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Using the Index of Biotic Integrity of Fish Communities to Evaluate Habitat Quality in Middle Chattahoochee River Tributaries

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Using the Index of Biotic Integrity of Fish Communities to Evaluate Habitat Quality in Middle Chattahoochee River Tributaries

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Abstract

An ichthyological survey was conducted within the lower Piedmont and upper Coastal Plain physiographic regions of the middle Chattahoochee River drainage basin between August 1998 and September 2000. Sampling was conducted by Columbus State University (CSU) under contract to Columbus Water Works for the purpose of obtaining biological measurements of watershed health. Objectives of the survey were the establishment of a data baseline of IBI scores for this ecoregion and to ascertain if there was a correlation between the IBI score and human influence. The thesis to be tested is: 'Fish community IBI scores of different watersheds within the Middle Chattahoochee drainage basin will reflect varying degrees of anthropogenic impact on habitat quality.' Samples were taken twice per year during Spring and Fall over a time span of two years in order to obtain representative samples during periods of normal and low seasonal flow, respectively. Samples were obtained using backpack and boat-borne electroshocking equipment following standard protocol. Fish assemblages collected at stream sites were analyzed using scoring criteria for an Index of Biotic Integrity developed by Georgia Department of Natural Resources for wadeable streams in the Apalachicola drainage basins of the Piedmont Ecoregion of Georgia. A total of 7715 individuals of 48 species were collected from the tributary streams and a total of 8322 individuals of 43 species were collected from the mainstem of the Chattahoochee River during this survey. No correlation could be detected between IBI score and chemical water quality in the tributary streams. The IBI scores exhibited significant positive correlation with physical stream

habitat features as measured using the Habitat Assessment Index during three of the four sampling seasons. The only land use feature that the IBI score appeared correlated with was urbanization, which exhibited significant negative correlation during the first two sampling seasons. Finally, the IBI scores of three of the streams appeared to be positively influenced by a period of prolonged drought in the Middle Chattahoochee drainage basin. Drought conditions may have reduced negative impacts on habitat quality that are reflected in IBI scores. The three streams that exhibited the greatest improvement in IBI score as the drought progressed were in watersheds with urban/suburban development that would be expected to suffer greater impact from storm-water runoff than streams in more rural areas. During the second two seasons, as the drought progressed, IBI scores no longer reflected a significant effect from urbanization. Additionally, streams with higher IBI scores exhibited low variability in their scores while streams with lower IBI scores exhibited highly variable scores. The conclusion was reached that fish community IBI scores are indicative of anthropogenic impacts to habitat quality with the caveat that climatic anomalies, such as drought, may lead to temporarily inflated IBI scores in the more impacted streams that do not accurately reflect true watershed health.

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Introduction Monitoring of physical and chemical characteristics of aquatic systems has long been the primary means for determining water quality. More recently, biological monitoring has gained acceptance as an important component in an overall approach to water resource management that positions habitat quality on equal footing with consumptive requirements for water quality. Resident biota are subject to chemical and physical influences on a continuum, in contrast to chemical data reflecting short-term conditions existing at the time of sample collection. Bioassessment represents a summation of many physical, chemical, and biological processes manifested in the existing condition of the biological community (Yoder *et al.* 1988). Prior to the last twenty years, biologists lacked the methodology to rapidly assess aquatic communities affected by water quality and were unable to provide water resource managers with the input needed to maintain the biological integrity of affected watersheds (Fausch *et al.* 1984).

The use of fish communities for biomonitoring offers numerous advantages. Fish assemblages can be found in even the smallest of water bodies and can be efficiently sampled by the professional due to their high visibility. Some species are highly tolerant of pollutants while others are sensitive to even the slightest environmental perturbation. The community is usually comprised of several trophic levels (planktivore, herbivore, insectivore, piscivore, and omnivore) throughout the aquatic food web, providing an integrative perspective of habitat conditions (Karr *et al.* 1986). Fish populations remain relatively stable outside of their spawning seasons and because of their motility they reflect a range of conditions present in their surrounding environment. Relative longevity of most species allows for temporal assessment of habitat conditions and analysis of the effects of pollutants and other stressors on the fish community (Karr *et al.* 1986, Harris 1995).

