abundance and biomass of adult and age-0 smallmouth bass are related to stream gradient, (2) determine if fish assemblage attributes are related to stream gradient, and (3) determine if other physical habitat variables are important to the distribution of smallmouth bass and associated species. Through this project I hoped to better understand both the physical and ecological relationships of small streams in agricultural watersheds. My goals were to obtain sufficient information to evaluate and protect stream fish habitat in the Des Moines Lobe, better understand the relationships between fish communities and smallmouth bass, and examine biotic and abiotic factors affecting smallmouth bass presence/absence in streams and the level at which they operate.

STUDY AREA

The Des Moines Lobe extends south from Minnesota to approximately the city of Des Moines in central Iowa. This region was formed by the action of glacial ice during the Late Wisconsinan period and differs from other regions of the state in that it was not covered with wind-deposited loess (Figure 3). It is the most recently glaciated area of Iowa with deposits of glacial till dating back to the Woodfordian or Cary Age, some 12,000 to 14,000 years before present (Prior 1991; Thompson 1992). Topography within the Des Moines Lobe is highly variable. The landscape appears generally flat but it is characterized by areas of abrupt knobby terrain in the form of terminal, recessional, and end moraines (Prior 1991 Figure 4). Boulders and cobbles of igneous and metamorphic origin are scattered throughout the region.

Soils within the Des Moines Lobe have poorly-sorted particle sizes and are often high in organic material. This combination has resulted in soils which drain slowly. Before settlement, the region was almost entirely covered by tallgrass prairie dotted with small wetlands known as prairie potholes (Thompson 1992). Few of these natural areas exist today, however, because of artificial draining. Although cattle and hog production is common in the area, the rich organic soils, recognized by many as among the most productive soils in the world, are kept almost exclusively in corn and soybean production.

The Des Moines Lobe is a subregion of the Western Corn Belt Plains Ecoregion designated by the U. S. Environmental Protection Agency (Omernik et al. 1993). Virtually all drainages in the region flow in a south-easterly direction as part of the Mississippi River Basin. Streams typically originate from headwaters in ponds or

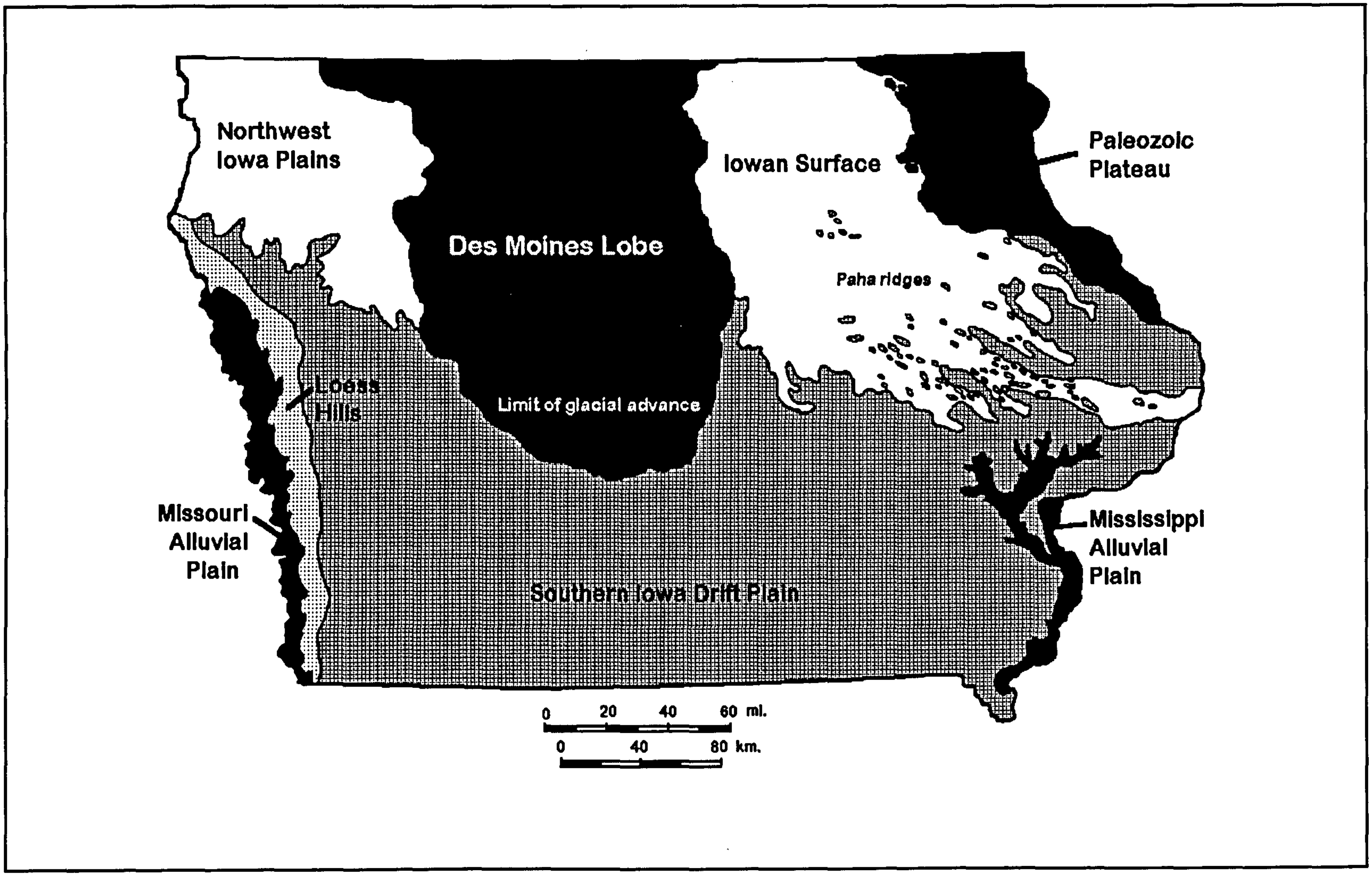

Figure 3. Landform regions of Iowa (modified from Prior 1991).

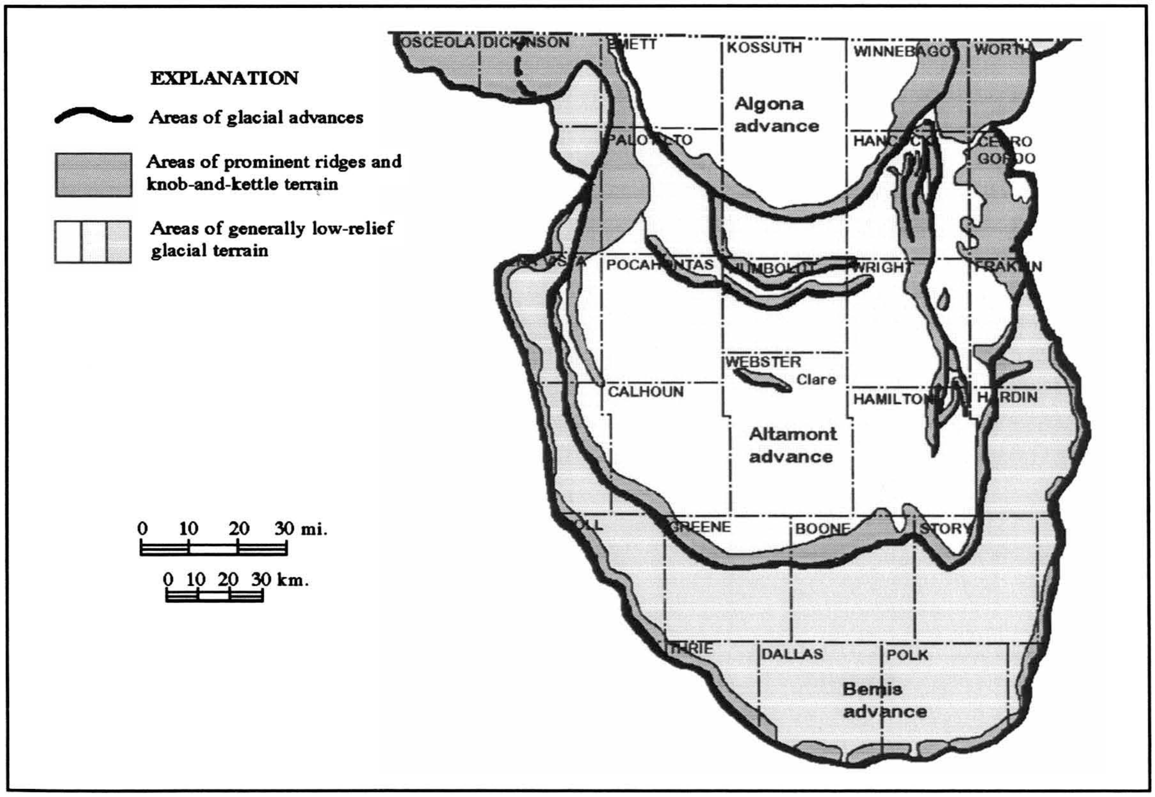

Figure 4. Glacial advances of the Des Moines Lobe (from Prior 1991).

marshes over flat expanses or from drainage ditches designed for agricultural purposes (Larimer 1974; Prior 1991; Menzel 1987). Only a few major river valleys were formed on the Des Moines Lobe and these were cut narrow and deep by glacial meltwaters (Figure 5). Sand, gravel, and boulders were deposited, and areas of Pennsylvanian bedrock were exposed. Terraces of uneroded outwash deposits remain along some river valleys. Narrow belts of deciduous forests consisting of cottonwood, silver maple, and box elder, are often located along lower reaches of rivers (Thompson 1992).

Five of the major rivers draining the Des Moines Lobe have historically supported smallmouth bass (Meek 1892; Reynolds 1965; Harlan and Speaker 1956; Paragamian

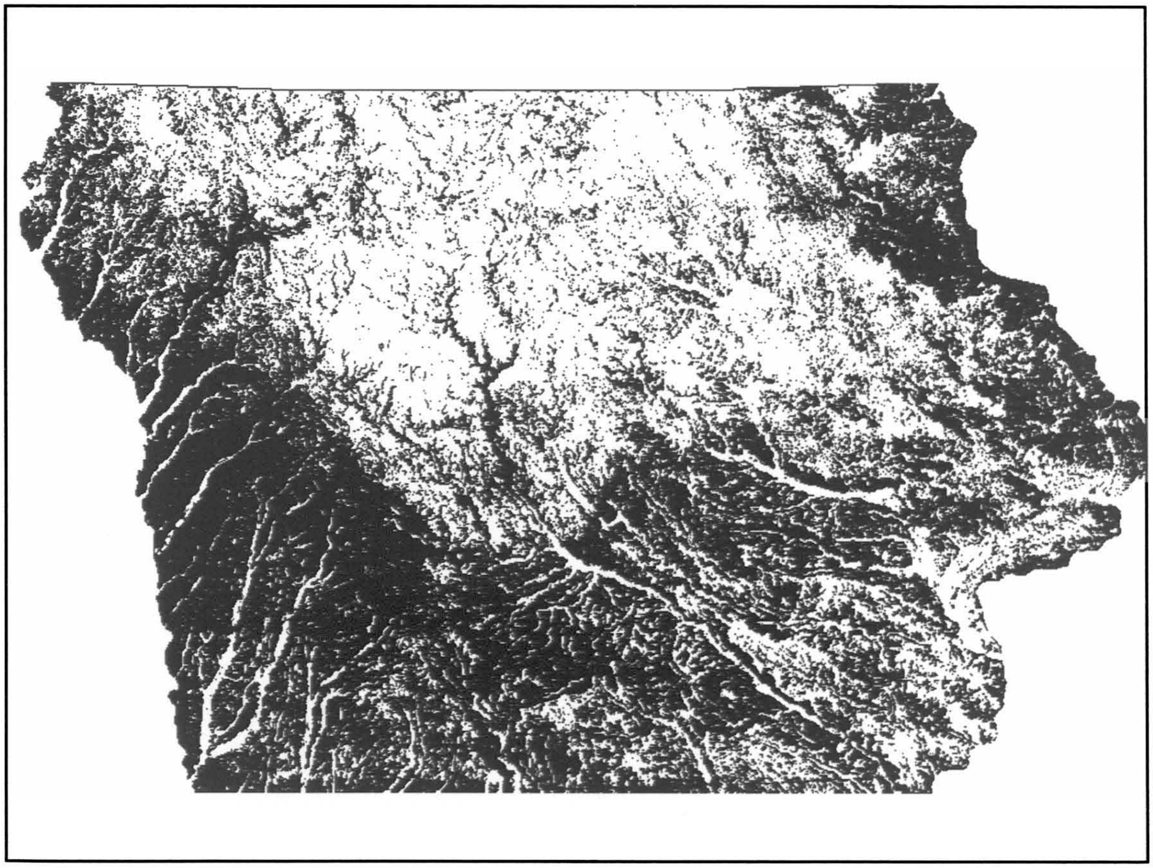

Figure 5. Relief map depicting deep river valleys and edges of the Des Moines Lobe. Light areas represent low relief; dark areas represent high relief.

1990). These are the Raccoon, Des Moines, Boone, South Skunk, and Iowa. The Raccoon River, located along the western edge of the Des Moines Lobe, corresponds with the western edge of the natural range of smallmouth bass in Iowa.

METHODS

Preliminary Study

A preliminary investigation was conducted to determine if a relationship might exist between stream gradients and smallmouth bass distribution in the Des Moines Lobe. River and stream fish locality data from throughout the area were compiled from sampling records of the Iowa Department of Natural Resources and Iowa State University. Because of some disparity between sampling efforts and gear types as well as prolonged anthropogenic effects on stream habitat, only collecting records since 1975 were used. Drainage areas were determined for each sample location using Larimer (1974). Only records with drainage areas of 44 km^2 or greater were used. Records were sorted into two categories: smallmouth bass present (at least one individual captured) or absent (no smallmouth captured). Equal numbers of each category were selected at random. Data points were plotted by legal description on a 1.2 m x 1.4 m combined map of several counties in the region. Map scale was to the nearest 0.27 km. Stream gradient estimates were obtained for each site using U.S. Geological Survey 7.5 minute topographic maps. This was done by dividing the distances between the nearest intersecting contours upstream and downstream by the change in elevation.

To investigate the relationship between smallmouth bass and slope for both rivers and streams, two data sets were analyzed. First, from three of the largest rivers (Boone, Iowa, and South Skunk) three sites each were selected where smallmouth bass had been found, and three were chosen where bass had not been found. Within a river, sites were selected in close proximity to each other to minimize geographical and drainage area variability. Drainage areas ranged from 85.4 to 1890.0 km^2. Using a second data set, sixteen smaller streams (drainage areas 51.8 km^2 to 419.4 km^2) were compared. Streams were selected at random from tributaries of mainstem rivers having sustaining populations of smallmouth bass. Eight streams had records of smallmouth bass presence and the other eight had none.

Statistical analyses were conducted using Statistical Analysis Systems (SAS Institute 1990). The river data set was analyzed for gradient and drainage area differences using 2x3 ANOVA with smallmouth bass presence/absence and rivers as treatments. Unpaired *t*-tests were then conducted for each river to determine if mean gradients and drainage areas were significantly different between sites with bass present and those with bass absent. One-way ANOVA and Duncan's Multiple Range Test (SAS Institute 1990) were used to test differences among smallmouth bass treatments. The stream data set was analyzed using unpaired *t*-tests to explore differences between mean gradients of streams with bass present and streams with bass absent. *t*-tests were conducted using both gradient and drainage area as variables. I hypothesized that smallmouth bass presence/absence would be determined by gradient and not by drainage area size for both data sets. Results were considered significant at $P < 0.05$ for all tests.

Results

Mean gradient for the nine river sites where smallmouth bass were present was 0.88 m/km and mean drainage area was 1,250.4 km^2 (Table 1). For the nine sites which lacked bass, mean gradient and drainage area were 0.51 m/km and 1,127.1 km^2, respectively. Overall, the gradient differences between the two groups were statistically

Table 1. Results of gradient and drainage area analyses for rivers in preliminary study.

	SMB present	SMB absent	
River (N)	Mean ± SE	Mean ± SE	*P*
	Gradient (m/km)		
So. Skunk (3)	0.92 ± 0.17[a,b]	0.67 ± 0.02[a]	0.219[1]
Iowa (3)	1.20 ± 0.21[a]	0.40 ± 0.04[b]	0.020[1]
Boone (3)	0.52 ± 0.17[b]	0.47 ± 0.09[b]	0.783[1]
Mean ± SE (9)	0.88 ± 0.13	0.51 ± 0.49	
P	0.101[3]	0.039[3]	0.046[2]
	Drainage area (km^2)		
So. Skunk (3)	695.2 ± 108.9[a]	700.8 ± 473.2[a]	0.991[1]
Iowa (3)	1776.0 ± 37.7[b]	1431.67 ± 245.3[a]	0.238[1]
Boone (3)	1279.9 ± 71.8[c]	1248.73 ± 244.59[a]	0.911[1]
Mean ± SE (9)	1250.4 ± 161.0	1127.1 ± 201.8	
P	< 0.001[3]	0.348[3]	0.741[2]

[1] P-value for unpaired *t*-test.
[2] P-value for *F*-test interaction (river x SMB P/A) using 2x3 ANOVA.
[3] One-way ANOVA; post hoc test of differences among means using Duncan's Multiple Range test; values with a letter in common are not significantly different.

significant ($F = 4.018$, $N = 18$). This was primarily attributable to gradient distinctions within Iowa River sites. Gradient differences also existed between rivers but no pattern was evident.

Iowa River sites tended to be largest in drainage area while South Skunk River sites were the smallest (Table 1). Mean drainage areas were not significantly different between the two bass treatments and between river sites which lacked bass ($F = 0.307$, $N = 2$). However, where bass occurred, differences between drainage areas were significant between rivers and highly significant overall.

Gradients of tributary streams were highly variable, ranging from 0.36 to 1.7 m/km where smallmouth bass were absent (mean = 1.25, $n = 8$), and from 1.33 to 6.06 where smallmouth bass were present (mean = 2.44, $n = 8$). There was a significant difference in gradients between the two groups ($t = 2.147$, df = 14, $P < 0.05$). Mean drainage areas where smallmouth bass were present (136.9 ± 26.5 SE) were not significantly different ($t = -0.411$, df = 14, $P > 0.68$) from drainage areas where smallmouth bass were absent (154.9 ± 34.9 SE). A scatter plot revealed that the highest stream gradient at a site where smallmouth bass were present (6.06 m/km) was an outlier compared to all others. To eliminate potential bias of the outlier, it, along with the lowest gradient where smallmouth bass were not present (0.36 m/km), was omitted from the data set and the unpaired t-test was repeated. Even with this smoothing of the data set, there were significant gradient differences ($P < 0.02$) between the two groups.

Preliminary conclusions

In central Iowa, the uniqueness of the Des Moines Lobe landform separates the characteristics of its streams from those of other parts of the state. Areas of higher relief and stream gradients occur within a mostly flat region in association with moraines and old river valleys (Prior 1976). The results of this study indicate that smallmouth bass presence is correlated with areas of higher gradient stream and river reaches. For both sets of data, bass occurrence was not related to drainage area size. Because relative abundance data were not available, however, interpretation of these results is subjective. As "presence" or "absence" hinged on a single capture, the inferred association of bass with higher gradients needed verification by another approach.

Field Study Design

Based on the results from the preliminary study, further investigation into the influence of stream gradient was undertaken at two spacial scales using field and map measurements. Field sampling was designed primarily to test for gradient effects within a hierarchical framework from landform region to stations within each stream. Candidate streams were restricted to those with recent records of smallmouth bass. Thirty-two sampling sites from eleven streams in three watersheds were selected (Figure 6) from over 110 locations inspected. Station selection was based primarily on: (1) stream gradient measured in the field, (2) general habitat characteristics, (3) longitudinal distance from mouth, and (4) access to the site. Only reaches of stream with similar width, depth, and habitat features were sampled.

At each station, proximate stream gradient was measured as slope of the water

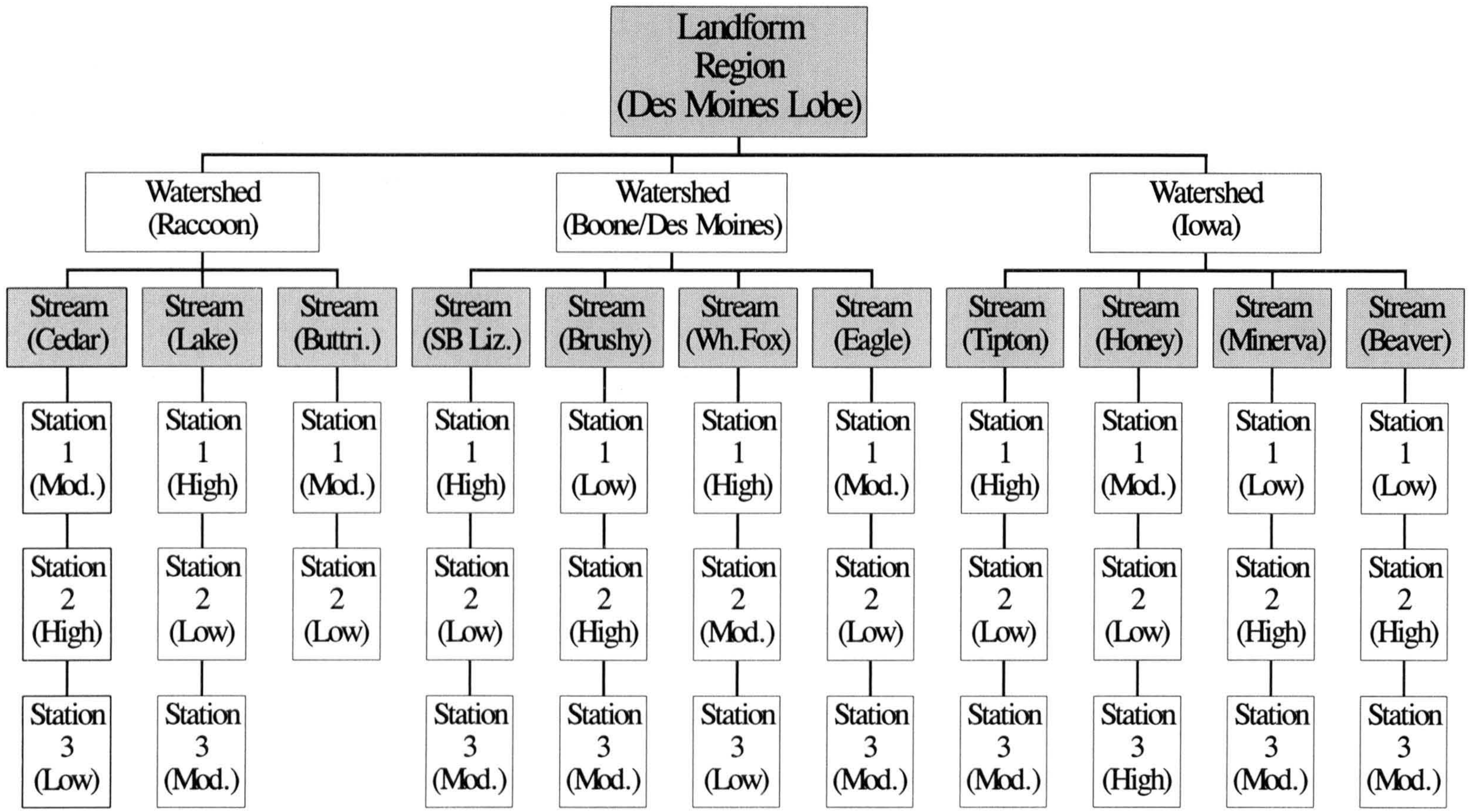

Figure 6. Study design and distribution of stream gradient categories of sites sampled. Station number indicates relative position to mouth, station one being the uppermost.

surface using a surveyor's level and stadia rod. The average of two measurements taken at 100 m segments was recorded for each station. My initial goal was to arbitrarily identify and sample one "low," one "moderate," and one "high" gradient station for each of twelve streams. Due to difficulties in locating high gradient sites, this was not possible. For each stream the highest gradient sites available that met the selection criteria were selected. The tendency of low gradient sites to occur near the mouth of streams within the river flood plain was recognized, and these areas were avoided. Likewise, an effort was made to sample moderate and high gradient areas at various longitudinal positions from the mouth.