For the fish survey team, an extensive database of life history information on practically every fish species is available. Proficiency at taxonomic identification can be accomplished with a modicum of training and experience. Extensive collections that have been acquired by state wildlife agencies and academic institutions provide a database available for quantitative and qualitative evaluation of fish communities (Karr *et al.* 1986). Moderate emphasis on quality control can provide the survey team a consistency in sampling methods that ensures representation of all species present and replication of samples for data analysis (Harris 1995).

James Karr (1981) proposed an Index of Biotic Integrity (IBI) to more effectively use biomonitoring of fish communities to assess stream water quality and environmental degradation in midwestern U.S. watersheds. Use of an index allows for the simplification of biological data into a readily usable form (Gerritson 1995). Karr's IBI emphasizes the ecological significance of community structure and function by measuring species richness, abundance, and composition of the fish community (Schleiger 2000). Karr and Dudley (1981) maintain that changes in ecosystem health due to alteration of flow or habitat can be quantified using characteristics of community structure or function that may not be visibly reflected by water chemistry (Bowen *et al.* 1996). The foremost attribute of the IBI is its ability to formulate a single ecologically based index of the quality of a water resource by integrating data from the individual, population, community, zoogeographic, and ecosystem levels (Karr *et al.* 1986).

The IBI consists of twelve measures (or metrics) within three categories (species composition, trophic composition, and fish abundance/condition) indicative of a range of fish community characteristics. Twelve data sets are obtained and rated 1, 3, or 5 depending on whether the data set deviates strongly, somewhat, or not at all from what would be expected if the given site was minimally impacted or not impacted. An overall IBI score is then derived from the sum of the twelve measures (Karr *et al.* 1986). This single value represents overall habitat conditions for a given reach and is more easily interpreted, especially by non-professionals, than complex analyses (Bowen *et al.* 1996). Furthermore, the particular type of impact to the stream is reflected in the value of the individual metric (Harris 1995). Numerous ichthyologists have shown correlation between indices such as IBI score and measures of environmental impact and habitat quality (Shields *et al.* 1995). McCormick *et al.* (2001) described a strong correlation between IBI and a multivariate measure of habitat quality. DeVivo *et al.* (1997) and Shields *et al.* (1995) found same-site IBI scores to be highly variable at urban locations. Paul and Meyer (2001) cite Wang *et al.* (2000) for having found significantly lower IBI scores in mixed urban/agricultural catchments than strictly agricultural catchments.

Biological integrity, defined by Karr and Dudley (1981) as “the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats of the region,” is reflective of many factors beyond a toxic discharge at the end of a pipe. Water resources are subject to withdrawl for industry and irrigation, impoundment, channelization, habitat fragmentation, wetland dredge and fill, and introduction of non-native species; all resulting in a reduction in biological integrity. In addition to providing an assessment of environmental health, the biological integrity of fish communities illustrates the social costs of habitat degradation due to the readily appreciable aesthetic and economic value of the taxa (Simon 1999).

Impetus for this study was 'The Middle Chattahoochee Watershed Study' prepared by Wet Weather Engineering & Technology Company, LLC for the Columbus Water Works of Columbus, Georgia, and funded, primarily, through the Water Environment Research Federation and the United States Environmental Protection Agency. Funding for the biological surveys was provided to Columbus State University. The study is a prelude to the establishment of total maximum daily loads (TMDLs) by government agencies in June 2002. Section 303(d) of the Clean Water Act requires the establishment of TMDLs in water bodies identified as impaired in order to control point and non-point source pollutant loads within the watershed. Among the goals of the watershed study is the provision of water resource managers with basin-specific data that accurately reflect water quality within the watershed (WWETCO 1998).