Fish and habitat sampling was conducted on 200 m long stations at all 32 sites between late July and mid October 1995. Habitat data were collected immediately before fish sampling or soon thereafter. Upstream (and occasionally downstream) boundaries were located at riffles, shallow bars, or other natural impediments wherever possible to minimize fish passage into and out of the station.

To investigate the question of slope effects on a broader scale, stream gradient was measured cartographically using U.S. Geological Survey 7.5 minute topographic maps. Each station was plotted to within 0.10 km of the actual sample location, and gradient estimates were obtained from the nearest contour lines upstream and downstream of the site. Longitudinal gradient profiles of the eleven streams sampled were generated using the techniques described by Trautman (1942). At each topographic contour line intersecting the stream, stream elevation and distance from the mouth were recorded. Where elevation at the mouth of a stream was not indicated on the map, the mid-point of the nearest two contours was used as a starting elevation.

Habitat Sampling

A habitat survey of stream dimensions, substrate type, cover, and land usage, was conducted using a modification of the transect-reach method described by Simonson et al. (1994). Most in-stream variables were measured or estimated at four equally-spaced points and at the deepest point along each of thirteen cross-sectional transects (Table 2). Data for all variables except embededdness were later averaged over all points along each transect and also averaged over all transects for each station. Embededdness, which is the degree to which coarse particles such as gravel and rubble/cobble are surrounded by or covered with fine particles such as sand or silt, was visually estimated and averaged only for transect points where large particles were observed. Overhead canopy was measured at each transect point using a forester's spherical densiometer. The densiometer was modified to make sampling easier by sectioning off the outer 1/3 of the grid so that only seventeen grid vertices were exposed. The number of those points intersected by overhead canopy were counted, and a percentage was later obtained.

Other variables such as riparian conditions, channel habitat features, and general physical and chemical parameters were measured or estimated once per transect or once per station. Basic water quality parameters including water temperature, dissolved oxygen, turbidity, and conductivity were measured on site using a Horiba® portable water quality tester. Stream discharge (flow) was obtained by the velocity/area method using a Swoffer® current velocity meter.

Table 2. Habitat variables and frequency measured or estimated at each sample station.

Once Per Station	Once Per Transect
Stream gradient (m/km)	Mean width (m)
Flow (m^3/s)	Habitat type (riffle, pool, run)
Distance between riffles, pools, and runs (m)	Riparian Land Use
Distance between in-station bends (m)	- Cropland (%)
Riffle (%)	- Pasture (%)
Pool (%)	- Meadow (%)
Run (%)	- Woodland (%)
Water Temperature (C^0)	- Shrub (%)
Dissolved Oxygen (mg/L)	- Developed (%)
Conductivity (µmhos @ 25^0 C)	- Exposed rock (%)
Turbidity (NTU)	- Exposed gravel (%)
	- Exposed bare soil (%)
Five Points Per Transect	- Other (%)
	Boulder cover (m)
Mean depth (m)	Woody debris cover (m)
Embeddedness (%)	Undercut bank cover (m)
Substrate Type	Other cover (m)
- Boulder (% > 0.25 m)	Riparian buffer width up to 10 m (m)
- Rubble/cobble (% 0.065-0.24 m)	Bank erosion within 1 m (m)
- Gravel (% 0.002-0.064 m)	Bank erosion-entire (%)
- Sand (% 0.000062-0.0019)	
- Silt (%)	
- Clay (%)	
- Detritus (%)	
Algae (%)	
Macrophytes (%)	
Shading (%)	

Fish Sampling

Fish were collected by electrofishing using pulsed-DC current from a gas-powered backpack shocker. Multiple passes consisting of two upstream runs (left and right shoreline) and one downstream run (middle) were made at each station. Blocknets were not used because they proved to be relatively ineffective. Results from preliminary sampling using the same techniques verified that species richness and abundance did not differ significantly from block-netted stations (Kaminski, unpublished data). Other researchers have demonstrated that fish movement into and out of electrofishing stations without blocknets is negligible (Simonson and Lyons 1995), especially when station boundaries are located near natural fish barriers such as riffles. All fish were picked up using 6.35 mm mesh long-handled dipnets. Game fish were identified, counted, and weighed in the field before being released back into the water. Non-game species not easily identifiable in the field were preserved for laboratory verification and enumeration.

The Index of Biotic Integrity (IBI) developed by Karr (1981) and modified for Iowa streams (Liang 1990) was further adjusted and applied to the fish community data to quantify attributes of the fish assemblage at each station. For this study, some of the metrics from previous versions of the IBI were replaced because they described fish community attributes not characteristic of the streams studied. For example, since no hybrid fish were collected and very few fish were diseased or deformed, these two metrics were omitted. Proportion of simple lithophilous spawners (species that broadcast their eggs on clean gravel) and number of benthic insectivorous species were added (Table 3). So as not to reduce the accuracy of the IBI, individuals less than 25 mm and age-0 fish were not included in the computations (Angermeier and Karr 1986; Lyons 1992). Maximum Species Richness (MSR) plots were developed in order to provide scoring criteria for species richness and composition. This was necessary because other applications of the IBI modified for Iowa streams were based on low species richness estimates obtained from lower quality streams or stations (Liang 1990; Wilton 1996).

Table 3. Index of Biotic Integrity metrics used to assess fish communities sampled.

1. Total number of fish species.
2. Number of sunfish species (Centrarchidae) except *Micropterus*.
3. Number of darter species (Percidae).
4. Number of sucker species (Catostomidae).
5. Number of intolerant species
6. Proportion of individuals as tolerant species.
7. Proportion of individuals as omnivores
8. Proportion of individuals as insectivorous cyprinids (Cyprinidae).
9. Proportion of individuals as top carnivores.
10. Number of benthic insectivores.
11. Number of individuals in sample (CPUE).
12. Percent simple lithophilous spawners

Construction of MSR plots was based on techniques described by Lyons (1992). Scoring and guidelines used to interpret IBI scores (Table 4) were from Karr (1981).

Data Analysis

All analyses were conducted using Statistical Analysis Systems (SAS Institute 1990). Analysis of variance was used to explore differences between stream gradient measurements taken in the field and measurements taken from topographic maps. To determine if smallmouth bass and IBI scores were related to stream gradient, a series of univariate tests was conducted using general linear models procedures. For each station, total abundance, adult abundance, age-0 abundance, total biomass of smallmouth bass, and IBI scores were the dependent variables. Stream gradient measurements taken in the field were analyzed as both continuous and discrete independent variables by grouping them into categories of "low" (0.1-0.4 m/km), "moderate" (0.5-1.6 m/km), and "high" (1.9-3.7 m/km). Gradient measurements taken from topographic maps were grouped and

Table 4. Index of Biotic Integrity score interpretation guidelines (from Karr 1981).

Overall Score	Class	Attributes
57-60	Excellent	Comparable to the best situations without influence of man; all regionally expected species for the habitat and stream size, including the most intolerant forms, are present with full array of age and sex classes; balanced trophic structure.
48-52	Good	Species richness somewhat below expectation, especially due to loss of most intolerant forms; some species with less than optimal abundances or size distribution; trophic structure shows some signs of stress.
39-44	Fair	Signs of additional deterioration include fewer intolerant forms, more skewed trophic structure (eg. increasing frequency of omnivores); older age classes of top predators may be rare.
28-35	Poor	Dominated by omnivores, pollution-tolerant forms, and habitat generalists; few top carnivores; growth rates and condition factors commonly depressed; hybrids and diseased fish often present.
≤ 23	Very Poor	Few fish present, mostly introduced or very tolerant forms; hybrids common; disease, parasites, fin damage, and other anomalies regular.

and analyzed in a similar fashion.

Using all habitat variables a principal components analysis (PCA) was conducted to search for linear combinations of the variables to best explain variation in the data. After several trials, some habitat variables were deleted because of very low correlations. In a PCA with 29 variables, the first four principal components accounted for 62% of the variability in the data.

Further analyses were performed using the results of PCA. Scores of the first four principal components were tested for correlation with all fish and habitat variables using a Pearson correlation analysis. Habitat variables with significantly high positive or negative loadings ($P < 0.01$) for each of the four principal components were retained as "habitat indices". The six highest correlated variables from each principal component were used for each of the four indices. These four linear combinations of variables were then correlated with fish variables to determine which "index" of variables best described smallmouth bass and IBI scores.

Additional methods of determining importance of habitat variables from PCA were undertaken using stepwise and maximum R^2 improvement (MAXR) regression models (SAS Institute 1990). Stepwise selection adds and deletes variables from the model based on significance of the F-statistic. The MAXR technique selects the best model for one or more variables which produces the highest R^2. The best one to six variable models were obtained using age-0 and adult smallmouth bass as the dependent variables.

RESULTS

Stream Gradient

Only three streams known to support smallmouth bass in the Raccoon River watershed had sites of suitable gradient, width, depth, and distance from the mouth for the study. One of these, Buttrick Creek, lacked the above characteristics at all but two sites. Hence, only one low (0.4 m/km) and one moderate (1.0 m/km) gradient station were sampled at Buttrick Creek. Similarly, only two streams in the Boone River watershed (Eagle and White Fox creeks) and two in the Des Moines River watershed (Brushy and South Branch Lizard creeks) fit the sample design. However, since the two rivers join near the mouths of these tributaries and share many physical and biological characteristics (Liang 1990), streams in these watersheds were combined. Because a third, high gradient site (> 1.6 m/km) was not available on Eagle Creek, two "moderate" stations (0.75 and 0.9 m/km) were included. The widest range of gradients sampled on a single stream was 0.1 to 3.7 m/km at White Fox Creek (Table 5).

Stream gradients determined from 7.5 minute topographic maps ranged from 0.39 to 3.41 m/km overall (Table 5). Although these gradient estimates were similar to those measured in the field overall, they varied greatly at some stations (Figure 7). Unpaired t-tests revealed that overall differences between means of the measurements were not significant ($P = 0.09$, $n = 32$). The greatest differences between the two techniques or scales of measurement were apparent at lower gradients. There were highly significant differences ($P < 0.01$, $n = 11$) between field and map gradient measurements at stations in the low gradient category. Measurements approximated each other more closely at

Table 5. Stream gradients (m/km) and station number (in parentheses) measured in the field and from 7.5 minute topographic maps.

	Category			
Watershed	"Low"	"Moderate"	"High"	Mean
		Field		
Raccoon				
Cedar Creek	0.3 (3)	1.5 (1)	2.1 (2)	1.3
Lake Creek	0.2 (2)	0.8 (3)	1.9 (1)	1.0
Buttrick Creek	0.4 (2)	1.0 (1)	----	0.7
Boone/Des Moines				
Eagle Creek	0.45 (2)	0.75 (3), 0.9 (1)	----	0.7
Brushy Creek	0.3 (1)	0.7 (3)	2.1 (2)	1.0
South Branch Lizard Creek	0.2 (2)	0.5 (3)	1.9 (1)	0.9
White Fox Creek	0.1 (3)	0.9 (2)	3.7 (1)	1.6
Iowa				
Tipton Creek	0.4 (2)	1.3 (3)	2.1 (1)	1.3
Honey Creek	0.2 (2)	1.2 (1)	2.6 (3)	1.3
Minerva Creek	0.15 (1)	1.0 (3)	2.4 (2)	1.2
Beaver Creek	0.1 (1)	1.6 (3)	3.0 (2)	1.6
Mean	0.25	1.0	2.4	
		Topographic Maps		
Raccoon				
Cedar Creek	0.39 (3)	0.77 (1)	1.46 (2)	0.87
Lake Creek	0.71 (3)	1.03 (2)	1.08 (1)	0.94
Buttrick Creek	0.37 (1)	0.76 (2)	----	0.60
Boone/Des Moines				
Eagle Creek	0.54 (3)	0.82 (2)	1.11 (1)	0.82
Brushy Creek	2.10 (1)	2.10 (2)	3.16 (3)	2.45
South Branch Lizard Creek	1.22 (3)	1.48 (2)	1.72 (1)	1.47
White Fox Creek	0.97 (3)	1.72 (2)	2.43 (1)	1.71
Iowa				
Tipton Creek	1.18 (3)	1.72 (2)	2.83 (1)	1.91
Honey Creek	1.09 (2)	1.58 (3)	1.80 (1)	1.49
Minerva Creek	1.71 (3)	1.72 (1)	1.89 (2)	1.77
Beaver Creek	1.72 (3)	1.89 (1)	3.41 (2)	2.34
Mean	1.09	1.42	2.09	

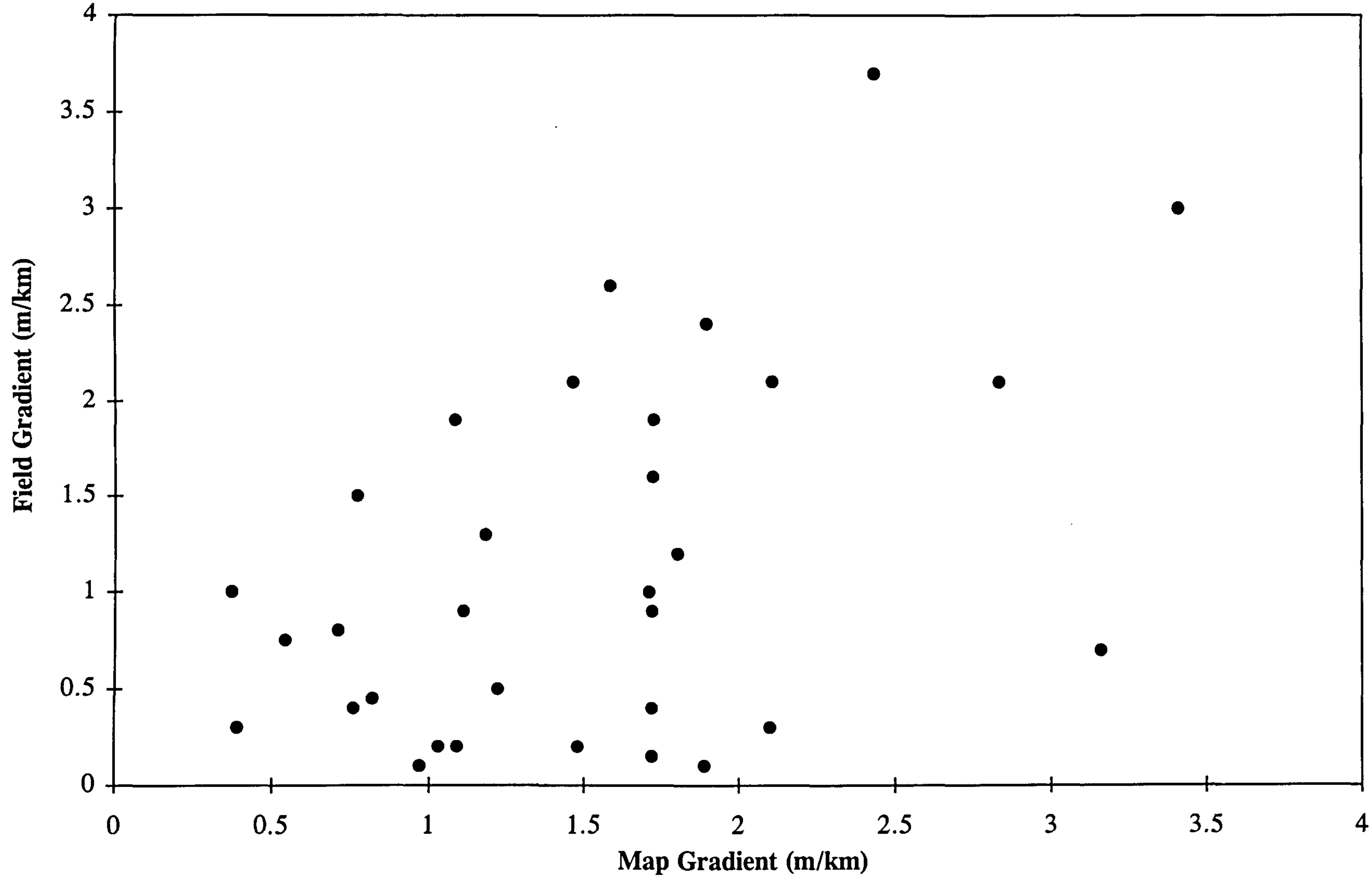

Figure 7. Stream gradients of sample locations measured in the field plotted against stream gradients measured from 7.5 minute topographic maps.

moderate ($P > 0.19$, $n = 12$) and high ($P > 0.26$, $n = 9$) gradient stations.

Fish

A total of fifty species representing ten families were collected during the study (Table 6). Relative tolerance of each species to poor water quality, siltation, and other forms of environmental degradation was determined from Lyons (1992) and by personal observation. One intolerant species currently on the Iowa Threatened Species List, the American brook lamprey (*Lampetra appendix*) was encountered in two of the four Iowa River tributaries studied. Three ammocoetes were collected from Honey Creek, and one was collected from Minerva Creek. The Topeka shiner (*Notropis topeka*), currently under consideration for federal listing as threatened or endangered in the Midwest, was encountered in the Raccoon River watershed. One adult was captured from Cedar Creek and one male in breeding condition and a juvenile were captured from Lake Creek (see Appendix F).

Although numbers were generally low, smallmouth bass were captured at most stations in the Boone/Des Moines and Iowa watersheds (Tables 7-8). Individuals were classified as either age-0 or adults. Age-0 bass ranged from 32 mm total length (TL) in early summer to over 100 TL mm in the fall. Juveniles greater than 130 mm TL and all others presumed to be at least one year old and were grouped as adults. Only one bass, a juvenile from Buttrick Creek (165 mm TL), was encountered from the Raccoon River watershed.

Table 6. Species encountered in fish survey.

			Watershed		
Common Name	Scientific Name	Tolerance*	Raccoon	Boone/ Des Moines	Iowa
American brook lamprey	*Lampetra appendix*	NT			X
Gizzard shad	*Dorosoma cepedianum*	-	X		
Northern pike	*Esox lucius*	-		X	
Central stoneroller	*Campostoma anomalum*	-	X	X	X
Largescale stoneroller	*Campostoma oligolepis*	NT			X
Common carp	*Cyprinus carpio*	T	X	X	
Brassy minnow	*Hybognathus hankinsoni*	-	X	X	X
Hornyhead chub	*Nocomis biguttatus*	-		X	X
Emerald shiner	*Notropis atherinoides*	-		X	
Common shiner	*Luxilus cornutus*	-	X	X	X
Bigmouth shiner	*Notropis dorsalis*	-	X	X	X
Rosyface shiner	*Notropis rubellus*	NT	X	X	
Spotfin shiner	*Cyprinella spiloptera*	-	X	X	X
Sand shiner	*Notropis stramineus*	-	X	X	X
Topeka shiner	*Notropis topeka*	NT	X		
Suckermouth minnow	*Phenacobius mirabilis*	-	X	X	X
Bluntnose minnow	*Pimephales notatus*	T	X	X	X
Fathead minnow	*Pimephales promelas*	T	X	X	X
Blacknose dace	*Rhinichthys atratulus*	T	X	X	X
Creek chub	*Semotilus atromaculatus*	T	X	X	X
River carpsucker	*Carpiodes carpio*	-	X	X	X
Quillback	*Carpiodes cyprinus*	-	X	X	X
White sucker	*Catostomus commersoni*	T	X	X	X
Northern hog sucker	*Hypentelium nigricans*	NT	X	X	X
Bigmouth buffalo	*Ictiobus cyprinellus*	-		X	
Golden redhorse	*Moxostoma erythrurum*	-	X	X	X
Shorthead redhorse	*Moxostoma macrolepidotum*	-	X	X	X
Black bullhead	*Ameiurus melas*	-		X	
Yellow bullhead	*Ameiurus natalis*	T	X	X	X
Channel catfish	*Ictalurus punctatus*	-	X	X	X
Slender madtom	*Noturus exilis*	NT	X	X	
Stonecat	*Noturus flavus*	NT	X	X	X
Flathead catfish	*Pylodictis olivaris*	-	X		X
Brook stickleback	*Culaea inconstans*	NT			X

* Relative ability of species to withstand environmental degradation in Iowa streams. "T" = tolerant, "NT" = not tolerant, "-" = neither strongly tolerant or intolerant.

Table 6. (continued).

Rock bass	*Ambloplites rupestris*	NT		X	
Green sunfish	*Lepomis cyanellus*	T	X	X	X
Orangespotted sunfish	*Lepomis humilis*	-	X	X	X
Bluegill	*Lepomis macrochirus*	-	X	X	X
Smallmouth bass	*Micropterus dolomieu*	NT	X	X	X
Largemouth bass	*Micropterus salmoides*	-	X	X	X
Black crappie	*Pomoxis nigromaculatus*	-		X	
Iowa darter	*Etheostoma exile*	NT			X
Fantail darter	*Etheostoma flabellare*	-	X	X	X
Johnny darter	*Etheostoma nigrum*	-	X	X	X
Banded darter	*Etheostoma zonale*	NT		X	X
Yellow perch	*Perca flavescens*	-		X	
Blackside darter	*Percina maculata*	-	X	X	X
Slenderhead darter	*Percina phoxocephala*	NT	X	X	X
Freshwater drum	*Aplodinotus grunniens*	-		X	
Total number of species			36	42	36

Stream gradient and IBI scores

Fish community IBI scores ranged from 23 to 48 with highest mean scores occurring at high gradient stations (Table 9). According to classification criteria (Table 4), most of the stations scored in the "fair" to "poor" classes. Only one station, Tipton Creek 1, scored as "good". IBI scores ($N = 32$) were significantly related to stream gradient measured in the field ($P = 0.016$, $r^2 = 0.179$), but were only weakly related ($P = 0.115$, $r^2 = 0.08$) to gradient measured from topographic maps (Figure 8).

Stream gradient and smallmouth bass

Only streams in the Boone/Des Moines and Iowa river watersheds, and Buttrick Creek station 2 (where one smallmouth bass was present), were included in the stream gradient analyses ($n = 25$). There were no significant relationships ($P > 0.05$) between

Table 7. Smallmouth bass abundance and biomass at Boone/Des Moines River watershed stations.

Stream	Gradient Class	Adults	Age-0	Total	Total biomass (g)
Brushy Creek	Low	0	14	14	28
	Mod.	0	15	15	29
	High	0	5	5	14
	Subtotal	0	34	34	71
Eagle Creek	Low	0	5	5	34
	Mod.	0	3	3	18
	Mod.	0	0	0	0
	Subtotal	0	8	8	52
South Branch Lizard Creek	Low	3	11	14	389
	Mod.	1	0	1	760
	High	2	1	3	85
	Subtotal	6	12	18	1234
White Fox Creek	Low	0	5	5	24
	Mod.	3	5	8	717
	High	5	4	9	206
	Subtotal	8	14	22	947
	Total	14	68	82	2304

Table 8. Smallmouth bass abundance and biomass in Iowa River watershed stations.

Stream	Gradient Class	Adults	Age-0	Total	Total Biomass (g)
Beaver Creek	Low	0	5	5	35
	Mod.	0	0	0	0
	High	0	34	34	149
	Subtotal	0	39	39	184
Honey Creek	Low	0	0	0	0
	Mod.	1	1	2	109
	High	0	1	1	5
	Subtotal	1	2	3	114
Minerva Creek	Low	5	2	7	589
	Mod.	0	0	0	0
	High	4	9	13	374
	Subtotal	9	11	20	963
Tipton Creek	Low	4	0	4	1004
	Mod.	3	4	7	992
	High	4	3	7	1345
	Subtotal	11	7	18	3341
	Total	21	59	80	4602

Table 9. Index of Biotic Integrity scores according to gradient category as measured in the field. Station number is in parentheses.

Watershed	Gradient Category			
	Low	Moderate	High	Mean
Raccoon River				
Cedar Creek	23 (3)	37 (1)	38 (2)	32.7
Lake Creek	28 (2)	29 (3)	38 (1)	31.7
Buttrick Creek	34 (2)	36 (1)	----	35.0
Mean	28.3	34.0	38.0	32.9[1]
Boone/Des Moines River				
Eagle Creek	32 (2)	38 (3) 36 (1)	----	35.3
Brushy Creek	38 (1)	30 (3)	36 (2)	34.7
South Branch Lizard Creek	38 (2)	34 (3)	42 (1)	38.0
White Fox Creek	40 (3)	43 (2)	44 (1)	42.3
Mean	37.0	36.2	40.7	37.6[1]
Iowa River				
Tipton Creek	44 (2)	46 (3)	48 (1)	46.0
Honey Creek	28 (2)	35 (1)	36 (3)	33.0
Minerva Creek	30 (1)	32 (3)	32 (2)	31.3
Beaver Creek	28 (1)	28 (3)	39 (2)	31.7
Mean	32.5	35.3	38.8	35.5[1]
Category Mean	32.6	35.2	39.2	35.6[2]

[1] Mean of individual scores for watershed.
[2] Overall mean (N = 32).

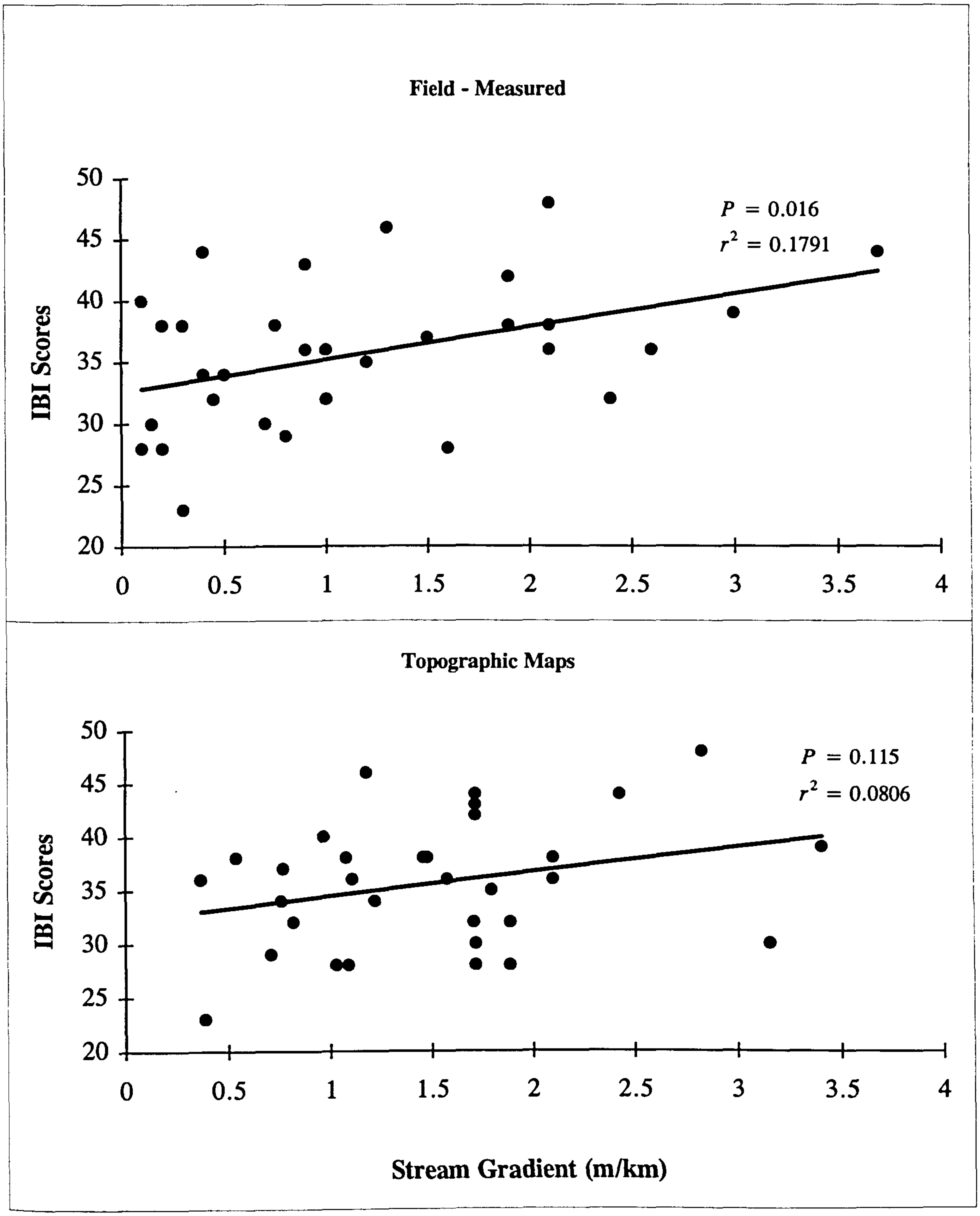

Figure 8. Relationship between stream gradient and IBI scores at 32 stations sampled from July - October, 1995.

field-measured gradient and smallmouth bass variables, including age-0 abundance (Figure 9), adult abundance, and total biomass of smallmouth bass. Map-determined gradients were not significantly related to adult abundance or total biomass ($P > 0.05$), however, there was a highly significant relationship with age-0 fish (Figure 9). The relationship for total abundance of smallmouth bass was also highly significant since age-0 fish comprised over 77% of the catch.

Principal Components Analysis

Habitat data from all 32 stations were used in the PCA. The first four principal components explained 61.6% of the variation among the 29 habitat variables (Appendix G). Principal component one (PC1) accounted for 21.8% of the variability, and PC2 through PC4 accounted for 16.6%, 12.1%, and 11.1%, respectively. Principal components PC5 and beyond each explained less than 10% of the variability and were not examined in detail. Correlations between scores of the first four components and all fish and habitat variables were considered significant at the alpha = 0.05 level and highly significant at 0.01.

PC1 conceptually represented "seasonal attributes" in the data. The first component was positively correlated with flow, depth, maximum depth, stream width, and turbidity. Negatively correlated were embeddedness and sand (Table 10). These associations reflect high flow conditions during July and early August. The first principal component was not correlated with IBI scores or any of the smallmouth bass variables (all $P > 0.31$).

Principal components 2 and 3 were described largely by instream channel features

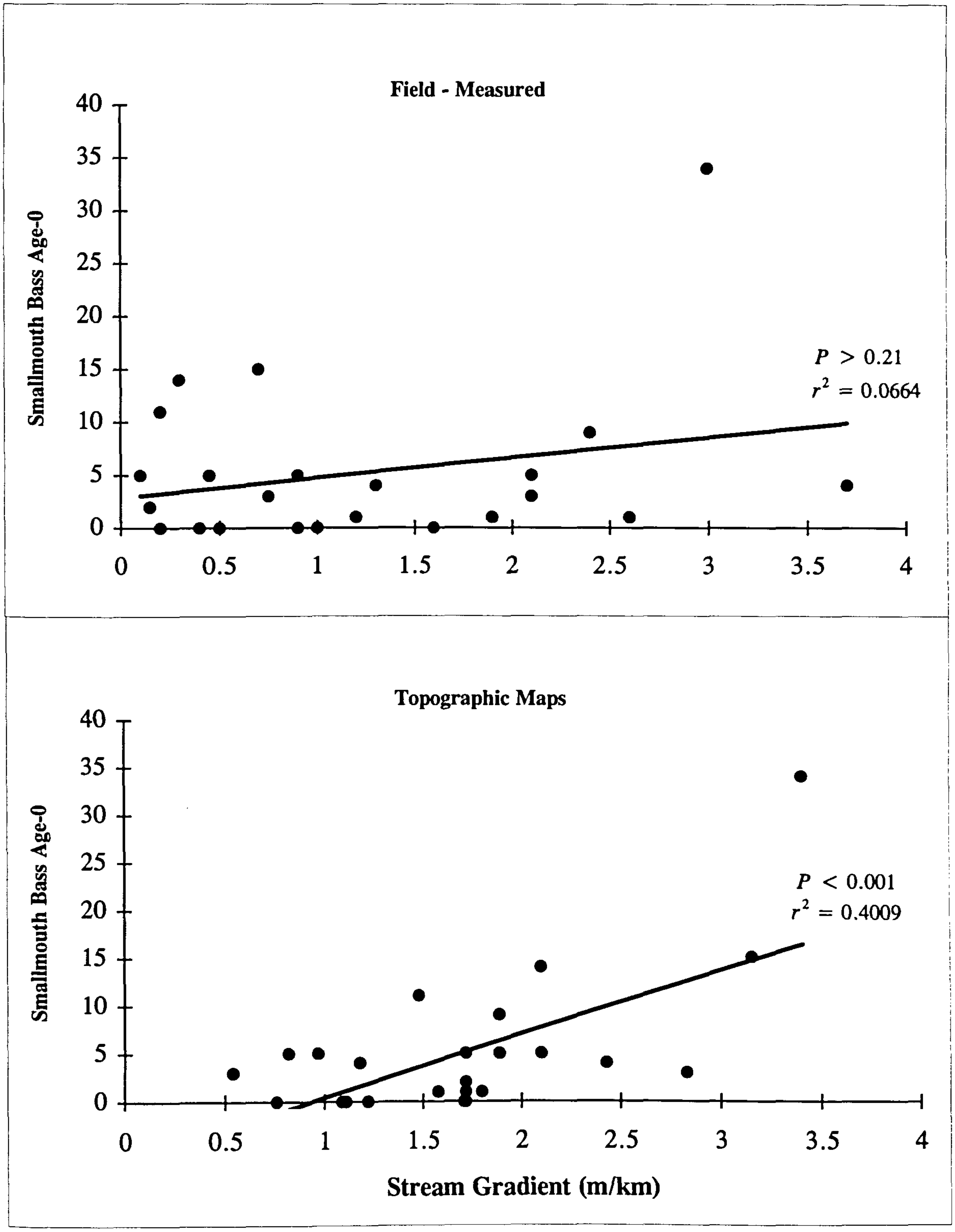

Figure 9. Relationship between stream gradient and smallmouth bass age-0 abundance at 25 stations sampled from July - October, 1995.

Table 10. Pearson Correlation Coefficients *(r)* for habitat variables[1] and fish variables[1,2] (bold) significantly correlated with principal components 1 through 4. * Indicates $P < 0.05$,** indicates $P < 0.01$.

Variable	(r)	Variable	(r)
PC1		**PC2**	
Flow	0.86**	Rubble/cobble	-0.71**
Maximum depth	0.82**	Run	0.67**
Mean width	0.80**	Riffle	-0.66**
Mean depth	0.75**	Field gradient	-0.65**
Turbidity	0.69**	Bank erosion	0.62**
Embeddedness	-0.63**	Boulder	-0.58**
Drainage area	0.62**	Map gradient	-0.54**
Boulder	0.58**	Silt	0.53**
Sand	-0.55**	Pool	-0.50**
Rubble/cobble	0.53**	Pasture	0.49**
Shrub	0.51**	Meadow	-0.48**
Water temperature	0.49**	Buffer width	-0.47**
Gravel	0.45**	Conductivity	0.42*
Meadow	-0.40*	Depth	0.41*
Conductivity	0.37*	Woody debris cover	0.37*
Riffle	0.36*	**IBI scores**	**-0.35***
IBI scores	**0.18**	**Adult SMB**	**-0.32**
Adult SMB	**0.13**	**Age-0 SMB**	**-0.06**
Age-0 SMB	**-0.10**	**SMB biomass**	**-0.04**
SMB biomass	**-0.003**		
PC3		**PC4**	
Clay	0.64**	Woodland	0.71**
Pasture	0.59**	Shading	0.59**
Meadow	-0.54**	Buffer width	0.58**
Map gradient	0.52**	Silt	-0.51**
Buffer width	-0.51**	Water temperature	-0.50**
Pool	0.51**	Boulder cover	-0.50**
Woody debris cover	0.48**	Pasture	-0.50**
Gravel	0.47**	Woody debris cover	0.48**
Run	-0.47**	Bank erosion	0.45**
Age-0 SMB	**0.46***	**Age-0 SMB**	**-0.39**
Drainage area	-0.44*	**SMB biomass**	**-0.28**
Bank erosion	0.38*	**Adult SMB**	**-0.21**
SMB biomass	**0.34**	**IBI scores**	**-0.03**
IBI scores	**0.32**		
Adult SMB	**-0.03**		

[1] Sample *N* for habitat variables and IBI scores = 32.
[2] Sample *N* for smallmouth bass variables = 24.

and riparian land use. PC2 represented channel features primarily related to low stream gradient. This component was negatively correlated with rubble/cobble, boulder, riffles, map and field gradient, and positively correlated with run, bank erosion, and silt. Pasture and meadow riparian landuse variables were inversely correlated with PC2 (Table 10). There was a significant negative correlation of PC2 with IBI scores ($P = 0.048$, $r = -0.35$) but no correlations with smallmouth bass variables.

Positively correlated with PC3 were clay, pasture, map gradient, pool, woody debris cover, gravel, and bank erosion. Variables indicative of undisturbed riparian zones, such as meadow and buffer width, were negatively correlated. Age-0 smallmouth bass abundance was significantly correlated with PC3 ($P = 0.025$). Positive PC3 values can be described as representing higher gradient sites with gravel and pool habitat bordered by pasture landuse. These areas are suitable as "good nursery areas" for age-0 smallmouth bass.

PC4 represented the approximate inverse of PC3 positive values, describing "poor nursery areas" for smallmouth bass. There were high positive correlations between PC4 scores and riparian features of woodland, shading, and buffer width. There were high negative correlations with silt, water temperature, pasture and boulder cover. Abundance of age-0 smallmouth bass was negatively correlated with PC4 but not significantly ($P = 0.058$, $r = -0.39$) as was adult abundance ($P = 0.32$, $r =- 0.21$). Conceptually, a positive PC4 value described well-shaded stream sites relatively lower in silt, water temperature, and boulder cover.

A plot of principal components 3 and 4 illustrates that age-0 smallmouth bass occurred in higher proportion at sites with high scores for PC3 and low scores for PC4 (Figure 10). Although age-0 smallmouth bass were not collected from Raccoon River tributaries during the study, plotted scores for PC3 and PC4 did not indicate poor nursery areas at most sites.

Habitat Index Models

To develop linear models relating habitat features to fish community characteristics, the six variables having the greatest explanatory power in each of the first four principal components were employed. Models were constructed and regressed against dependent fish variables: age-0 and adult smallmouth bass, total smallmouth bass biomass, and IBI scores (Table 11). Index models were of the form: $Index_A = Y1 - \overline{Y}$ $SD_{Y1} + Y2 - \overline{Y}2/ SD_{Y2} .... Y6 - \overline{Y}6/SD_{Y6}$; where Yx = variable x, $\overline{Y}x$ = mean of variable x, and SD_{Yx} = standard deviation of x.

Where two or more variables described essentially the same habitat feature, the lesser correlated variable (lower absolute value of r) was omitted from the model to avoid redundancy. Thus, maximum depth ($r = 0.82$) was included in the model instead of mean depth ($r = 0.75$) for Index One, and pasture ($r = 0.59$) was selected to represent landuse instead of meadow ($P = -0.54$) for Index Three. Because their occurrences were rare and relationships with individual fish variables were not significant, boulder cover and woody debris cover were not included in the index models. Boulder cover comprised only 0.2% of stream areas sampled while woody debris cover comprised 5.1%. Correlation analysis performed on individual fish and habitat variables (during PCA) revealed that neither boulder cover or woody debris cover were significantly correlated

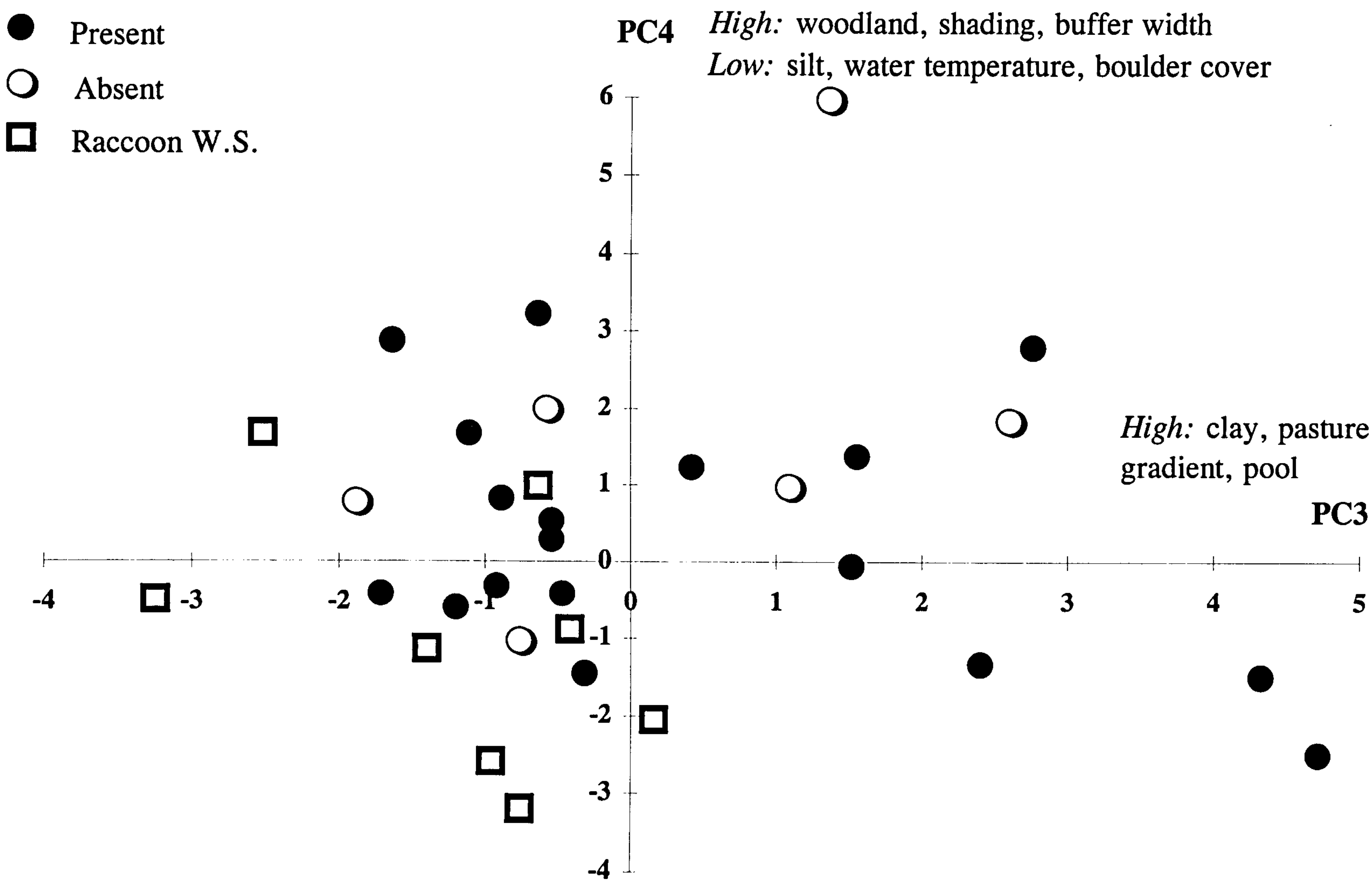

Figure 10. Plot of sample station scores for principal components three (PC3) and four (PC4). Positive PC3 scores described "good" smallmouth bass nursery areas, positive PC4 scores described "poor" nursery areas.

Table 11. Index models developed from habitat variables most correlated with fish variables from Principal Components Analysis.