The watershed study and the ichthyological survey were conducted within the contiguous drainage areas of the Middle Chattahoochee River watershed between West Point Dam and Walter F. George Reservoir. Water flow and quality are historically affected by the presence of nine dams between the cities of West Point and Columbus (WWETCO 1998), where the 'fall line' delineates a change in physiographic region from Piedmont to upper Coastal Plain. Water quality is also affected by urban impact from growing metropolitan areas and suburban development within the watershed. A map of the stream survey sites within the study area is shown in Figure 1.

One objective of this ichthyological survey was to establish a data baseline of IBI scores for this ecoregion for the purpose of comparison with future surveys and evaluations. Another objective was the quantification of fish communities using the IBI in order to ascertain if there was a correlation between the IBI score and human influence. The thesis to be tested is: 'Fish community IBI scores of different watersheds within the Middle Chattahoochee drainage basin will reflect varying degrees of anthropogenic impact on habitat quality.'

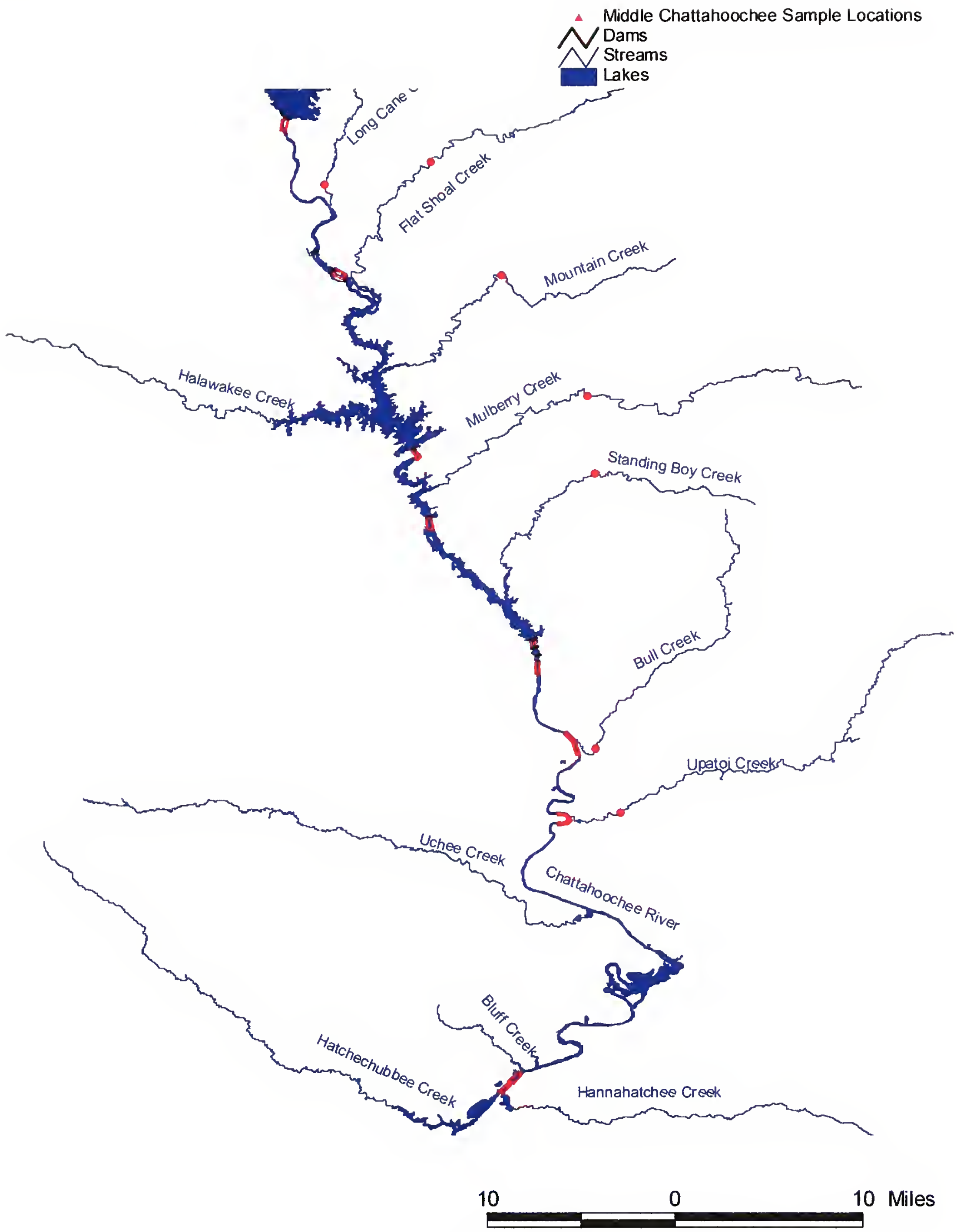

Figure 1. Survey Sites within the Middle Chattahoochee Drainage Basin

Methods This study was conducted in the Southern Plains ecoregion (Omernik 1987) with four stream sites and six mainstem sites located within the lower Piedmont physiographic region. Three stream sites and six mainstem sites are located in the upper Coastal Plain. Streams in the survey area varied in geomorphology from typical lower Piedmont streams characterized by alternating riffles, runs, and pools to the alluvial streams of the upper coastal plain typified by widening flood plains draining the Piedmont (Wharton 1978, Schleiger 2000). The stream reaches sampled were typically sand bottomed pools and runs with graveled raceways. Logjams were frequently encountered within the reach as well as occasional rock outcroppings.

Streams surveyed include Long Cane, Flat Shoals, Mountain Oak, Mulberry, Standing Boy, Bull, and Upatoi Creeks in Georgia. The mainstem of the Chattahoochee River was sampled immediately downstream of West Point, Bartlett's Ferry, Goat Rock, and Eagle-Phenix dams, downstream of Riverview shoals, and immediately upstream and downstream of the outflows of Bull and Upatoi Creeks and the Mead plant at Cottonton, Alabama.