Index One = (flow - 0.430)/0.574 + (maximum depth - 0.421)/0.139 + (mean width - 10.425)/3.039 + (turbidity - 57.531)/66.256 - (embeddedness - 38.331)/11.272 + (drainage area - 253.140)/116.767

Index Two = - (rubble/cobble - 10.094)/10.168 + (run - 80.938)/13.363 - (riffle - 6.563)/7.278 - (field gradient - 1.148)/0.947 + (bank erosion - 42.688)/15.542 - (boulder - 2.103)/2.434

Index Three = (clay - 2.986)/2.910 + (pasture - 17.497)/32.397 + (gravel - 21.659)/9.917 + (map gradient - 1.515)/0.745 - (buffer width - 77.603)/37.064 + (pool - 12.500)/8.332

Index Four = (woodland - 5.759)/6.577 + (shading - 22.913)/14.495 + (buffer width - 77.603)/37.064 - (silt - 8.569)/6.829 - (water temperature - 20.103)/7.357 - (pasture - 17.497)/32.397;

---

with smallmouth bass variables and IBI scores (all $P > 0.12$). No fish variables were significantly related ($P < 0.05$) to Index One (Table 12). Adult smallmouth bass abundance was related to Index Two. Age-0 smallmouth bass abundance was more highly correlated with Index Three (high gradient open pasture sites with clay, gravel and pools) than Index Four (cooler, well-shaded sites with protected stream banks and low in silt), even though relationships with both were statistically significant. Total smallmouth bass biomass and IBI scores were also significantly related to Index four.

Smallmouth Bass Regression Models

Two model selection methods, STEPWISE and MAXR (SAS Institute 1990), were used in regression analyses of the same 29 habitat variables used in PCA. Age-0 and adult smallmouth bass abundance were the dependent variables. Variables having *P*-

Table 12. Relationship of Index models with fish variables. First number denotes adjusted R^2 value and second number (in parentheses) denotes probability > F. * Indicates P significant at 0.05.

	Smallmouth Bass			Fish Community
Index	Age-0 Abundance	Adult Abundance	Total Biomass	IBI Scores
One	- 0.020 (0.476)	- 0.043 (0.921)	- 0.042 (0.847)	- 0.024 (0.512)
Two	- 0.035 (0.660)	0.125 (0.047)*	- 0.037 (0.713)	0.071 (0.105)
Three	0.293 (0.003)*	- 0.041 (0.808)	0.068 (0.110)	0.067 (0.113)
Four	0.148 (0.033)*	- 0.031 (0.598)	0.176 (0.021)*	0.187 (0.018)*

values under 0.150 (four for age-0 and five for adult models) were retained in the STEPWISE procedure. From the MAXR method, I selected the first six (best one to six-variable) models for observation. The best single variable related to age-0 smallmouth bass abundance under both model methods was percent clay substrate (Tables 13-14, Figure 11). For best two to four-variable models, map gradient was first added followed by clay, pool, and meadow. The MAXR procedure added habitat variables depth and rubble/cobble, and depth and maximum depth, for best five and six-variable age-0 models, respectively (Table 14).

Five variables were retained in stepwise regression models for adults (Table 13). The first one to three-variable models were identical to those generated using MAXR. Conductivity was the single variable most strongly related to smallmouth bass adult abundance (Tables 13-14, Figure 11). Clay was the second most-related variable. Conductivity and clay were not related to each other, according to correlation analysis

Table 13. Summary of stepwise regression models for age-0 and adult smallmouth bass. No other habitat variables met the 0.1500 significance level for entry into the model.

Model (Variables)	Variable Entered	Variable R^2	Model R^2	Variable *P*-value	Model *P*-value
	Dependent Variable Age-0 Smallmouth Bass Abundance				
1	Clay	0.540	0.540	0.0001	0.0001
2	Map gradient	0.126	0.667	0.0101	0.0001
3	Pool	0.073	0.740	0.0273	0.0001
4	Meadow	0.028	0.769	0.1413	0.0001
	Dependent Variable Adult Smallmouth Bass Abundance				
1	Conductivity	0.218	0.218	0.0214	0.0214
2	Clay	0.191	0.409	0.0164	0.0040
3	Silt	0.098	0.508	0.0589	0.0023
4	Pasture	0.056	0.565	0.1314	0.0023
5	Woodland	0.068	0.633	0.0826	0.0016

(r = -0.11, P = 0.55). Silt was the third variable retained in the models. Conductivity did not improve the R^2 values of maximum improvement models four, five, and six, and was therefore replaced. The most statistically sound (R^2 = 0.684, P = 0.0014) and conceptually meaningful model for adults was a six-variable model obtained using the MAXR procedure. This model included map gradient, silt substrate, shading, clay substrate, pasture, and woodland (Table 14).

Table 14. Best one to six-variable maximum R^2 improvement models for age-0 and adult smallmouth bass.

Model (Variables)	Model Equation	R^2	*P*-value
	Dependent Variable Age-0 Smallmouth Bass Abundance		
1	Age-0 = 1.47 + 1.88(clay)	0.540	0.0001[1]
2	Age-0 = -7.33 + 4.19(map gradient) + 1.47(clay)	0.667	0.0001[1]
3	Age-0 = -3.89 + 4.06(map gradient) + 1.70(clay) - 0.30(pool)	0.741	0.0001[1]
4	Age-0 = -1.25 + 3.67(map gradient) + 1.66(clay) - 0.04(meadow) - 0.31(pool)	0.769	0.0001[1]
5	Age-0 = 10.89 - 22.60(mean depth) + 0.20(rubble/cobble) + 2.09(clay) - 0.09(meadow) - 0.33(pool)	0.794	0.0001
6	Age-0= 4.98 + 2.32(map gradient) - 37.44(mean depth) + 1.83(clay) - 0.06(meadow) - 0.32(pool) + 18.59(maximum depth)	0.809	0.0001
	Dependent Variable Adult Smallmouth Bass Abundance		
1	Adult = 7.46 - 0.01(conductivity)	0.219	0.0214[1]
2	Adult = 8.48 - 0.28(clay) - 0.01(conductivity)	0.410	0.0040[1]
3	Adult = 10.35 - 0.15(silt) - 0.27(clay) - 0.01(conductivity)	0.508	0.0023[1]
4	Adult = 8.40 - 0.26(silt) - 0.03(buffer width) - 0.54(clay) - 0.15(woodland)	0.641	0.0014
5	Adult = 4.35 + 0.81(map gradient) - 0.23(silt) - 0.61(clay) + 0.03(pasture) - 0.13(woodland)	0.654	0.0010
6	Adult = 3.76 + 0.93(map gradient) - 0.25(silt) + 0.03 (shading) - 0.61(clay) + 0.03(pasture) - 0.16(woodland)	0.684	0.0014

[1] Model result the same as that obtained using stepwise regression procedure.

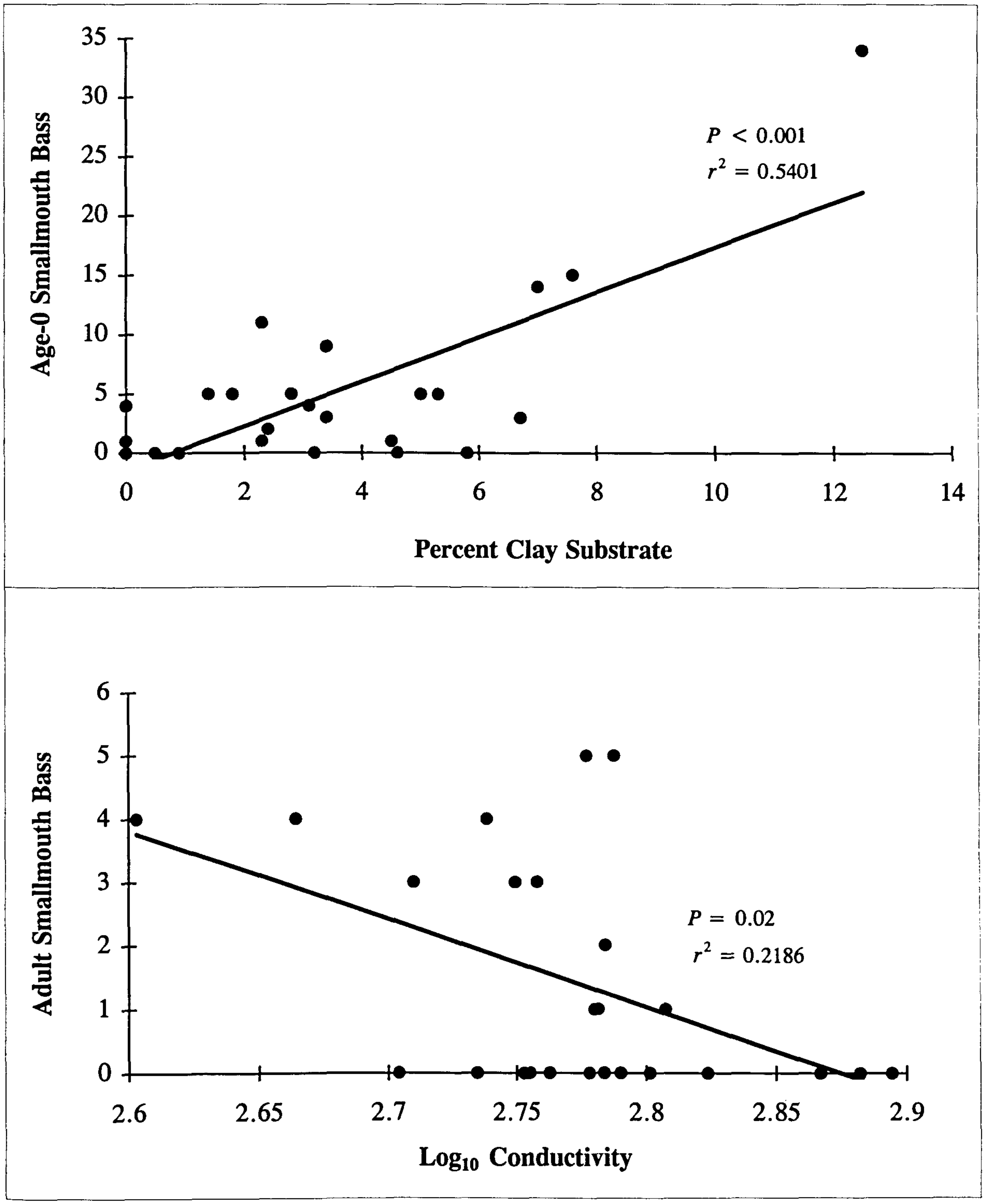

Figure 11. Scatter plots of individual habitat variables most-related to age-0 and adult smallmouth bass abundance (percent clay substrate and conductivity) as determined by stepwise and maximum R^2 improvement regression models.

DISCUSSION

Smallmouth Bass Recruitment

Unseasonably cool temperatures and high flows may have influenced smallmouth bass abundance and spawning success in central Iowa watersheds during 1995. Most of western and central Iowa experienced abnormally cool, wet weather during late spring and early summer. Areas of the Raccoon River watershed, in particular, received frequent heavy rainfalls from late April to July and experienced below-normal temperatures throughout May and early June. Smallmouth bass typically spawn during May in Iowa, beginning when water temperatures reach about 15^0 to 18^0 C (Cleary 1956; Harlan and Speaker 1956; Reynolds 1965). In this study, smallmouth bass appeared to be adversely affected by the weather in every watershed, however, populations in tributaries of the Raccoon River were likely influenced the most. Several age-0 largemouth bass were encountered in all three tributaries in late July and early August, but only one smallmouth bass (a sub-adult) was collected at this time. During the last week of August, Iowa Department of Natural Resources personnel collected three sub-adults (approximately 152 mm TL) from Buttrick Creek, and five sub-adults from West Buttrick Creek. One age-0 smallmouth bass (approximately 50 mm TL) was captured from West Buttrick Creek (Thomas Wilton, unpublished data). The absence of breeding adults and presence of only one young-of-the year from these collections suggests that at least some adults had spawned but their nests probably failed during rain events. Smallmouth bass fry may have succumbed to high flows, high turbidity, or both (Cleary 1956; Reynolds 1965; Simonson and Swenson 1990; Lukas and Orth 1995).

Another of the Raccoon watershed sites (Lake Creek 1) was revisited on October 24. Two breeding-size adults (245 & 420 mm) and one age-0 (68 mm) smallmouth bass were collected from approximately 50% of the original station.[1] These adults may have moved into the stream and spawned after high flows receded. Reynolds (1965) found that because of high water levels, smallmouth bass did not migrate into a tributary of the Des Moines River to spawn until June 1. They then continued to spawn until mid July, even though the water temperature had exceeded 26^0. He concluded that water level may be more important than water temperature in triggering Des Moines River smallmouth bass to spawn. The relatively small length of the age-0 smallmouth bass captured at Lake Creek 1 also suggests a late spawn. Stream-dwelling smallmouth bass in Iowa typically average 100 mm or more at the end of their first year (Tate 1949; Paragamian 1981, 1984).

The diminutive size of most age-0 bass collected from Boone/Des Moines and Iowa river tributaries provided evidence that adults nested more than once during the season. Smallmouth bass often renest if their first attempt fails (Cleary 1956; Reynolds 1964) and may renest even if the earlier attempt was successful (Pflieger 1975). At some stations, a few notably larger young-of-the year, believed to be survivors from early, less successful nests, were captured along with the more abundant recently-hatched young. It became apparent during the remainder of the sampling period that two distinct cohorts of age-0 smallmouth bass existed. Young that were able to survive high water levels during

[1] A malfunction in the electroshocker prevented resampling of the entire station.

the early summer had achieved lengths 30 to 40 mm greater than those hatched during the dry weeks that followed.

Factors Affecting Fish Communities and Smallmouth Bass

Fish community sampling and IBI

To date, versions of the IBI that have been modified for use in Iowa streams (Liang 1990; Wilton 1996) encompass metrics and scoring frameworks for both low quality and high quality streams. Also, length of stream sampled and efficiency of collection gear used varied, making species richness expectations unclear and transferability of these versions limited. As Lyons et al. (1996) suggest, the correct version of the IBI should be matched with the type of stream. Thus, both warmwater and coldwater versions have been developed in Wisconsin to encompass most streams in the state. The IBI criteria used in this study of smallmouth bass streams in central Iowa, is not recommended for application in highly perturbed ecosystems or for streams in other landform regions.

Effectiveness of fish sampling efforts was good as measured by number of species encountered in the study. Overall IBI scores of streams in the Boone/Des Moines watershed appeared similar to Liang's findings (1990) of the highest quality sites in the Boone River and selected tributaries. Scores of most individual metrics, however, especially those dealing with species richness (such as total number of species), were higher in this study. This may be attributable to shorter stream lengths sampled by Liang (100 feet). Sampling distance of 200 m, which is approximately 20 times the mean channel width of streams studied, and average shock time of 2 to 2 1/2 hours, appeared to have adequately accounted for most fish species present in each stream. Other workers advocate sampling at least 35 times the mean channel width, or at least 150 m when species richness estimates are to be made (Lyons 1992). Relatively straight streams with homogenous habitats, which are common throughout Iowa, may have lower fish diversity and therefore require less sampling to account for all species present. Species richness estimates in this study were comparable to those found by Wilton (1996) at 107 m to 364 m stations in some of the same streams within the Des Moines Lobe. Paragamian (1990) encountered similar species composition using a combination of rotenone and electrofishing at 91 m to 198 m blocknetted river and stream stations. For sampling fish communities in relatively homogenous habitats of wadeable central Iowa streams, thorough electrofishing of stations approximately 20 times the mean channel width appears to be sufficient when blocknets are not used.

Fish community relationships

Higher IBI scores at stations of higher local (field-measured) gradient suggested that fish community attributes are closely related to small scale (centimeters to meters) spatial habitat heterogeneity. On small spatial scales, habitat heterogeneity is usually associated with differences in current velocity, substrate size, and depth, related to riffle-pool development, and variables such as woody debris and shading which are contributed by the riparian environment (Schlosser 1991). IBI scores were significantly correlated with Index Four, which included variables having positive associations with woodland, shading and buffer width, and negative associations with silt, water temperature, and pasture. While spacial heterogeneity on a larger spacial scale can, of course, be associated with the same features, larger expanses of higher stream gradient were better represented by Index Three. That is, at sections with higher map gradients where row cropping is not generally feasible, streams were bordered by pasture land that provided little stream shading. These areas were not well correlated with fish community attributes as measured with the IBI. Higher stream gradients at the local scale promoted higher IBI scores (i.e., better overall fish community structure and function) primarily because such areas had greater species composition and richness metric values (i.e., number of darter, sucker, intolerant, benthic insectivore, and total species).

Within the Des Moines Lobe and other recently glaciated midwestern landforms there are less-altered reaches of stream in otherwise disturbed agricultural settings that may serve as "oases" for fish communities (Luey and Adelman 1980). This study suggests that the most diverse fish communities in central Iowa tend to be associated with reaches of higher gradient and greater habitat heterogeneity created by glaciation on a landscape scale, but which operate at a localized spatial scale.

Smallmouth bass habitat - adults

The relatively low number of adult smallmouth bass collected in this study was likely a function of stream size (Lyons 1991; Lyons et al. 1988), turbidity (Menzel et al. 1984) and time and duration of spawning (Reynolds 1965). Since the tributaries sampled were relatively narrow and shallow compared to their mainstem rivers, the likelihood of collecting many post-spawn adults was poor (Reynolds 1965). Lyons (1991) found that smallmouth bass (adults and juveniles combined) in Wisconsin streams tended to occur in streams wider than 8 m. Heavy rains accompanied by high turbidity from suspended silt particles probably further reduced the number of adults entering the swollen streams. High flow conditions during spawning have been known to disturb smallmouth bass nesting patterns (Reynolds 1965), sometimes several times during the same season (Lukas and Orth 1995).

Although several variables were found to be related to adult smallmouth bass abundance, none described physical features normally associated with the species. Many workers have described critical habitat requirements of smallmouth bass in the Midwest and concur that the most important physical features include: adequate coarse or rocky substrate and current velocity, higher stream gradient, and larger stream size (Trautman 1942; Cleary 1956; Harlan and Speaker 1956; Reynolds 1965; Pflieger 1975; Bulkley et al. 1976; Paragamian 1980, 1981, 1984,1987; Lyons 1992; Lyons et al. 1988). In none of the above studies, however, were habitat requirements of age-0 and adults differentiated. Index Two, a six-variable model which incorporated habitat variables that were most correlated with PC2 (rubble/cobble, run, riffle, field-measured gradient, bank erosion, and boulder) was the only significant combination resembling previous smallmouth bass habitat descriptors. Surprisingly, except for run and bank erosion, these variables were inversely related to adult smallmouth bass abundance. This suggests that adults actually avoid areas of tributary streams with rubble/cobble, riffles, high gradient and boulders. Catch rates of adults, however, were low (N=36). The small sample size of adult fish in this study did not allow for conclusive statistical analyses of the data.

Smallmouth bass habitat - age-0

Since few studies in the Midwest have specifically evaluated habitat requirements of age-0 and adult smallmouth bass separately (Paragamian 1981; Roseboom et al. 1992) little is yet known about habitat utilization at various life stages. Schlosser (1991) contended that habitats of juveniles (in general) are normally different than those of adults on small spacial scales although habitat use on both large and small scales can be heavily influenced by reproductive movements. Evidence from this study supports this premise as age-0 smallmouth bass seemingly chose different habitats than adults and even preferred habitats less favorable to fish communities as a whole. Habitat Index Four described conditions more favorable to fish communities in general, but which were not necessarily optimal for young-of-the-year smallmouth bass. Results of PCA, linear regression, and habitat index models indicated that age-0 bass preferred higher gradient stream areas on the large (map) scale with gravel and pool habitat, bordered by open pastures.

Bulkley et al. (1976) concluded that relationships between smallmouth bass and stream gradient in Iowa rivers and streams were statistically significant. Paragamian (1981) contended, however, that substrate was a more meaningful measure of smallmouth bass habitat quality than stream gradient. He recommended stocking age-0 and age I bass in reaches containing gravel and rubble/cobble in pools. Although Trautman (1942) did not differentiate among age groups, he recommended using stream gradient as the criterion for smallmouth bass stocking in Ohio. There are similarities in the findings between Trautman's study and this one.

Most of Ohio was last glaciated during the Wisconsinan period (10,500 to 30,000 years ago), the same time at which the Des Moines Lobe was formed in Iowa (Prior 1991). Young-of-the year smallmouth bass were captured at stream gradients in the Des Moines Lobe comparable to those of the best smallmouth bass streams studied by Trautman (1942) in Ohio (1.3 - 3.8 m/km). This study showed that a highly significant relationship existed between age-0 smallmouth bass and stream gradient measured from topographic maps. Higher gradient stream reaches in central Iowa and similar midwestern glacial landscapes may be vital smallmouth bass nursery or spawning habitat and can be readily identified from topographic maps.

APPENDIX A.

SPECIES ASSIGNMENTS FOR IBI

Table A1. Species assignments used in this study for Index of Biotic Integrity metrics classification.

Group	Species
Sunfish:	Rock bass, green sunfish, orangespotted sunfish, bluegill, black crappie.
Darters:	Iowa darter, fantail darter, johnny darter, banded darter, blackside darter, slenderhead darter.
Suckers:	River carpsucker, quillback, white sucker, northern hog sucker, bigmouth buffalo, golden redhorse, shorthead redhorse.
Intolerants:	American brook lamprey, largescale stoneroller, rosyface shiner, Topeka shiner, northern hog sucker, stonecat, slender madtom, brook stickleback, smallmouth bass, rock bass, Iowa darter, banded darter, blackside darter, slenderhead darter.
Tolerants:	Blacknose dace, creek chub, black bullhead, yellow bullhead, green sunfish.
Omnivores:	Common carp, bluntnose minnow, fathead minnow, river carpsucker, quillback, white sucker.
Insectivorous Cyprinids:	Hornyhead chub, emerald shiner, common shiner, bigmouth shiner, rosyface shiner, spotfin shiner, sand shiner, Topeka shiner, suckermouth minnow.
Top Carnivores:	Northern pike, channel catfish, flathead catfish, rock bass, smallmouth bass, largemouth bass, black crappie.
Benthic Insectivores:	Suckermouth minnow, northern hog sucker, golden redhorse, shorthead redhorse, black bullhead, yellow bullhead, slender madtom, stonecat, Iowa darter, fantail darter, johnny darter, banded darter, blackside darter, slenderhead darter, freshwater drum.
Simple Lithophilous Spawners:	Emerald shiner, common shiner, rosyface shiner, suckermouth minnow, blacknose dace, white sucker, northern hogsucker, golden redhorse, shorthead redhorse, banded darter, blackside darter, slenderhead darter.

APPENDIX B.

LEGAL DESCRIPTIONS OF STUDY SITES

Table B1. County, legal description, and river mile (upstream of mouth) of sampling sites at starting point.