Sampling was conducted by Columbus State University (CSU) under contract to Columbus Water Works with the objective of obtaining biological measurements of watershed health. Samples were obtained twice per year during Fall and Spring over a time span of two years (1998 – 2000) in order to obtain representative samples at the outset and following periods of seasonally reduced flow.

Location of each sampling site was determined by several factors. Access for personnel and all necessary sampling equipment required a stream reach near a highway crossing but care was taken to sample only upstream of the right of way in order to minimize the effects of anthropogenic disturbance resulting from bridge construction and the passage of traffic. The site was also selected for lack of upstream perturbations such as bridges. Finally, sample site location was coordinated with continuously-reading water quality probes at all stream sites except Long Cane Creek, where the creek was sampled several hundred meters downstream of the water quality probe (Birkhead, pers com). The specific locations of tributary stream sample sites were:

Long Cane Creek, immediately upstream of Old West Point Rd., Troup Co., GA. (10/29/98, 6/10/99, 12/10/99, 7/11/00)

Flat Shoals Creek, immediately upstream of State Route 18, Troup Co., GA. (10/23/98, 5/26/99, 11/22/99, 7/19/00)

Mountain Oak Creek, immediately upstream of State Route 219, Harris Co., GA. (10/20/98, 5/19/99, 11/18/99, 7/14/00)

Mulberry Creek, immediately upstream of Hamilton-Mulberry Grove Rd., Harris Co., GA. (7/23/98, 5/25/99, 11/30/99, 9/8/00)

Standing Boy Creek, immediately upstream of Fortson Rd., Harris Co., GA. (10/9/98, 5/18/99, 11/17/99, 7/14/00)

Bull Creek, immediately upstream of U.S. 27/280, Muscogee Co., GA. (10/15/98, 6/7/99, 11/5/99, 7/5/00)

Upatoi Creek, immediately upstream of Engineer-Santa Fe Rd., Ft. Benning Reservation, Chattahoochee/Muscogee Co., GA. (11/3/98, 6/15/99, 12/29/00)

After the sample site had been determined, a reach of stream was measured to a length of fifteen times average stream width to delineate the beginning and end of the sampling session. Initial sampling efforts revealed that a stream reach of this length would encompass at least six replicates of representative habitat types (Hardin, Columbus State University, pers. com.). A 6.7m x 2m seine of 5mm mesh was placed at the downstream end of the sample reach as a block-net and held in place by two persons.

Another individual with a Smith-Root Model 12-B backpack electrofisher then entered the stream at a point approximately one stream width above the block-net and initiated electrofisher operation in a downstream direction, sweeping open areas to stun fishes or drive them toward the block-net. Hydraulic refugia such as submerged stumps and undercut banks were probed thoroughly with the anode to dislodge any stunned specimens. The electrofisher operator, and often one of the seiners, also carried a dip net in order to capture any specimens that immediately surfaced. Upon reaching the block-net, the electrofisher operator exited the stream, the block-net was pulled and the contents emptied. The block-net was then reset at the point where the electrofisher operator had initially entered the stream. The whole process was then repeated up to the terminal point of the measured reach.

Riverine sites were sampled discontinuously along the littoral zone at fifteen points approximately one river width apart for a total reach length of approximately fifteen times the river width. Dams and shoals were sampled along both banks below the site and outflows were sampled only along the bank where the outflow originated. In order to acquire a representative sample, an effort was made to select habitat types for sampling in proportion to habitat types existing within the survey area (Barbour *et al.* 1999). Habitats sampled included snags, rock outcrops, sand-bars, and vegetation. The riparian zone was typically wooded. Samples were taken using a 4.7m aluminum-hulled outboard-motor boat equipped with a Smith-Root GPP electrofishing system. The shocking boat was motored toward the bank at idle speed and electroshocking commenced when the substrate became visible to the pedal operator (usually at a depth of approximately one meter). Both the pedal operator and motor operator wielded 5mm mesh dip-nets for collecting stunned fishes and the motor operator was often able to retrieve fishes that drifted with the current out of reach of the pedal operator. The specific locations and dates of Chattahoochee River sample sites were:

Downriver from West Point Dam, Troup Co., GA.
(11/19/98, 7/22/99, 1/13/00, 5/18/00)

Downriver from Riverview Shoals, Harris Co., GA.
(11/5/98, 7/20/99, 12/22/99, 5/11/00)

Downriver from Bartlett's Ferry Dam, Harris Co., GA.
(12/15/98, 7/15/99, 12/17/99, 5/8/00)

Downriver from Goat Rock Dam, Muscogee Co., GA.
(12/10/98, 7/15/99, 12/15/99, 5/8/00)

Downriver from Oliver Dam, Muscogee Co., GA.
(12/3/98, 7/30/99, 1/4/00, 5/12/00)

Downriver from Eagle-Phenix Dam, Muscogee Co., GA.
(11/29/98, 7/8/99, 11/3/99, 5/4/00)

Upriver from confluence with Bull Cr., Muscogee Co., GA.
(10/22/98, 7/6/99, 11/12/99, 5/4/00)

Downriver from confluence with Bull Cr.,Muscogee Co., GA.
(10/22/98, 7/6/99, 11/10/99, 5/4/00)

Upriver from confluence with Upatoi Cr., Muscogee Co., GA.
(10/22/98, 7/6/99, 12/10/99, 5/5/00)

Downriver from confluence with Upatoi Cr., Chattahoochee Co., GA.
(10/22/98, 6/25/99, 12/8/99, 5/5/00)

Upriver from Mead Coated Board, Stewart Co., GA.
(10/27/98, 6/22/99, 1/6/00, 5/9/00)

Downriver from Mead Coated Board, Stewart Co., GA.
(10/27/98, 6/22/99, 1/6/00, 5/9/00)

The majority of fishes collected from stream and riverine sites were identified in the field and returned to their habitat after enumeration. Deformities, eroded fins, lesions, and tumors (DELTs) were noted during identification. Unidentifiable fishes were placed in labeled containers, preserved in 10% formalin, and transported to the CSU laboratory for identification and enumeration.