Raccoon River Watershed

Buttrick Creek
Station 1 - Greene County: T83N R30W S24 NW 1/4 NE 1/16; RM 3.46
Station 2 - Greene County: T83N R30W S14 NE 1/4 NE 1/16; RM 6.79

Cedar Creek
Station 1 - Greene County: T85N R32W S33 NW 1/4 NE 1/16; RM 0.95
Station 2 - Greene County: T85N R32W S21 SE 1/4 SW 1/16; RM 2.72
Station 3 - Calhoun County: T86N R31W S6 SW 1/4 SW 1/16; RM 27.23

Lake Creek
Station 1 - Calhoun County: T86N R34W S14 NW 1/4 SW 1/16; RM 2.15
Station 2 - Calhoun County: T86N R34W S12 SE 1/4 NW 1/16; RM 4.4
Station 3 - Calhoun County: T86N R33W S7 NE 1/4 NW 1/16; RM 6.59

Boone/Des Moines Watershed

Brushy Creek
Station 1 - Webster County: T 87N R27W S10 NE 1/4 SE 1/16; RM 2.26
Station 2 - Webster County: T 87N R27W S3 SE 1/4 SE 1/16; RM 2.78
Station 3 - Webster County: T 88N R27W S22 SW 1/4 NW 1/16; RM 8.35

Eagle Creek
Station 1 - Wright County: T90N R26W S36 NE 1/4 SW 1/16; RM 1.92
Station 2 - Wright County: T90N R25W S7 SW 1/4 SW 1/16; RM 8.23
Station 3 - Wright County: T90N R25W S5 SW 1/4 NW 1/16; RM 10.62

South Branch Lizard Creek
Station 1 - Webster County: T 89N R29W S26 NE 1/4 NW 1/16; RM 1.08
Station 2 - Webster County: T 89N R29W S31 NE 1/4 SE 1/16; RM 10.13
Station 3 - Webster County: T 89N R29W S30 SE 1/4 NW 1/16; RM 12.87

White Fox Creek
Station 1 - Hamilton County: T89N R25W S33 NW 1/4 SE 1/16; RM 0.78
Station 2 - Hamilton County: T89N R25W S21 SW 1/4 NE 1/16; RM 2.82
Station 3 - Hamilton County: T89N R25W S3 NE 1/4 SW 1/16; RM 8.04

Table B1. (continued)

Iowa River Watershed

Beaver Creek
Station 1 - Hardin County: T87N R20W S2 SW 1/4 NW 1/16; RM 5.51
Station 2 - Hardin County: T88N R20W S27 SE 1/4 NE 1/16; RM 7.93
Station 3 - Hardin County: T88N R20W S17 NE 1/4 SE 1/16; RM 12.5
Honey Creek
Station 1 - Marshall County: T85N R19W S6 NE 1/4 SE 1/16; RM 4.68
Station 2 - Hardin County: T86N R20W S30 NW 1/4 SE 1/16; RM 7.63
Station 3 - Hardin County: T86N R20W S22 NE 1/4 NE 1/16; RM 11.24
Minerva Creek
Station 1 - Marshall County: T85N R20W S35 NE 1/4 SW 1/16; RM 7.75
Station 2 - Marshall County: T85N R20W S6 SE 1/4 SE 1/16; RM 16.25
Station 3 - Story County: T85N R21W S1 NW 1/4 SW 1/16; RM 19.65
Tipton Creek
Station 1 - Hardin County: T87N R20W S21 SW 1/4 SW 1/16; RM 0.35
Station 2 - Hardin County: T87N R21W S25 SE 1/4 NE 1/16; RM 4.27
Station 3 - Hardin County: T87N R21W S26 NW 1/4 NW 1/16; RM 7.87

APPENDIX C.

LONGITUDINAL STREAM PROFILES

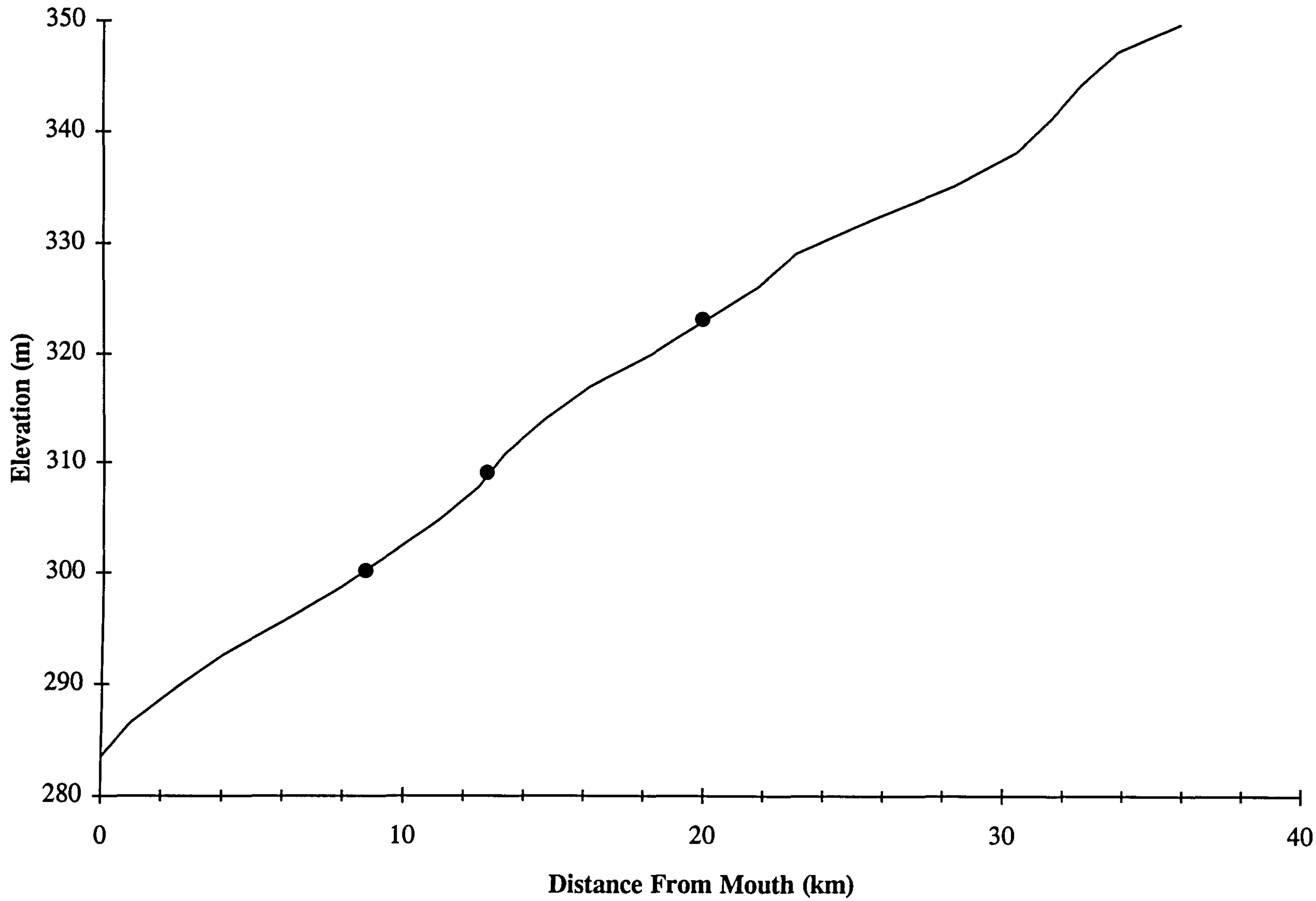

Figure C1. Profile and station locations of Beaver Creek.

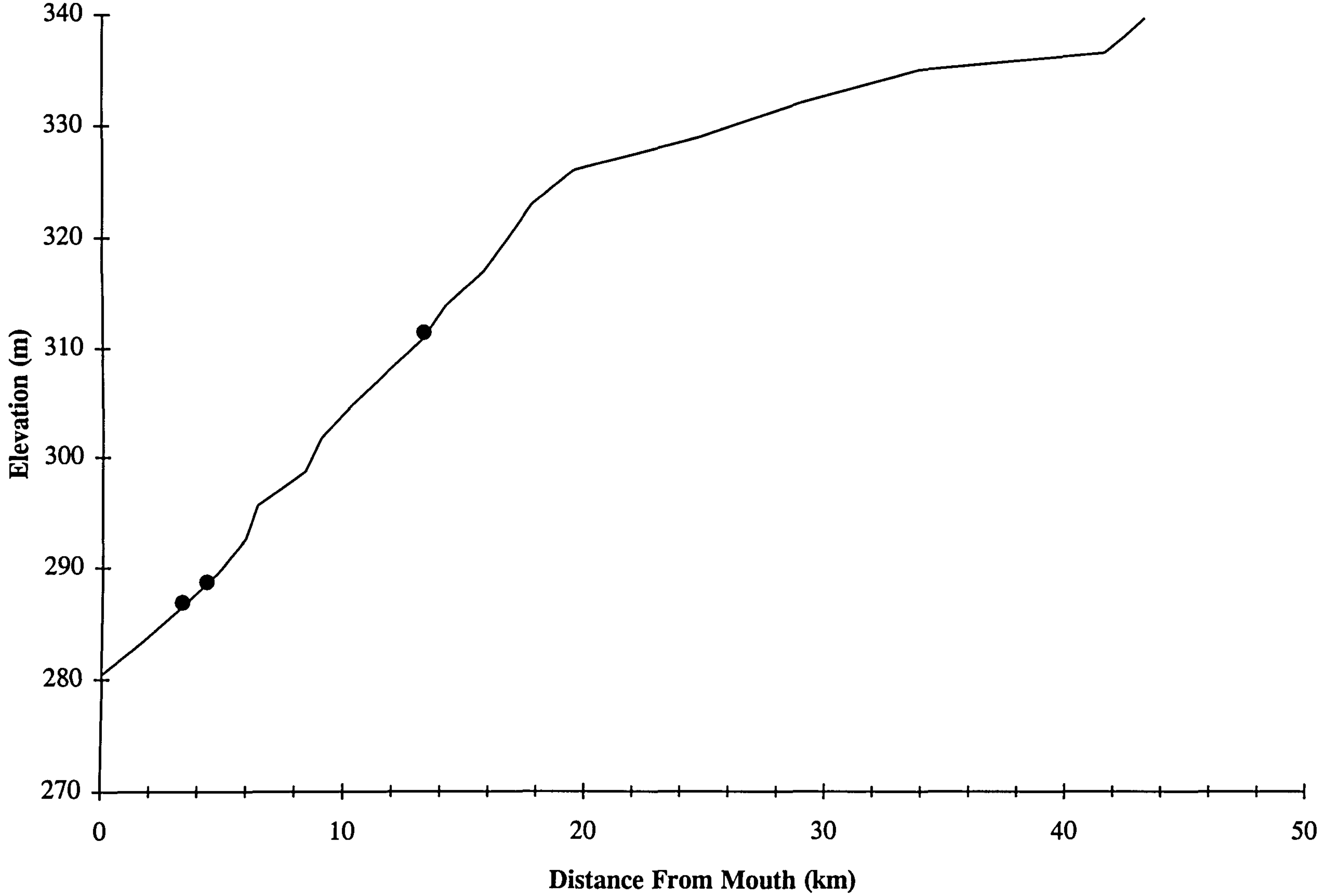

Figure C2. Profile and station locations of Brushy Creek.

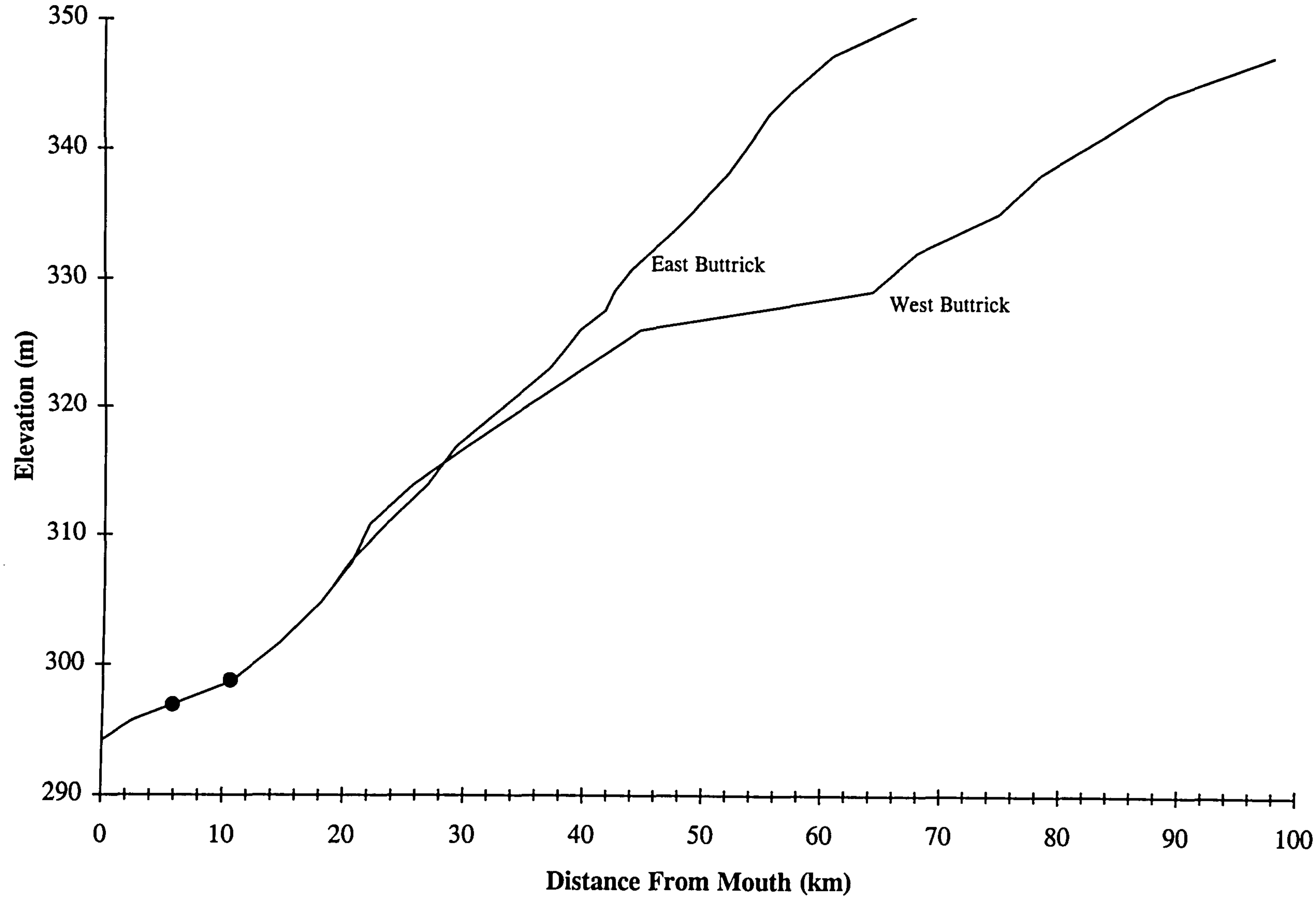

Figure C3. Profile and station locations of Buttrick Creek.

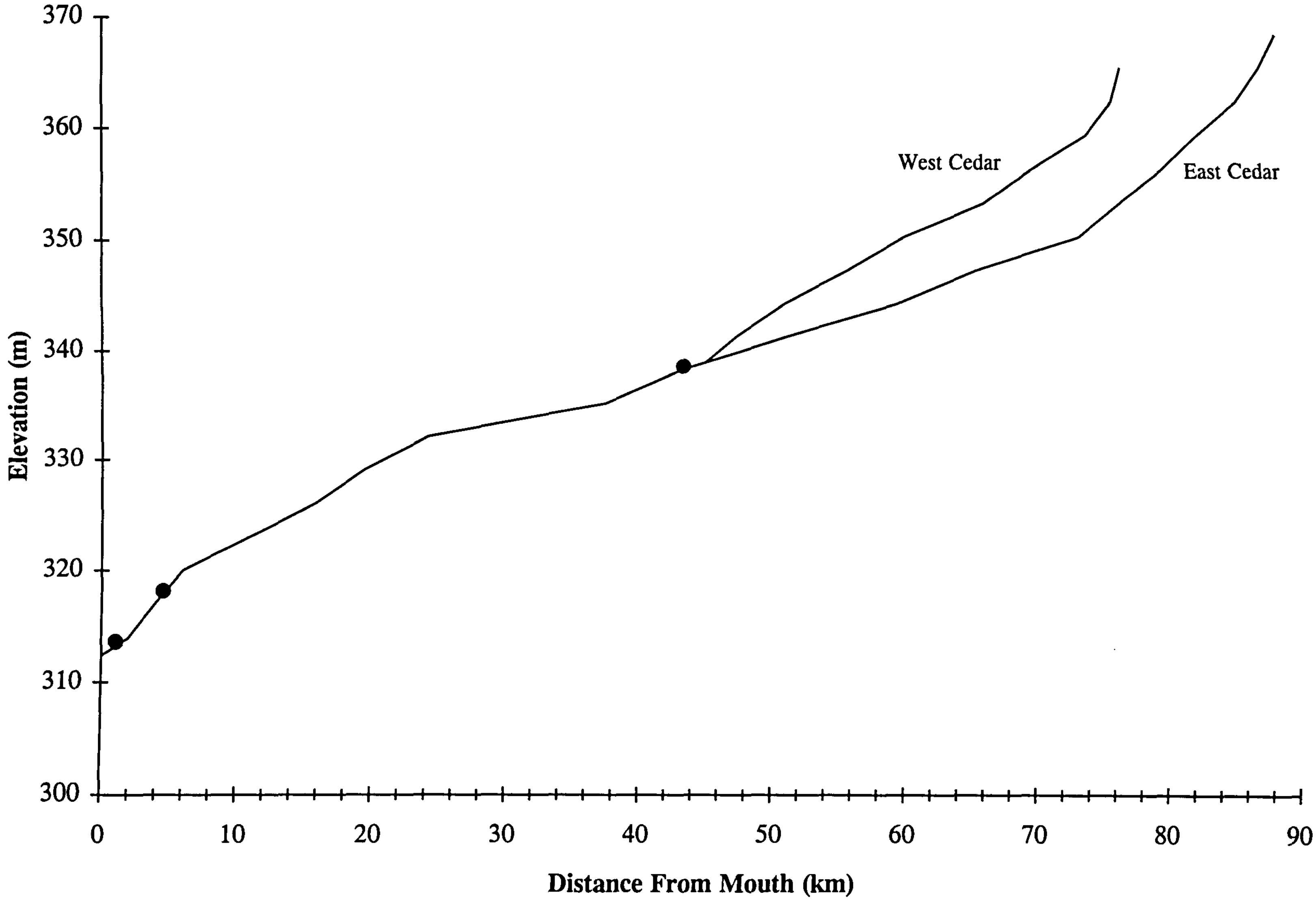

Figure C4. Profile and station locations of Cedar Creek.

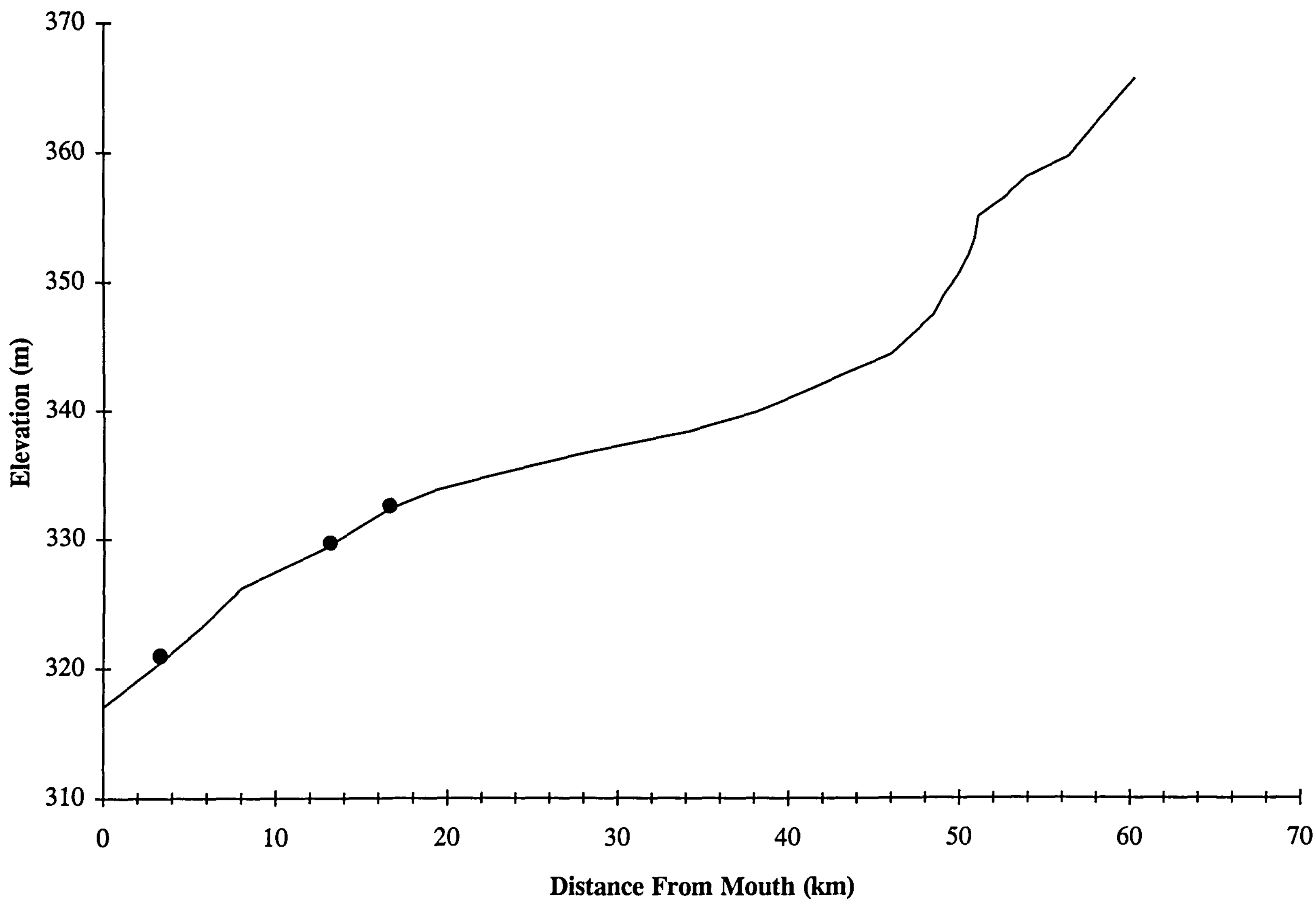

Figure C5. Profile and station locations of Eagle Creek.

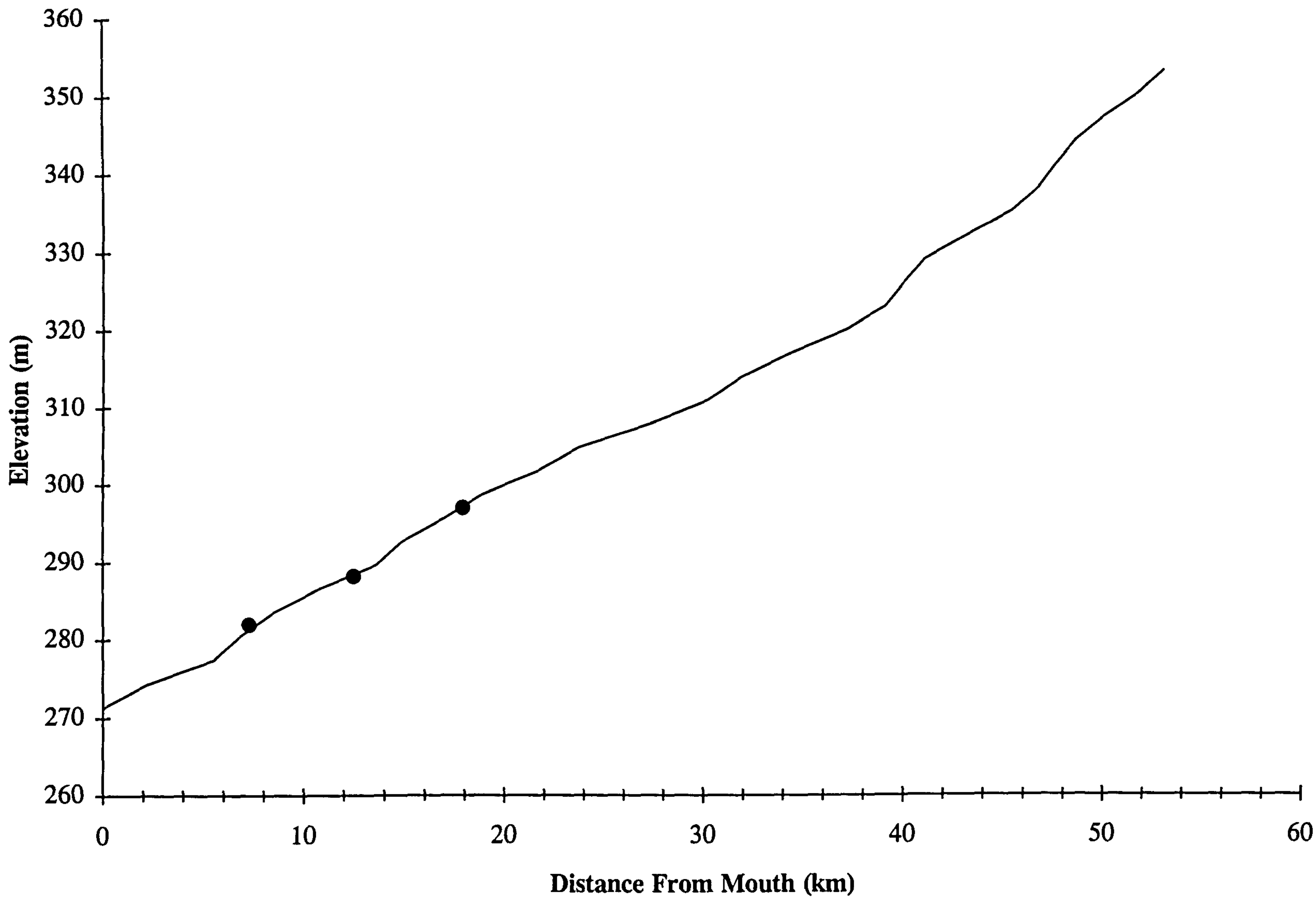

Figure C6. Profile and station locations of Honey Creek.

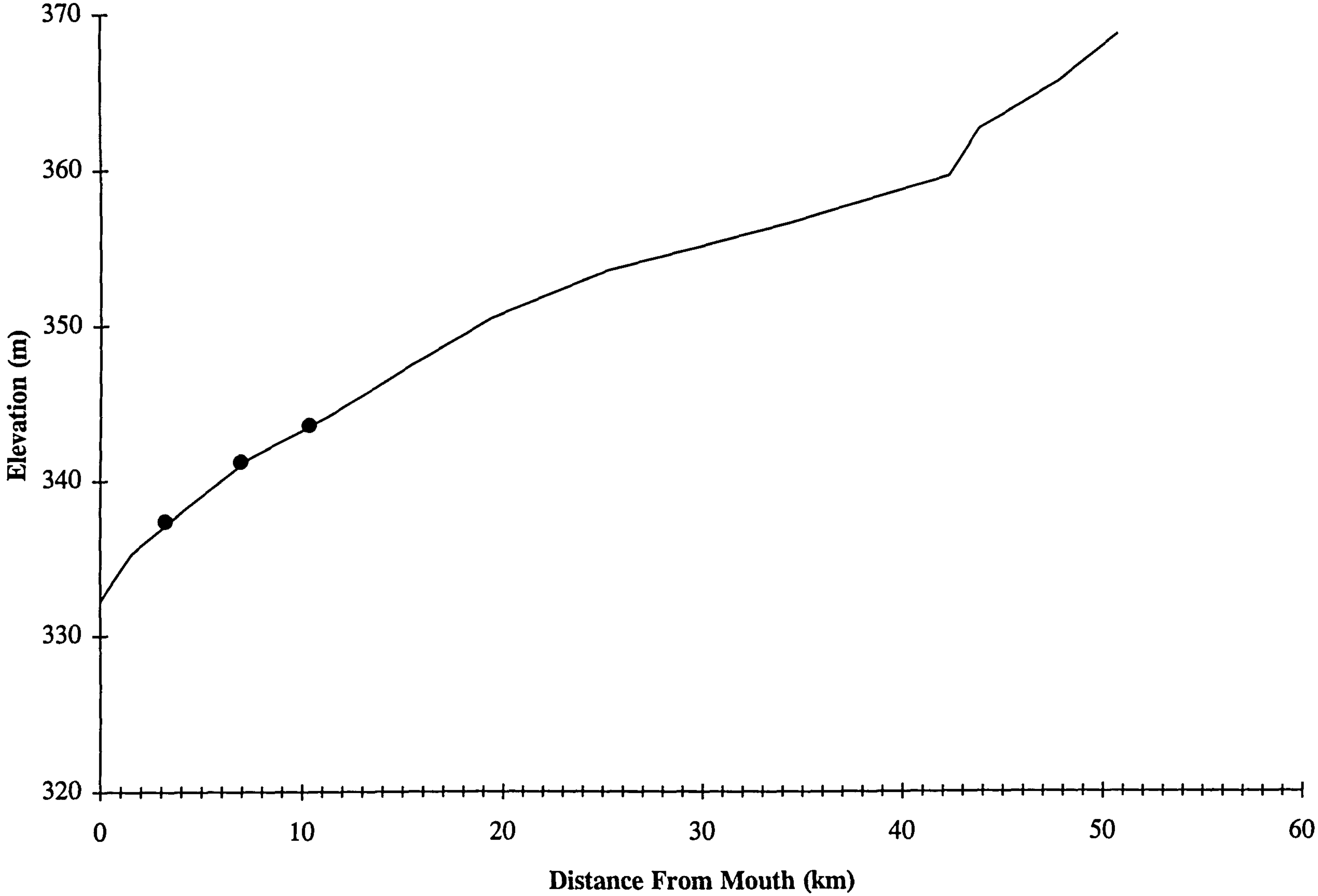

Figure C7. Profile and station locations of Lake Creek.

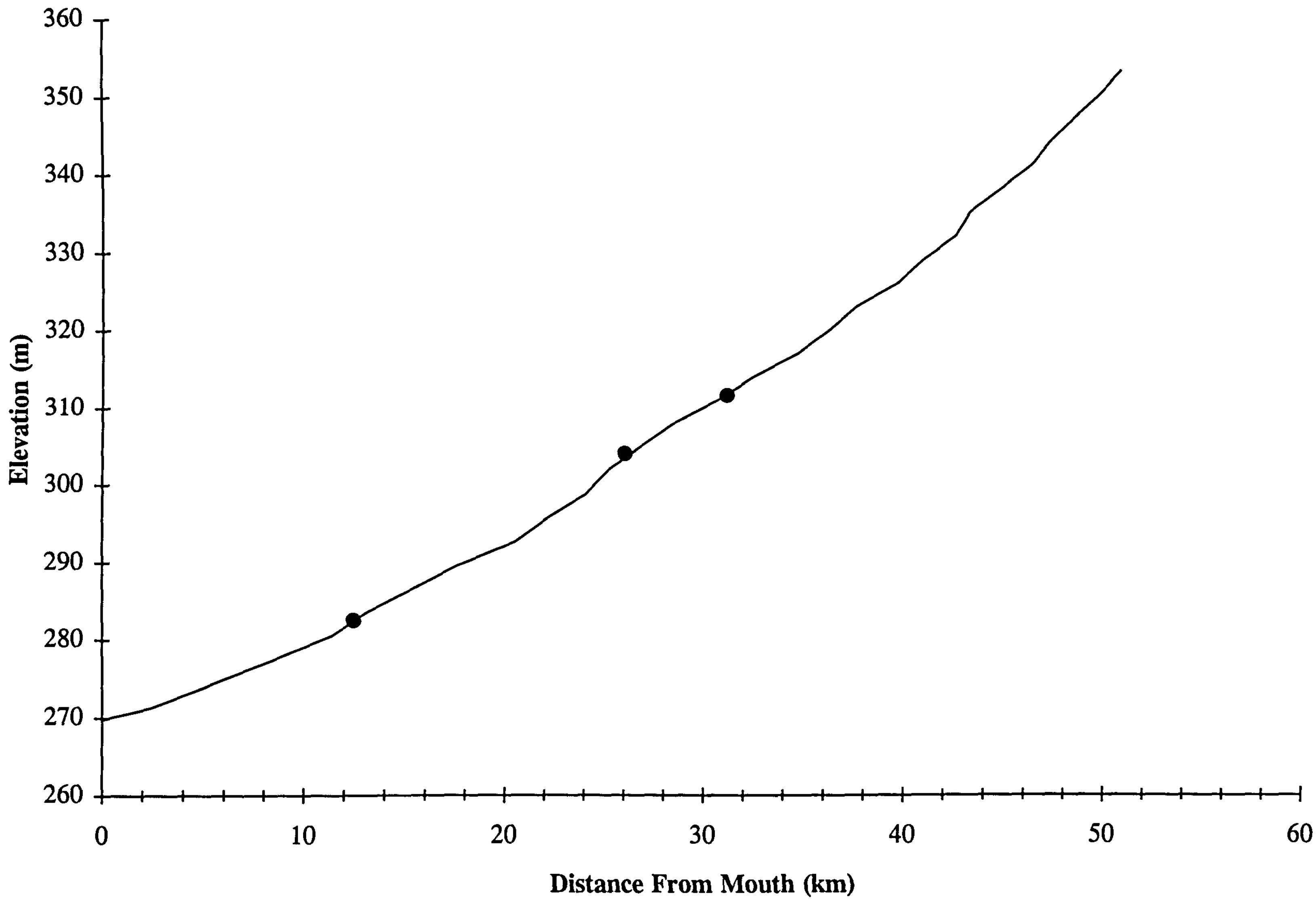

Figure C8. Profile and station locations of Minerva Creek.

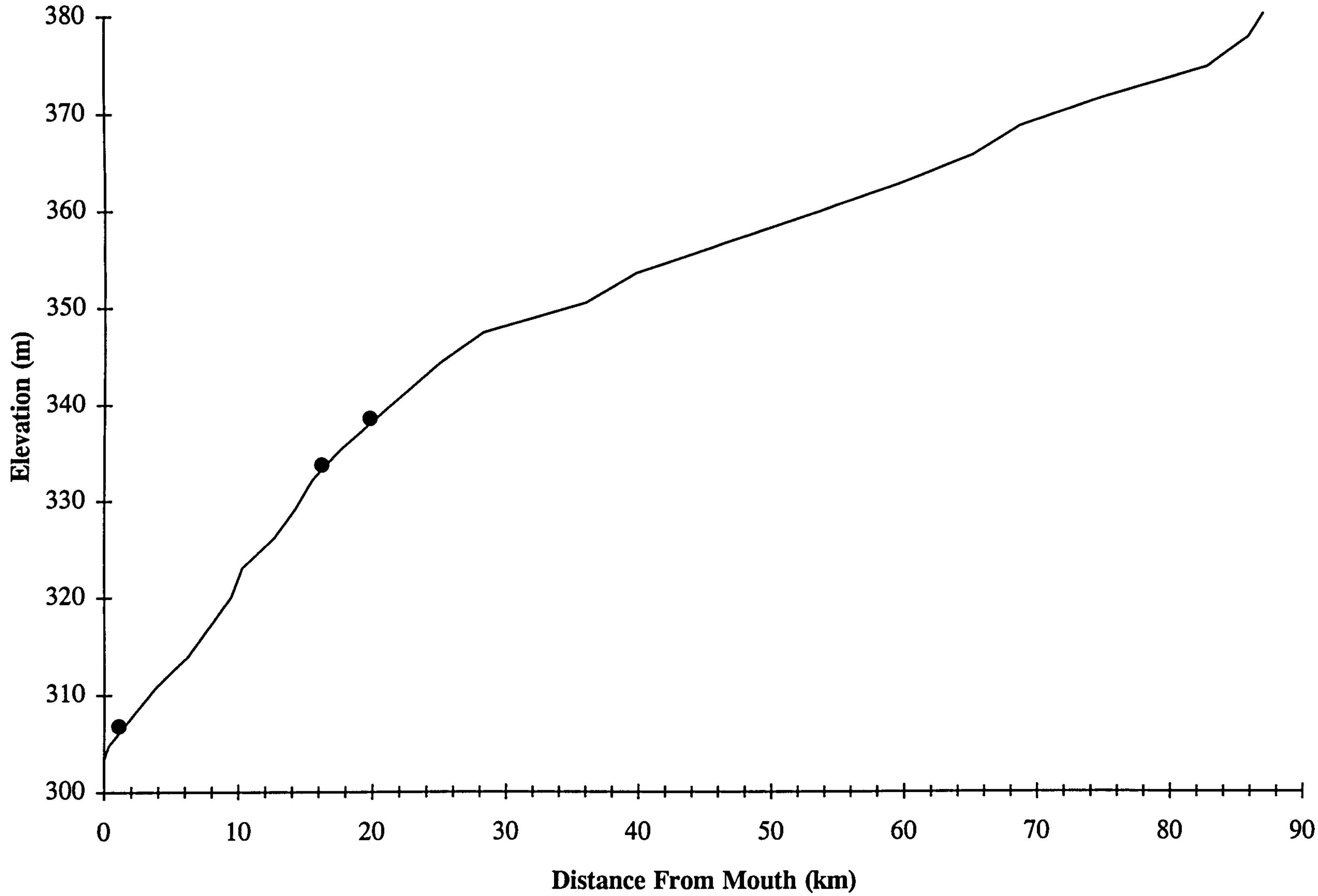

Figure C9. Profile and station locations of South Branch Lizard Creek.

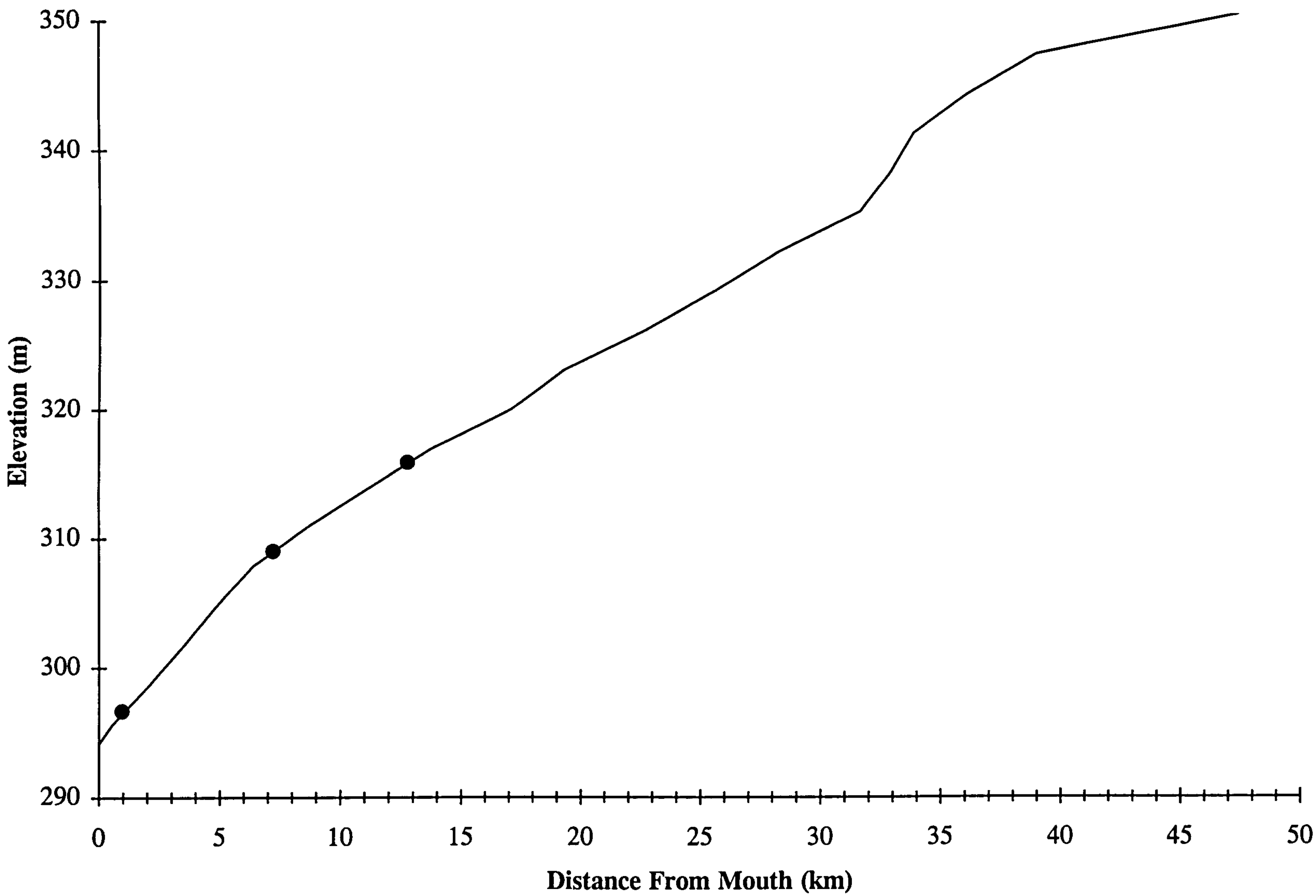

Figure C10. Profile and station locations of Tipton Creek.

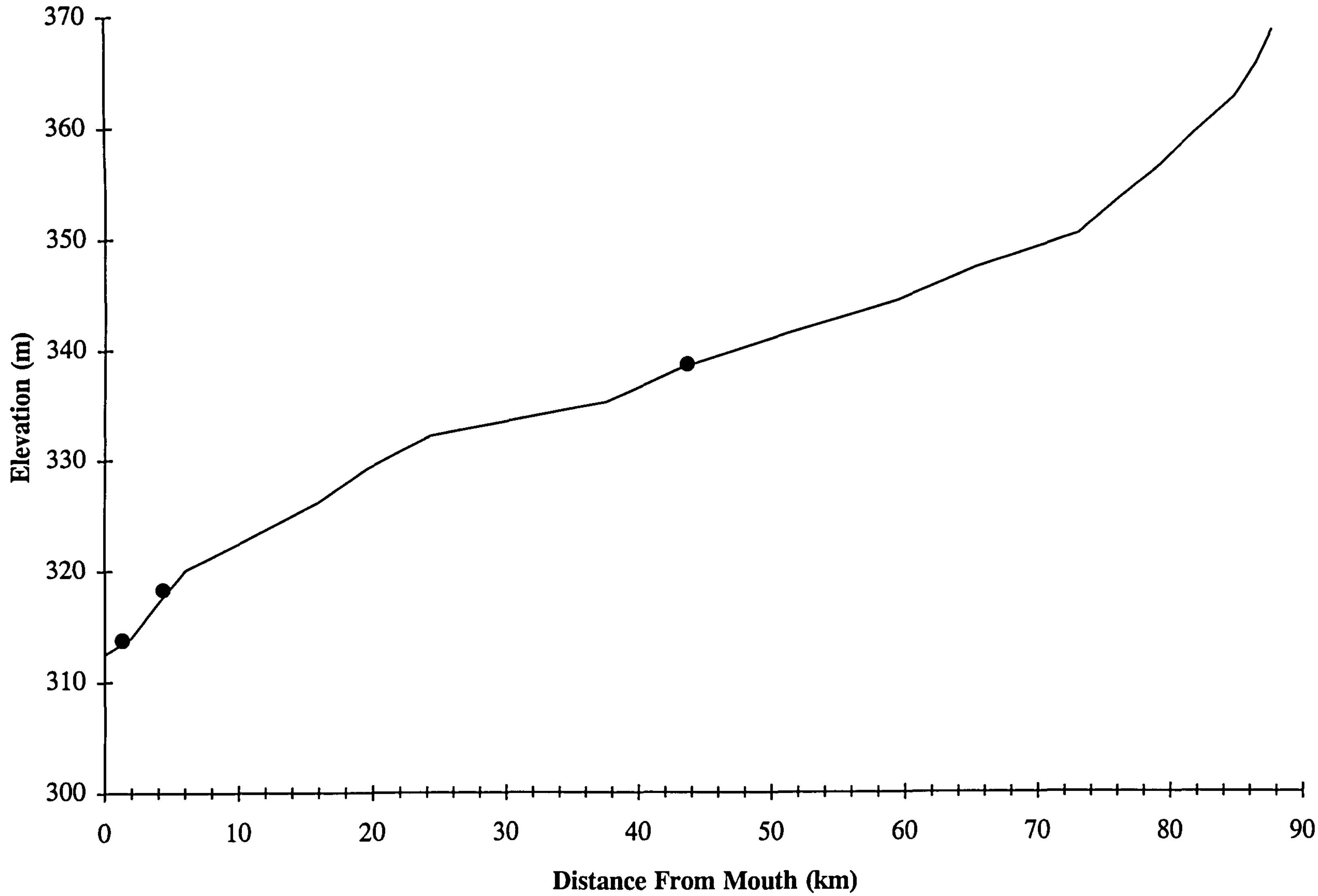

Figure C11. Profile and station locations of White Fox Creek.

APPENDIX D.

WATER QUALITY PARAMETERS

Table D1. Water chemistry parameters for Raccoon River watershed stations.