Fish assemblages collected at stream sites were analyzed using scoring criteria for an Index of Biotic Integrity developed by Georgia Department of Natural Resources for wadeable streams in the Apalachicola drainage basins of the Piedmont Ecoregion of Georgia (GADNR 2000). A synopsis of these criteria specific to the samples taken in this survey can be found in Table 1.

Attempted analysis of fish assemblages collected from riverine sites was suspended pending development by GADNR of a standardized protocol for assessing the Index of Biotic Integrity of fish populations sampled from large lotic systems and reservoirs. Several researchers, including Bowen *et al.* (1996), Simon & Emery (1995), Oberdorf & Hughes (1992), and Harris & Silveira (1999) have modified Karr's IBI for use in great rivers and a standardized protocol for the Piedmont Ecoregion of Georgia is thought to be forthcoming (Shaner, Georgia Dept. Nat. Res., pers com). Metrics used in a great river IBI should reflect the influence of anthropogenic disturbances such as industrial or municipal discharge, siltation, channelization, and impoundment. Currently, most of the recommended IBI metrics have been formulated for lower-order streams and may not be applicable to large or great rivers. Biological reference condition expectations may need to be revised to reflect appropriate population size, physical anomalies, and the presence of impoundment adapted species (Simon *et al.* 1995).

Scoring of the individual metric was accomplished by assigning a value of one, three, or five to the metric, indicating that the species composition of the metric reflected severe, moderate, or minimal impact, respectively, to the population within the sample area. Metrics 1-6 were scored using Maximum Species Richness graphs formulated by GADNR(2000). These graphs are required to ameliorate the effect of drainage basin area on species richness in smaller watersheds. Species richness increases as drainage basin area increases until reaching an asymptote where the effect is no longer felt (GADNR 2000). MSR graphs for Metrics 1 through 6 are found in Appendix 1. Scoring criteria for Metrics 7 through 12 are listed in Table 2.

Upon determining a score for each metric, the scores were totaled for a combined score that would reflect the biological integrity of that particular watershed. Table 3 delineates the scoring range for each integrity class and its attributes.

IBI scores obtained from sampling sites between October 1998 and September 2000 were first compared to YSI (Yellow Springs Institute) water quality probe data taken from each site at approximately the same time. IBI data were then compared to water quality data taken at roughly biweekly intervals in 2000 by the US Geological Survey.

The IBI scores were also compared to the Habitat Assessment Index for each stream during a given sampling interval. The HAI is a component of the USEPA's Rapid Bioassessment Protocol (RPB) (Barbour *et al.* 1999) that measures the physical characteristics of a stream reach. Ten metrics are scaled within four condition categories to integrate all of the physical features of the stream into an index measuring between 7 and 200. HAI scores were assessed by the Department of Environmental Science of Columbus State University as part of the GADNR Ecoregions Reference Site Project. The HAI score for each stream is contained in the Habitat Assessment Field Data Sheet found in Appendix 4. A Chi-square test of independence between HAI score and IBI score for each sampling interval was completed in order to determine that the data were distributed evenly enough for use in a parametric test for correlation. Relevant Chi-square calculations and conclusions (Ambrose *et al.* 1977) are found in Appendix 5. IBI scores were then plotted against HAI scores for each of the four sampling intervals using Microsoft Excel.

IBI scores were further analyzed for correlation with the physiographic features and land use patterns of their respective tributary steam drainage basins. Data for these drainage basins are listed in Table 7. Analysis was accomplished using the non-parametric Spearman's Rank Correlation due to clumping of the physiographic feature data.

Finally, the tributary stream IBI scores were analyzed for correlation with drought conditions that persisted over the four sampling intervals. First, a Chi-square test determined that the IBI scores for the four sampling seasons were evenly distributed, allowing the use of a parametric test for correlation. Calculations and conclusions of the Chi-square test are found in Appendix 7 (Ambrose *et al.* 1977).