Cedar Creek			
	Station 1	Station 2	Station 3
Date	7/25/95	7/24/95	7/26/95
Time	14:05	11:25	11:35
Water Temperature (C^0)	26.7	24.9	25.1
Dissolved Oxygen (mg/L)	7.5	7.9	8.1
Conductivity (µmhos/cm)	745	714	780
Turbidity (NTU)	50	90	78
Lake Creek			
Date	8/1/95	8/1/95	8/2/95
Time	10:55	13:40	14:00
Water Temperature (C^0)	21.7	23.8	24.5
Dissolved Oxygen (mg/L)	11.9	12.3	10.6
Conductivity (µmhos/cm)	624	780	696
Turbidity (NTU)	15	29	92
Buttrick Creek			
Date	8/3/95	8/7/95	
Time	14:00	11:15	
Water Temperature (C^0)	27.9	24.2	
Dissolved Oxygen (mg/L)	11.2	8.8	
Conductivity (µmhos/cm)	665	605	
Turbidity (NTU)	14	17	

Table D2. Water chemistry parameters for Boone/Des Moines watershed stations.

South Branch Lizard Creek

	Station 1	Station 2	Station 3
Date	8/12/95	8/10/95	8/12/95
Time	10:12	14:15	13:22
Water Temperature (C^0)	26.0	29.1	29.1
Dissolved Oxygen (mg/L)	8.1	8.6	7.9
Conductivity (µmhos/cm)	609	562	642
Turbidity (NTU)	265	111	270

Brushy Creek

	Station 1	Station 2	Station 3
Date	8/27//95	8/15/95	8/14/95
Time	14:10	13:50	13:45
Water Temperature (C^0)	25.2	25	25.8
Dissolved Oxygen (mg/L)	10.6	10.1	8.3
Conductivity (µmhos/cm)	566	569	579
Turbidity (NTU)	140	131	29

White Fox Creek

	Station 1	Station 2	Station 3
Date	8/17/95	8/25/95	8/26/95
Time	13:40	14:05	10:07
Water Temperature (C^0)	26.7	28.9	22.6
Dissolved Oxygen (mg/L)	9.9	11.2	8.0
Conductivity (µmhos/cm)	614	573	633
Turbidity (NTU)	26	55	11

Eagle Creek

	Station 1	Station 2	Station 3
Date	10/22/95	10/21/95	10/20/95
Time	13:50	12:35	11:45
Water Temperature (C^0)	7.0	6.0	7.7
Dissolved Oxygen (mg/L)	16.6	16.5	-
Conductivity (µmhos/cm)	736	762	784
Turbidity (NTU)	10	10	82

- Indicates data not available due to equipment failure.

Table D3. Water chemistry parameters for Iowa River watershed stations.

Tipton Creek

	Station 1	Station 2	Station 3
Date	9/8/95	9/15/95	9/16/95
Time	16:30	09:05	17:36
Water Temperature (C^0)	23.1	17.4	22.1
Dissolved Oxygen (mg/L)	14.7	7.6	14.5
Conductivity (µmhos/cm)	401	462	513
Turbidity (NTU)	45	48	-

Honey Creek

	Station 1	Station 2	Station 3
Date	9/16/95	9/23/95	9/23/95
Time	17:00	12:55	14:00
Water Temperature (C^0)	22.8	11.8	14.5
Dissolved Oxygen (mg/L)	9.6	10.3	12.5
Conductivity (µmhos/cm)	603	600	617
Turbidity (NTU)	-	-	28

Minerva Creek

	Station 1	Station 2	Station 3
Date	10/7/95	10/6//95	10/5/95
Time	11:08	14:00	10:10
Water Temperature (C^0)	10.6	12.8	13.3
Dissolved Oxygen (mg/L)	7.1	6.1	6.2
Conductivity (µmhos/cm)	599	548	608
Turbidity (NTU)	8	50	-

Beaver Creek

	Station 1	Station 2	Station 3
Date	10/8/95	10/20/95	10/13/95
Time	10:15	09:15	11:51
Water Temperature (C^0)	9.1	10.2	17.7
Dissolved Oxygen (mg/L)	9.1	-	-
Conductivity (µmhos/cm)	506	543	666
Turbidity (NTU)	10	10	16

- Indicates data not available due to equipment failure.

APPENDIX E.

HABITAT DATA

Table E1. Habitat data for Beaver Creek stations.

Habitat Variable	Station 1	Station 2	Station 3	Mean
Gradient (m/km)	0.1	3.0	1.6	1.6
Drainage area (km^2)	133.1	115.2	62.1	103.5
Flow (m^3/s)	0.011	0.015	0.006	0.011
Mean width (m)	10.4	7.5	5.3	7.7
Mean depth (m)	0.28	0.23	0.15	0.22
Max. depth of runs & pools (m)	0.36	0.32	0.20	0.29
Run (%)	90	74	84	83
Riffle (%)	0	13	6	6
Pool (%)	10	13	10	11
Boulder (%)	1.2	0.0	1.8	1.0
Rubble/cobble (%)	1.8	5.5	7.2	4.8
Gravel (%)	8.1	22.5	24.5	18.4
Sand (%)	79.8	47.2	56.7	61.2
Silt (%)	2.9	9.5	6.0	6.1
Clay (%)	5.3	12.5	3.2	7.0
Detritus (%)	0.6	2.8	0.6	1.3
Pasture (%)	0.0	88.5	0.0	29.5
Bare soil (%)	6.5	11.5	6.7	8.2
Meadow (%)	69.6	0.0	79.2	49.6
Shrub (%)	18.1	0.0	4.6	7.6
Woodland (%)	5.8	0.0	9.2	5.0
Other (%)	0.0	0.0	1.3	0.4
Embeddedness (%)	39.0	47.2	39.5	41.9
Boulder cover (%)	0.0	0.0	0.0	0.0
Woody debris cover (%)	0.0	6.0	0.0	2.0
Bank erosion (%)	33.1	52.1	40.2	41.8
Buffer width w/in 10 m (%)	86.9	7.7	100.0	64.9
Shading (%)	4.7	3.4	46.5	18.2
Algae (%)	5.9	16.1	11.1	11.0
Macrophytes (%)	3.6	1.2	0.4	1.7

Table E2. Habitat data for Brushy Creek stations.

Habitat Variable	Station 1	Station 2	Station 3	Mean
Gradient (m/km)	0.3	2.1	0.7	1.0
Drainage area (km^2)	248.5	229.1	189.0	222.2
Flow (m^3/s)	0.462	0.447	0.476	0.462
Mean width (m)	10.5	6.6	10.3	9.1
Mean depth (m)	0.31	0.21	0.37	0.30
Max. depth of runs & pools (m)	0.43	0.29	0.48	0.40
Run (%)	75	86	79	80
Riffle (%)	5	3	7	5
Pool (%)	20	11	14	15
Boulder (%)	0.1	1.1	4.4	1.9
Rubble/cobble (%)	1.7	15.5	21.6	12.9
Gravel (%)	29.3	12.2	28.5	23.3
Sand (%)	52.1	60.2	30.9	47.7
Silt (%)	6.4	6.6	6.0	6.3
Clay (%)	7.0	2.8	7.6	5.8
Detritus (%)	3.5	1.6	1.9	2.3
Pasture (%)	0.0	0.0	0.0	0.0
Bare soil (%)	20.8	37.7	29.6	29.4
Meadow (%)	18.1	30.4	33.8	27.4
Shrub (%)	45.4	16.9	33.5	31.9
Woodland (%)	2.7	2.3	2.3	2.4
Other (%)	14.6	12.7	0.8	9.4
Embeddedness (%)	53.3	47.5	32.6	44.5
Boulder cover (%)	0.2	0.1	0.0	0.1
Woody debris cover (%)	14.5	0.0	10.5	8.3
Bank erosion (%)	38.7	45.0	42.3	42.0
Buffer width w/in 10 m (%)	100.0	100.0	100.0	100.0
Shading (%)	14.2	21.3	17.0	17.5
Algae (%)	1.2	0.0	0.0	0.4
Macrophytes (%)	0.0	0.3	0.0	0.1

Table E3. Habitat data for Buttrick Creek stations.

Habitat Variable	Station 1	Station 2	-	Mean
Gradient (m/km)	1.0	0.4		0.7
Drainage area (km^2)	543.7	551.5		547.6
Flow (m^3/s)	0.426	0.614		0.520
Mean width (m)	13.9	13.3		13.6
Mean depth (m)	0.29	0.27		0.28
Max. depth of runs & pools (m)	0.35	0.40		0.38
Run (%)	95	94		94.5
Riffle (%)	5	0		2.5
Pool (%)	0	6		3
Boulder (%)	1.7	0.2		1.0
Rubble/cobble (%)	10.4	0.5		5.5
Gravel (%)	17.8	10.0		13.9
Sand (%)	55.2	77.1		66.2
Silt (%)	11.9	10.8		11.4
Clay (%)	0.0	0.0		0.0
Detritus (%)	3.1	1.5		2.3
Pasture (%)	0.0	0.0		0.0
Bare soil (%)	16.9	39.2		28.1
Meadow (%)	75.0	23.1		49.1
Shrub (%)	4.6	13.8		9.2
Woodland (%)	3.5	4.6		4.1
Other (%)	0.0	19.2		9.6
Embeddedness (%)	31.2	34.0		32.6
Boulder cover (%)	0.0	0.0		0.0
Woody debris cover (%)	5.1	5.1		5.1
Bank erosion (%)	41.2	58.3		50.0
Buffer width w/in 10 m (%)	100.0	100.0		100.0
Shading (%)	10.8	44.0		27.4
Algae (%)	0.2	0.0		0.1
Macrophytes (%)	0.0	0.0		0.0

Table E4. Habitat data for Cedar Creek stations.

Habitat Variable	Station 1	Station 2	Station 3	Mean
Gradient (m/km)	1.5	2.1	0.3	1.3
Drainage area (km^2)	419.4	388.4	258.9	355.6
Flow (m^3/s)	0.680	0.904	0.543	0.709
Mean width (m)	12.4	16.9	10.9	13.4
Mean depth (m)	0.40	0.31	0.27	0.33
Max. depth of runs & pools (m)	0.52	0.44	0.35	0.44
Run (%)	65	43	97	68
Riffle (%)	9	36	0	15
Pool (%)	26	21	3	17
Boulder (%)	1.7	5.2	2.5	3.1
Rubble/cobble (%)	13.3	43.7	1.0	19.3
Gravel (%)	35.3	16.5	16.7	22.8
Sand (%)	40.1	30.8	63.6	44.8
Silt (%)	5.6	0.8	10.0	5.5
Clay (%)	1.2	0.0	5.8	2.3
Detritus (%)	2.8	3.1	0.4	2.1
Pasture (%)	0.0	0.0	66.9	22.3
Bare soil (%)	38.1	15.4	33.1	28.9
Meadow (%)	41.2	41.9	0.0	27.7
Shrub (%)	9.2	34.6	0.0	14.6
Woodland (%)	2.7	3.5	0.0	2.1
Other (%)	8.9	0.0	3.8	4.2
Embeddedness (%)	30.8	26.4	12.6	23.3
Boulder cover (%)	0.0	0.1	1.5	0.5
Woody debris cover (%)	0.6	0.1	0.1	0.3
Bank erosion (%)	37.9	32.3	52.5	40.9
Buffer width w/in 10 m (%)	98.5	73.1	0.0	57.2
Shading (%)	16.2	6.5	0.0	7.6
Algae (%)	0.6	3.9	0.0	1.5
Macrophytes (%)	0.0	0.0	0.0	0.0

Table E5. Habitat data for Eagle Creek stations.

Habitat Variable	Station 1	Station 2	Station 3	Mean
Gradient (m/km)	0.9	0.45	0.75	0.7
Drainage area (km^2)	271.9	251.7	238.2	253.9
Flow (m^3/s)	0.664	0.745	0.700	0.703
Mean width (m)	13.2	11.6	11.3	12.0
Mean depth (m)	0.38	0.36	0.41	0.38
Max. depth of runs & pools (m)	0.55	0.48	0.57	0.53
Run (%)	72	92	67	77
Riffle (%)	7	0	13	7
Pool (%)	21	8	20	16
Boulder (%)	1.3	2.0	0.9	1.4
Rubble/cobble (%)	4.9	0.6	6.6	4.0
Gravel (%)	28.4	19.3	37.6	28.4
Sand (%)	62.6	70.4	41.6	58.2
Silt (%)	0.2	3.1	5.4	2.9
Clay (%)	0.0	5.0	6.7	3.9
Detritus (%)	2.6	1.4	1.2	1.7
Pasture (%)	0.0	0.0	50.0	16.7
Bare soil (%)	40.8	3.8	6.5	17.0
Meadow (%)	2.7	81.5	24.2	36.1
Shrub (%)	16.2	1.5	11.5	9.7
Woodland (%)	35.8	8.5	7.7	17.3
Other (%)	7.6	1.5	0.0	3.0
Embeddedness (%)	38.6	25.5	25.1	29.7
Boulder cover (%)	0.0	0.0	0.0	0.0
Woody debris cover (%)	15.0	0.8	18.3	11.4
Bank erosion (%)	89.0	50.0	68.7	69.2
Buffer width w/in 10 m (%)	99.2	100.0	65.4	88.2
Shading (%)	55.9	22.3	37.2	38.5
Algae (%)	3.5	16.6	4.5	8.2
Macrophytes (%)	0.0	0.0	0.0	0.0

Table E6. Habitat data for Honey Creek stations.

Habitat Variable	Station 1	Station 2	Station 3	Mean
Gradient (m/km)	1.2	0.2	2.6	1.3
Drainage area (km^2)	228.6	194.2	173.5	198.8
Flow (m^3/s)	0.135	0.091	0.057	0.094
Mean width (m)	10.3	8.8	6.0	8.4
Mean depth (m)	0.19	0.16	0.17	0.17
Max. depth of runs & pools (m)	0.27	0.23	0.24	0.25
Run (%)	88	91	79	86
Riffle (%)	5	3	3	4
Pool (%)	7	6	18	10
Boulder (%)	1.8	0.0	3.9	1.9
Rubble/cobble (%)	11.0	0.4	4.6	5.3
Gravel (%)	11.4	11.8	17.8	13.7
Sand (%)	59.8	71.6	53.8	61.7
Silt (%)	9.2	12.5	11.8	11.2
Clay (%)	2.3	0.5	4.5	2.4
Detritus (%)	5.2	3.1	2.7	3.7
Pasture (%)	0.0	0.0	0.0	0.0
Bare soil (%)	0.0	0.0	1.5	0.5
Meadow (%)	75.8	84.6	83.1	81.2
Shrub (%)	18.1	9.2	11.9	13.1
Woodland (%)	6.2	6.2	3.5	5.3
Other (%)	0.0	0.0	0.0	0.0
Embeddedness (%)	41.0	49.7	34.6	41.8
Boulder cover (%)	0.0	0.0	0.0	0.0
Woody debris cover (%)	0.0	8.9	0.0	3.0
Bank erosion (%)	29.0	28.8	34.2	30.7
Buffer width w/in 10 m (%)	97.7	100.0	100.0	99.2
Shading (%)	22.4	7.3	29.4	19.7
Algae (%)	9.1	3.2	2.8	5.0
Macrophytes (%)	0.0	0.0	0.1	0.03

Table E7. Habitat data for Lake Creek stations.

Habitat Variable	Station 1	Station 2	Station 3	Mean
Gradient (m/km)	1.9	0.2	0.8	2.9
Drainage area (km^2)	334.0	327.5	321.0	327.5
Flow (m^3/s)	0.427	0.351	0.440	0.406
Mean width (m)	12.3	13.1	12.7	12.7
Mean depth (m)	0.38	0.46	0.30	0.38
Max. depth of runs & pools (m)	0.56	0.60	0.41	0.52
Run (%)	65	100	97	88
Riffle (%)	10	0	3	4
Pool (%)	25	0	0	8
Boulder (%)	5.5	0.0	0.0	1.8
Rubble/cobble (%)	23.0	4.9	11.4	13.1
Gravel (%)	12.8	22.3	28.0	21.0
Sand (%)	39.8	27.1	37.3	34.7
Silt (%)	10.4	36.4	21.5	22.8
Clay (%)	0.2	1.9	0.0	0.7
Detritus (%)	1.3	5.2	1.9	2.8
Pasture (%)	0.0	76.7	73.5	50.1
Bare soil (%)	3.8	13.3	40.0	19.0
Meadow (%)	75.4	0.0	13.8	29.7
Shrub (%)	11.5	0.0	9.2	6.9
Woodland (%)	1.5	7.5	0.8	3.3
Other (%)	0.4	0.0	0.0	0.1
Embeddedness (%)	32.0	50.6	27.8	36.8
Boulder cover (%)	0.5	0.0	1.4	0.6
Woody debris cover (%)	4.0	5.3	3.5	4.3
Bank erosion (%)	10.4	39.6	40.0	30.0
Buffer width w/in 10 m (%)	100.0	0.0	11.5	37.2
Shading (%)	7.1	31.0	17.6	18.6
Algae (%)	2.5	0.0	0.0	0.8
Macrophytes (%)	0.0	0.0	0.0	0.0

Table E8. Habitat data for Minerva Creek stations.

Habitat Variable	Station 1	Station 2	Station 3	Mean
Gradient (m/km)	0.15	2.4	1.0	1.2
Drainage area (km^2)	180.2	83.9	77.9	114.0
Flow (m^3/s)	0.029	0.004	0.002	0.012
Mean width (m)	10.8	6.1	5.6	7.5
Mean depth (m)	0.34	0.20	0.24	0.26
Max. depth of runs & pools (m)	0.48	0.35	0.32	0.38
Run (%)	92	65	75	77
Riffle (%)	0	10	5	5
Pool (%)	8	25	20	18
Boulder (%)	1.8	3.2	1.4	2.1
Rubble/cobble (%)	2.3	20.3	8.8	10.5
Gravel (%)	3.1	10.5	39.9	17.8
Sand (%)	77.5	58.5	29.2	55.1
Silt (%)	4.9	2.2	11.2	6.1
Clay (%)	2.4	3.4	4.6	3.5
Detritus (%)	7.9	1.2	1.7	3.6
Pasture (%)	0.0	0.0	0.0	0.0
Bare soil (%)	7.7	6.2	12.7	8.9
Meadow (%)	41.9	79.6	66.2	62.6
Shrub (%)	38.8	3.5	11.5	17.9
Woodland (%)	10.0	6.9	9.6	8.8
Other (%)	1.5	0.0	0.0	0.5
Embeddedness (%)	50.4	40.0	52.9	47.8
Boulder cover (%)	0.0	0.3	0.4	0.2
Woody debris cover (%)	17.2	0.0	0.0	5.7
Bank erosion (%)	47.3	27.3	39.0	37.9
Buffer width w/in 10 m (%)	100.0	100.0	96.2	98.7
Shading (%)	37.8	41.0	36.1	38.3
Algae (%)	2.5	0.0	0.0	0.8
Macrophytes (%)	0.3	0.0	0.0	0.1

Table E9. Habitat data for South Branch Lizard Creek stations.

Habitat Variable	Station 1	Station 2	Station 3	Mean
Gradient (m/km)	1.9	0.2	0.5	0.9
Drainage area (km^2)	388.4	295.2	290.0	324.5
Flow (m^3/s)	2.747	0.554	1.847	1.716
Mean width (m)	15.5	11.8	13.0	13.4
Mean depth (m)	0.54	0.31	0.56	0.47
Max. depth of runs & pools (m)	0.83	0.43	0.72	0.66
Run (%)	80	100	76	85
Riffle (%)	12	0	0	4
Pool (%)	8	0	24	11
Boulder (%)	9.3	2.8	1.4	4.5
Rubble/cobble (%)	28.0	3.7	6.1	12.6
Gravel (%)	26.3	37.8	37.2	33.8
Sand (%)	31.8	45.5	41.8	39.7
Silt (%)	4.3	4.8	5.2	4.8
Clay (%)	0.0	2.3	5.8	4.1
Detritus (%)	0.3	1.5	2.1	1.3
Pasture (%)	0.0	0.0	30.0	10.0
Bare soil (%)	13.8	14.6	25.4	17.9
Meadow (%)	27.7	11.5	5.4	14.9
Shrub (%)	42.3	68.1	37.7	49.4
Woodland (%)	16.2	0.8	0.0	5.7
Other (%)	0.0	4.6	1.5	2.0
Embeddedness (%)	23.2	27.2	26.1	25.5
Boulder cover (%)	0.8	0.3	0.0	0.4
Woody debris cover (%)	4.2	1.9	18.5	8.2
Bank erosion (%)	26.5	43.1	57.7	42.4
Buffer width w/in 10 m (%)	94.6	100.0	67.1	87.2
Shading (%)	16.2	6.9	21.4	14.8
Algae (%)	0.0	1.4	0.0	0.5
Macrophytes (%)	0.0	0.0	0.0	0.0

Table E10. Habitat data for Tipton Creek stations.

Habitat Variable	Station 1	Station 2	Station 3	Mean
Gradient (m/km)	2.1	0.4	1.3	1.3
Drainage area (km^2)	209.7	196.8	181.2	195.9
Flow (m^3/s)	0.028	0.007	0.010	0.015
Mean width (m)	7.7	8.2	7.9	7.9
Mean depth (m)	0.32	0.20	0.75	0.42
Max. depth of runs & pools (m)	0.46	0.29	0.33	0.36
Run (%)	62	67	81	70
Riffle (%)	15	13	6	11
Pool (%)	23	20	13	19
Boulder (%)	0.6	1.8	0.2	0.9
Rubble/cobble (%)	2.8	21.2	6.1	10.0
Gravel (%)	31.7	14.6	14.5	20.3
Sand (%)	48.2	52.0	59.8	53.3
Silt (%)	8.8	7.3	9.6	8.6
Clay (%)	3.4	0.9	3.1	2.5
Detritus (%)	4.5	2.2	6.5	4.4
Pasture (%)	78.5	0.0	95.8	58.1
Bare soil (%)	3.1	0.0	0.0	1.0
Meadow (%)	0.0	93.5	0.0	31.2
Shrub (%)	3.8	3.1	0.0	2.3
Woodland (%)	3.1	3.5	4.2	3.6
Other (%)	11.5	0.0	0.0	3.8
Embeddedness (%)	51.7	56.3	44.7	50.9
Boulder cover (%)	0.2	0.4	0.0	0.2
Woody debris cover (%)	10.5	0.0	6.2	5.6
Bank erosion (%)	49.2	23.8	59.6	44.2
Buffer width w/in 10 m (%)	5.8	100.0	0.0	35.3
Shading (%)	25.8	4.7	33.5	21.3
Algae (%)	0.0	0.0	0.0	0.0
Macrophytes (%)	0.0	0.0	0.0	0.0

Table E11. Habitat data for White Fox Creek stations.

Habitat Variable	Station 1	Station 2	Station 3	Mean
Gradient (m/km)	3.7	0.9	0.1	1.6
Drainage area (km^2)	287.4	233.0	197.5	239.3
Flow (m^3/s)	0.212	0.109	0.012	0.111
Mean width (m)	14.1	7.9	7.7	9.9
Mean depth (m)	0.31	0.33	0.29	0.31
Max. depth of runs & pools (m)	0.44	0.36	0.40	0.40
Run (%)	78	86	95	86
Riffle (%)	15	6	0	7
Pool (%)	7	8	5	7
Boulder (%)	9.5	0.0	0.0	3.2
Rubble/cobble (%)	26.9	5.5	1.7	11.4
Gravel (%)	27.4	25.3	14.0	22.2
Sand (%)	30.5	58.9	41.9	43.8
Silt (%)	3.7	7.2	18.0	9.6
Clay (%)	0.0	1.4	1.8	1.1
Detritus (%)	0.2	1.6	22.8	8.2
Pasture (%)	0.0	0.0	0.0	0.0
Bare soil (%)	14.6	25.8	41.9	27.4
Meadow (%)	13.1	32.3	48.8	31.4
Shrub (%)	40.8	30.0	2.7	24.5
Woodland (%)	9.2	4.6	1.9	5.2
Other (%)	21.5	9.6	0.0	10.4
Embeddedness (%)	37.4	39.7	58.0	45.0
Boulder cover (%)	0.0	0.5	0.0	0.17
Woody debris cover (%)	0.0	4.6	0.7	1.8
Bank erosion (%)	18.5	49.4	61.3	43.1
Buffer width w/in 10 m (%)	93.8	97.7	88.1	93.2
Shading (%)	25.3	36.9	32.8	31.7
Algae (%)	2.3	0.3	0.0	0.9
Macrophytes (%)	0.0	0.0	0.0	0.0

APPENDIX F.

FISH DATA

Table F1. Fish abundance and biomass (grams) collected from Beaver Creek stations.

Species	Station 1		Station 2		Station 3		Totals	
	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
Central stoneroller	56	619	85	1043	53	742	194	2404
Largescale stoneroller			6	90	2	50	8	140
Brassy minnow			1	7			1	7
Hornyhead chub	1	4	8	130			9	134
Common shiner	3	12	166	1618	94	558	263	2188
Bigmouth shiner	439	759	655	1349	296	537	1390	2645
Sand shiner	3	4	24	41			27	45
Suckermouth minnow			8	81			8	81
Bluntnose minnow	49	118	192	658	53	175	294	951
Fathead minnow	4	16	7	22			11	38
Blacknose dace	53	161	226	774	271	649	550	1584
Creek chub	93	922	182	2180	206	3639	481	6741
White sucker	1	18	150	5464	103	2949	254	8431
Brook stickleback	2	2			1	1	3	3
Smallmouth bass	5	35	34	149			39	184
Fantail darter	13	15	113	188			126	203
Johnny darter	139	275	181	348	255	269	575	892
Blackside darter			2	18	1	8	3	26
Species	14		17		11		18	
Totals	861	2960	2040	14160	1335	9577	4236	26697

Table F2. Fish abundance and biomass (grams) collected from Brushy Creek stations.

	Station 1		Station 2		Station 3		Totals	
Species	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
Central stoneroller	14	181	78	576	8	57	100	814
Common carp	1	24					1	24
Hornyhead chub	19	60	60	172	57	305	136	537
Emerald shiner			2	7			2	7
Common shiner	37	285	21	92	29	146	87	523
Bigmouth shiner	101	129	367	507	26	41	494	677
Rosyface shiner	21	32	19	28	10	15	50	75
Spotfin shiner	28	45	34	52	2	4	64	101
Sand shiner	78	95	288	291	32	36	398	422
Suckermouth minnow	7	30	18	113	3	17	28	160
Bluntnose minnow	225	386	723	1234	153	312	1101	1932
Fathead minnow			3	8			3	8
Blacknose dace	5	7	24	37	4	7	33	51
Creek chub	72	330	110	656	106	693	288	1679
River carpsucker	1	510					1	510
White sucker	16	302	20	371	8	546	44	1219
Northern hog sucker	11	502	14	581			25	1083
Golden redhorse	7	1640	2	360	1	580	10	2580
Shorthead redhorse			1	49			1	49
Channel catfish	1	380	1	580			2	960
Slender madtom			4	27			4	27
Stonecat			2	19	3	33	5	52
Rock bass	8	56	9	95	10	76	27	227
Green sunfish	3	18	2	14			5	32
Bluegill	3	27					3	27

Table F2. (continued)

Species	Station 1		Station 2		Station 3		Totals	
	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
Johnny darter	19	28	5	6	24	34		
Blackside darter	2	9	2	11	4	20		
Smallmouth bass	14	28	5	14	15	29	34	71
Largemouth bass	2	88					2	88
Fantail darter	18	21	33	48	41	47	92	116
Johnny darter	7	11	9	15	5	6	21	32
Yellow perch	1	3					1	3
Blackside darter	1	4			2	2	3	6
Species	26		25		19		31	
Totals	701	5194	1849	5946	515	2952	3065	14092

Table F3. Fish abundance and biomass (grams) collected from Buttrick Creek stations.

	Station 1		Station 2		Totals	
Species	Number	Biomass	Number	Biomass	Number	Biomass
Central stoneroller	12	136	1	13	13	149
Common carp			7	10230	7	10230
Brassy minnow	1	7	1	6	2	13
Common shiner			1	10	1	10
Bigmouth shiner	53	68	115	184	168	252
Spotfin shiner	47	71	60	105	107	176
Sand shiner	76	73	24	36	100	109
Suckermouth minnow	1	4			1	4
Bluntnose minnow	163	290	14	16	177	306
Creek chub	28	418	32	269	60	687
White sucker	1	18			1	18
Northern hog sucker	8	342	2	32	10	374
Golden redhorse	6	566	2	194	8	760
Shorthead redhorse	2	200			2	200
Yellow bullhead	2	15			2	15
Channel catfish	6	602	2	159	8	761
Slender madtom	1	6	1	3	2	9
Stonecat	10	165	4	26	14	191
Green sunfish	20	283	2	13	22	296
Orangespotted sunfish	1	3			1	3
Bluegill			1	10	1	10
Smallmouth bass			1	65	1	65
Largemouth bass	1	5			1	5
Fantail darter	5	11			5	11
Johnny darter	19	28	5	6	24	34

Table F3. (continued)

Species	Station 1		Station 2		Totals	
	Number	Biomass	Number	Biomass	Number	Biomass
Blackside darter	2	9	2	11	4	20
Slenderhead darter	1	3			1	3
Species	23		19		27	
Totals	466	3323	277	11388	743	14711

Table F4. Fish abundance and biomass (grams) collected from Cedar Creek stations.

	Station 1		Station 2		Station 3		Totals	
Species	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
Central stoneroller	2	10	27	182	1	4	30	196
Common carp	3	4590	4	4790	2	3340	9	12720
Brassy minnow					7	23	7	23
Common shiner			3	20			3	20
Bigmouth shiner	16	32	9	16	25	40	50	88
Spotfin shiner	62	94	51	90	17	28	130	212
Sand shiner	48	62	102	177	46	30	196	269
Topeka shiner			1	3			1	3
Suckermouth minnow	5	30	17	114			22	144
Bluntnose minnow	84	179	69	151	84	84	237	414
Fathead minnow					54	44	54	44
Blacknose dace			2	5			2	5
Creek chub	14	71	17	157	8	78	39	306
River carpsucker	1	222	2	810			3	1032
Quillback			1	36			1	36
White sucker			1	37			1	37
Northern hog sucker	5	415	10	1344			15	1759
Shorthead redhorse	2	210	6	478	1	35	9	723
Yellow bullhead					1	5	1	5
Channel catfish	1	6	13	3280	10	4555	24	7841
Slender madtom	5	30	5	13			10	43
Stonecat	5	39	33	414	1	8	39	461
Flathead catfish	1	410			1	2200	2	2610
Green sunfish	4	69	10	132	3	43	17	244
Orangespotted sunfish	1	4					1	4

Table F4. (continued)

Species	Station 1		Station 2		Station 3		Totals	
	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
Bluegill	1	3					1	3
Largemouth bass	2	3					2	3
Fantail darter	2	3					2	3
Johnny darter			1	4			1	4
Blackside darter	4	12	3	14	1	4	8	30
Slenderhead darter			4	13			4	13
Species	21		23		16		31	
Totals	268	6494	391	12280	262	10521	921	29295

Table F5. Fish abundance and biomass (grams) collected from Eagle Creek stations.

	Station 1		Station 2		Station 3		Totals	
Species	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
Central stoneroller	4	58	4	45	1	12	9	115
Brassy minnow	13	53					13	53
Hornyhead chub	30	139	27	196	6	54	63	389
Common shiner	62	505	46	744	68	738	176	1987
Bigmouth shiner	146	317	100	308	20	44	266	669
Rosyface shiner	18	36	1	2	3	7	22	45
Spotfin shiner	31	79	9	26	21	57	61	162
Sand shiner	148	243	79	143	39	69	266	455
Suckermouth minnow	4	26			3	31	7	57
Bluntnose minnow	55	144	57	210	37	132	149	486
Fathead minnow	1	2			2	5	3	7
Blacknose dace	3	8	16	40	21	81	40	129
Creek chub	65	558	75	1339	47	593	187	2490
White sucker	7	315	41	1272	22	855	70	2442
Northern hog sucker	7	1413	3	26	4	337	14	1776
Golden redhorse	1	85			2	708	3	793
Shorthead redhorse			1	250			1	250
Yellow bullhead					1	100	1	100
Channel catfish	3	7	2	4			5	11
Stonecat	2	27	8	131	1	3	11	161
Flathead catfish					2	5	2	5
Rock bass					1	13	1	13
Green sunfish	3	36	15	216	11	129	29	381
Orangespotted sunfish					3	21	3	21
Bluegill					1	21	1	21

Table F5. (continued)

	Station 1		Station 2		Station 3		Totals	
Species	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
Smallmouth bass			5	34	3	18	8	42
Largemouth bass	1	44			1	8	2	52
Johnny darter	24	50	119	291	10	22	153	363
Blackside darter	9	47	13	61	11	65	33	173
Species	22		19		25		31	
Totals	606	4113	621	5338	341	4128	1568	13569

Table F6. Fish abundance and biomass (grams) collected from Honey Creek stations.

	Station 1		Station 2		Station 3		Totals	
Species	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
Am. brook lamprey	3	8					3	8
Central stoneroller	101	943	46	398	76	748	223	2089
Largescale stoneroller	1	17	2	32	1	150	4	199
Brassy minnow	2	16					2	16
Hornyhead chub					1	46	1	46
Common shiner	86	710	172	519	122	1043	380	2272
Bigmouth shiner	645	1519	404	1044	498	995	1547	3558
Spotfin shiner	3	12			8	26	11	38
Sand shiner	38	73	100	122	14	29	152	224
Suckermouth minnow	41	281	1	6	31	258	73	545
Bluntnose minnow	361	828	192	489	114	321	667	1638
Fathead minnow	7	14	9	30	3	11	19	55
Blacknose dace	83	264	112	277	167	542	362	1083
Creek chub	273	1760	246	1785	232	1871	751	5416
River carpsucker	10	2296					10	2296
Quillback	2	39	2	42	1	18	5	99
White sucker	87	4187	60	1496	89	2445	236	8128
Northern hog sucker	7	250			27	1294	34	1544
Golden redhorse	4	450			3	557	7	1007
Yellow bullhead					1	8	1	8
Channel catfish	6	275	2	4	2	5	10	284
Stonecat	2	63			16	41	18	104
Green sunfish	1	16			2	28	3	44
Smallmouth bass	2	109			1	5	3	114
Johnny darter	33	57	102	235	69	171	204	463

Table F6. (continued)

Species	Station 1		Station 2		Station 3		Totals	
	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
Blackside darter			1	8	2	24	3	32
Species	23		15		23		26	
Totals	1798	14187	1451	6487	1480	10636	4729	31310

Table F7. Fish abundance and biomass (grams) collected from Lake Creek stations.

Species	Station 1		Station 2		Station 3		Totals	
	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
Gizzard shad	2	130	7	450			9	580
Central stoneroller			1	3			1	3
Common carp	3	4170	4	5470	5	4590	12	14230
Common shiner	1	4			9	104	10	108
Bigmouth shiner	37	64	21	20	103	144	161	228
Spotfin shiner	87	138	26	40	47	101	160	279
Sand shiner	53	60	53	36	76	112	182	208
Topeka shiner	2	2					2	2
Suckermouth minnow	1	10	1	5	14	96	16	111
Bluntnose minnow	118	176	172	224	94	204	384	604
Fathead minnow	5	7	17	17	8	12	30	36
Creek chub	19	162	7	52	17	164	43	378
Quillback	2	80					2	80
White sucker	2	39	4	48	10	246	16	333
Northern hog sucker	3	660	2	430	4	575	9	1665
Shorthead redhorse	1	18	1	5	1	12	3	35
Channel catfish	5	2380	2	1865	4	1620	11	5865
Slender madtom	1	14					1	14
Stonecat	10	112	1	5	12	163	23	280
Green sunfish	5	91	6	82	2	57	13	230
Largemouth bass	2	2	5	11	1	2	8	15
Fantail darter	3	4					3	4
Johnny darter			2	3	2	4	4	7
Blackside darter	1	7			5	30	6	37
Slenderhead darter	2	5	2	5			4	10

Table F7. (continued)

Species	Station 1		Station 2		Station 3		Totals	
	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
Species	24		20		19		25	
Totals	369	8585	335	8820	416	8424	1120	25829

Table F8. Fish abundance and biomass (grams) collected from Minerva Creek stations.

	Station 1		Station 2		Station 3		Totals	
Species	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
Am. brook lamprey	1	12					1	12
Central stoneroller	45	372	332	2490	193	1946	570	4808
Largescale stoneroller			5	80			5	80
Brassy minnow	7	23					7	23
Hornyhead chub	5	59	11	102			16	131
Common shiner	56	274	164	1210	278	1587	498	3071
Bigmouth shiner	433	830	306	543	547	898	1286	2271
Spotfin shiner	6	19					6	19
Sand shiner	28	42	11	26	4	8	43	76
Suckermouth minnow	1	5	4	28	4	26	9	59
Bluntnose minnow	31	60	155	397	508	1375	694	1832
Fathead minnow					15	38	15	38
Blacknose dace	89	265	372	1116	651	1542	1112	2923
Creek chub	107	899	288	3093	438	4007	833	7999
White sucker	1	30	78	5196	65	3915	144	9141
Northern hog sucker			2	838			2	838
Yellow bullhead					3	9	3	9
Stonecat	1	4					1	4
Green sunfish	2	5			1	37	3	42
Bluegill					1	14	1	14
Smallmouth bass	7	589	13	374			20	963
Largemouth bass	4	47					4	47
Fantail darter			16	23	1	3	17	26
Johnny darter	97	190	38	53	53	66	188	309
Blackside darter	8	60					8	60

Table F8. (continued)

Species	Station 1		Station 2		Station 3		Totals	
	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
Slenderhead darter	1	5					1	5
Species	20		15		15		26	
Totals	930	3760	1795	15569	2762	15471	5487	34800

Table F9. Fish abundance and biomass (grams) collected from South Branch Lizard Creek stations.

Species	Station 1 Number	Station 1 Biomass	Station 2 Number	Station 2 Biomass	Station 3 Number	Station 3 Biomass	Totals Number	Totals Biomass
Northern pike	1	90					1	90
Central stoneroller	10	113					10	113
Common carp	5	5500					5	5500
Hornyhead chub	17	142	9	28	5	20	31	190
Common shiner	9	45	9	59	24	198	42	302
Bigmouth shiner	2	4	87	131	30	54	119	189
Rosyface shiner	6	10	3	5			9	15
Spotfin shiner	34	66	65	94	33	42	132	202
Sand shiner	138	136	454	346	96	106	688	588
Suckermouth minnow			2	10	8	36	10	46
Bluntnose minnow	188	294	339	538	103	189	630	1021
Fathead minnow			1	1	2	3	3	4
Blacknose dace	6	12					6	12
Creek chub	25	163	7	63	19	177	51	403
River carpsucker	1	330					1	330
White sucker	2	92			6	378	8	470
Northern hog sucker	11	1392	3	245	8	295	22	1932
Golden redhorse	6	830	16	3229	7	898	29	4957
Shorthead redhorse	2	228	4	545	2	69	8	842
Channel catfish	1	1					1	1
Slender madtom	11	48	2	6	1	5	14	59
Green sunfish	10	83	9	158	2	12	21	253
Orangespotted sunfish	5	20					5	20
Bluegill	1	7					1	7
Smallmouth bass	3	85	14	389	1	760	18	1234

Table F9. (continued)

Species	Station 1		Station 2		Station 3		Totals	
	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
Largemouth bass	3	13					3	13
Fantail darter	14	29			4	8	18	37
Johnny darter	4	6	1	1	8	16	13	23
Banded darter	37	30	2	2	6	5	45	37
Yellow perch	1	3					1	3
Blackside darter	1	3	1	4			2	7
Species	30		20		20		31	
Totals	568	10038	1031	5913	371	3342	1970	19293

Table F10. Fish abundance and biomass (grams) collected from Tipton Creek stations.

Species	Station 1 Number	Station 1 Biomass	Station 2 Number	Station 2 Biomass	Station 3 Number	Station 3 Biomass	Totals Number	Totals Biomass
Central stoneroller	54	575	22	271	27	184	103	1030
Largescale stoneroller	49	441	8	113	8	54	65	608
Brassy minnow	8	33	12	65			20	98
Hornyhead chub	43	248	78	524	55	195	176	967
Common shiner	151	799	435	1957	419	2612	1005	5368
Bigmouth shiner	148	335	343	726	240	437	731	1498
Spotfin shiner	74	175	5	13			79	188
Sand shiner	218	307	152	226	21	31	391	564
Suckermouth minnow	18	127	60	437	6	29	84	593
Bluntnose minnow	306	729	728	1988	376	1163	1410	3880
Fathead minnow	1	3	5	18	4	13	10	34
Blacknose dace	21	54	196	541	113	305	330	900
Creek chub	85	643	183	1402	165	1222	433	3267
River carpsucker	23	6870	8	3500	1	320	32	10690
Quillback	1	388			1	15	2	403
White sucker	1	7	53	3550	139	7892	193	11449
Northern hog sucker	15	1238	11	2707	3	788	29	4733
Golden redhorse	14	2251	16	2018	33	5445	63	9714
Shorthead redhorse	1	25	9	856	2	73	12	954
Yellow bullhead					2	8	2	8
Channel catfish	8	5155			1	215	9	5370
Stonecat	11	92	9	97	2	13	22	202
Flathead catfish	1	5					1	5
Green sunfish			2	56	2	29	4	85
Orangespotted sunfish	1	3			1	11	2	14

Table F10. (continued)

Species	Station 1 Number	Station 1 Biomass	Station 2 Number	Station 2 Biomass	Station 3 Number	Station 3 Biomass	Totals Number	Totals Biomass
Bluegill	1	52					1	52
Smallmouth bass	7	1345	4	1004	7	992	18	3341
Largemouth bass	31	372	19	217	7	81	57	670
Iowa darter			1	1			1	1
Fantail darter	11	12	23	47	9	20	43	79
Johnny darter	12	20	126	241	49	76	187	337
Banded darter	25	27	3	2			28	29
Blackside darter	3	19	6	39	2	14	11	72
Species	30		27		27		33	
Totals	1342	22350	2517	22616	1695	22237	5554	67203

Table F11. Fish abundance and biomass (grams) collected from White Fox Creek stations.

	Station 1		Station 2		Station 3		Totals	
Species	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
Central stoneroller	69	852	32	430	3	24	104	1306
Brassy minnow	33	76					33	76
Hornyhead chub	26	84	65	177	19	67	110	328
Emerald shiner	4	8					4	8
Common shiner	24	238	43	267	15	177	82	682
Bigmouth shiner	78	99	407	763	58	132	543	994
Rosyface shiner	13	19	8	16			21	35
Spotfin shiner	50	67					50	67
Sand shiner	195	170	164	220	16	23	375	413
Suckermouth minnow	33	171	17	78	1	4	51	253
Bluntnose minnow	557	824	140	365	53	153	750	1342
Fathead minnow	2	4	2	5			4	9
Blacknose dace	3	5					3	5
Creek chub	22	197	182	1158	111	1075	315	2430
River carpsucker	6	3626					6	3626
Quillback	1	1408					1	1408
White sucker	23	1871	33	2441	40	3902	96	8214
Northern hog sucker	38	1304	19	900	1	39	58	2243
Bigmouth buffalo	1	2300					1	2300
Golden redhorse	8	618	13	4724	7	2792	28	8134
Shorthead redhorse	2	112	6	468			8	580
Black bullhead	7	334			2	230	9	564
Slender madtom	19	166	2	10	1	20	22	196
Stonecat	16	281	1	6	2	22	19	309
Rock bass	1	129	6	966	3	320	10	1415

Table F11. (continued)

Species	Station 1 Number	Station 1 Biomass	Station 2 Number	Station 2 Biomass	Station 3 Number	Station 3 Biomass	Totals Number	Totals Biomass
Green sunfish	262	1258	31	180	33	303	326	1741
Orangespotted sunfish	2	13					2	13
Smallmouth bass	9	206	8	717	5	24	22	947
Largemouth bass	13	55	1	3			14	58
Black crappie					1	41	1	41
Fantail darter	47	92	36	59	18	39	101	190
Johnny darter	5	7	55	96	51	104	111	207
Blackside darter	13	36	2	9	1	5	16	50
Slenderhead darter	3	10					3	10
Freshwater drum	1	840					1	840
Species	34		23		21		35	
Totals	1586	17480	1273	14058	441	9496	3300	41034

APPENDIX G.

HABITAT VARIABLES USED IN PCA

Table G1. Means and standard deviations of 29 habitat variables used in PCA.

Habitat Variable	Mean	SD
Field gradient (m/km)	1.15	0.95
Map gradient (m/km)	1.52	0.75
Drainage area (km^2)	253.14	116.77
Flow (m^3/s)	0.43	0.57
Mean width (m)	10.43	3.04
Mean depth (m)	0.31	0.10
Maximum depth of pools & runs (m)	0.42	0.14
Run (%)	80.94	13.36
Riffle (%)	6.56	7.28
Pool (%)	12.50	8.33
Boulder (%)	2.10	2.43
Rubble/cobble (%)	10.09	10.17
Gravel (%)	21.66	9.92
Sand (%)	50.95	15.22
Silt (%)	8.57	6.83
Clay (%)	2.99	2.91
Pasture (%)	17.50	32.40
Meadow (%)	39.79	31.68
Shrub (%)	17.25	17.08
Woodland (%)	5.76	6.58
Embeddedness (%)	38.33	11.27
Boulder cover (%)	0.21	0.38
Woody debris cover (%)	5.05	6.01
Bank erosion-entire (%)	42.69	15.42
Riparian buffer w/in 10 m (%)	77.60	37.06
Shading (%)	22.91	14.49
Water Temperature (C^0)	20.10	7.36
Conductivity (µmhos @ 25^0 C)	622.00	93.25
Turbidity (NTU)	57.53	66.26

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