Table 1. Refined Metrics for Middle Chattahoochee R. Tributary Stream Index of Biotic Integrity as Applied to this Study

Metric 1:	Number of Native Fish Species Excluding Hybrids and Introduced Species (*Notropis baileyi, Micropterus punctulatus, Morone chrysops x saxatalis, Perca flavescens, Cyprinus carpio*)
Metric 2:	Number of Benthic Insectivore Species (*Percina nigrofasciata, Noturus leptacanthus)*
Metric 3:	Number of Native Sunfish Species Includes all Centrarchids except *Micropterus sp., Pomoxis sp., Lepomis cyanellus*
Metric 4:	Number of Native Minnow Species Excludes introduced and pollution tolerant species (*Notropis baileyi, Semotilus thoreauianus, Cyprinus carpio, Notemigonus crysoleucas*)
Metric 5:	Number of Native Sucker Species (*Hypentelium etowanum, Minytrema melanops, Scartomyzon lachneri, Erimyzon oblongus, Moxostoma sp.)*
Metric 6(a):	Number of Intolerant Species, DBA > 20 sq. miles Includes *Cyprinella callitaenia, Notropis hypsilepis, Minytrema melanops, Scartomyzon lachneri, Micropterus cataractae, Ambloplites ariommus*
Metric 7:	Eveness Shannon's Diversity Index (from Kreb's computer program) X ln2 / ln # of species X 100%
Metric 8(b):	Proportion of Individuals that are *Lepomis*, DBA > 20 sq. miles
Metric 9:	Proportion of Individuals that are Insectivorous Minnows Includes *Cyprinella callitaenia, Cyprinella venusta, Ericymba buccata, Hybopsis sp.cf. winchelli, Notropis baileyi, Notropis hypsilepis, Notropis longirostris, Opsopoeodus emeliae, Luxilus zonistius, Notropis texanus*
Metric 10(a):	Proportion of Individuals that are Top Carnivores, DBA > 10 sq. miles Includes *Esox americanus, Esox niger, Ambloplites ariommus, Lepomis gulosus, Pomoxis nigromaculatus, Perca flavescens,* all species of *Micropterus*
Metric 11:	Catch Per Unit Effort (CPUE) per 200 meter Reach of Stream Total number of individuals excluding tolerant, hybrid, and introduced species (*Notropis baileyi, Ameiurus natalis, Gambusia affinis, Lepomis cyanellus, Micropterus punctulatus, Semotilus thoreauianus, Perca flavescens*)
Metric 12(a):	Proportion of Individuals that are Simple Lithophiles, DBA > 10 sq. miles Includes *Ericymba bucatta, Hybopsis sp.cf. winchelli, Luxilus zonistius, Notropis baileyi, Notropis hypsilepis, Notropis longirostris, Hypentelium etowanum, Minetrema melanops, Scartomyzon lachneri, Moxostoma sp., Percina nigrofasciata, Cyprinella venusta*

Table 2.
Scoring Criteria for IBI Species Composition Metrics in the Apalachicola Basin

Metric	Drainage Basin Area	Scoring Criteria 5	3	1
7. Eveness (*scored '1' if N < 100)	All	≥ 70%	70% - 50%	≤ 50%
8a. Proportion of Omnivores	< 20 mi^2	< 14%	≥ 14% - 28%	≥ 28%
8b. Proportion of Sunfish	> 20 mi^2	< 26%	≥ 26% - 46%	≥ 46%
9. Proportion of Insectivorous Cyprinids	All	> 44%	≤ 44% - 22%	≤ 22%
10a. Proportion of Top Carnivores	> 10 mi^2	> 3.5%	≤ 3.5% - 2.0%	≤ 2.0%
10b. Proportion of Pioneer Species	< 10 mi^2	< 29%	≥ 29% - 58%	≥ 58%
11. Individuals Collected per 200 Meters	> 10 mi^2	> 700	≤ 700 - 350	≤ 350
12. Proportion of Simple Lithophilic Species	> 10 mi^2	> 54%	≤ 54% - 30%	≤ 30%
13. Proportion of Fish with External Anomalies	All	> 1.2% - subtract 4 points from total score		

Table 3.
GA DNR Description of Integrity Classes (modified from Karr (1981) and Schleiger (2000))

IBI Score	Integrity Class	Attributes
52 - 60	Excellent	Comparable to the best regional reference conditions; includes all regionally expected species for the habitat and stream size; the most intolerant species are present with a full array of size classes; sucker, minnow, and benthic invertivore species are abundant; significant proportion of sample composed of simple lithophilic species; number of individuals abundant, representing a balanced trophic structure; eveness values are greater than 70.
44 - 50	Good	Species richness somewhat below expectation, especially due to the loss of the most intolerant forms; good number of individuals, with several species of suckers, minnows, and benthic invertivores present; trophic structure shows some signs of stress.
34 - 42	Fair	Species richness declines as some expectd species are absent; sucker, minnow, and benthic invertivore species in low abundance; trophic structure skewed toward generalist species as the frequency of omnivores and other tolerant species increases; abundance of simple lithophilic species decreases; increase in the frequency of pioneer species.
26 - 32	Poor	Sample dominated by omnivore, tolerant, and pioneer species; some samples may be dominated by sunfish; sensitive species absent; growth rates and condition factors commonly depressed and diseased fish are often present; number of individuals in low abundance; eveness values less than 60.
< 24	Very Poor	Few fish present, mostly tolerant and pioneer species; fish with diseases, eroded fins, lesions, and tumors common.

Results A total of 7715 individuals of 48 species was collected from the tributary streams and a total of 8322 individuals of 43 species was collected from the mainstem of the Chattahoochee River during this survey. The number of species and abundance for each survey site are listed in Table 4 for the tributaries and Table 5 for the mainstem. Appendix 2 lists the species and their abundance for each date and location in the survey.

IBI scores varied from 16 (very poor) in Long Cane Creek to 42 (good) in Mountain Oak Creek. Table 6 lists IBI scores for the tributary streams for each date and location. The calculations for each particular IBI score can be found in Appendix 3. Figure 2 illustrates, graphically, how the IBI scores delineate the integrity classes for each tributary stream.

No Correlation could be detected between IBI score and YSI water quality probe data. Unfortunately, since one of the primary emphases of the umbrella study was the evaluation of wet-weather phenomena, water quality probe data were only taken during rain events as stream flow increased, peaked, and finally subsided. Again, no correlation could be detected between IBI score and water quality data taken at roughly biweekly intervals in 2000 by the US Geological Survey. No data were available for normal flow conditions for comparison of ambient water quality to IBI scores. It is not known if there may have been a correlation between base-line water quality data and IBI scores, as many fish species are known for their ability to 'ride out' temporary perturbations in water quality.

On the other hand, all four sampling intervals exhibited a positive correlation between IBI score and HAI score. However, only the Fall 1998, Spring 1999, and Fall

1999 correlations were statistically significant (*r* = 0.707, *P* = 0.05, d.f. = 6), as determined by an r^2 value higher than 0.5 (Lewis 1966). Generally, an r^2 value higher than 0.5 ($-0.7 > r > 0.7$) is considered as indicative of a high degree of linear relationship when the data set is sufficiently large (Dunn 1964). A parametric test for correlation between IBI scores plotted against HAI scores for each of the four sampling intervals using Microsoft Excel is shown in Figures 3, 4, 5, and 6.

The only physiographic or land use feature of the drainage basins that exhibited significant correlation (*a* = 0.05) with IBI score was ‘Percent Urbanization’ for the surveys conducted in Fall 1998 and Spring 1999. IBI scores were negatively correlated to increasing urbanization during these two sampling intervals. A graphic representation of this correlation is shown in Figure 7.

A graphic representation of the distribution of the tributary stream IBI scores over two years of sampling, as seen in Figure 8, revealed a positive trend in IBI scores with the progression of the drought in the sampled stream reaches of Mulberry, Bull, and Long Cane Creeks.

Table 4.
Species and Abundance of Fishes Sampled from 8/98 to 9/00 from Tributaries of the Middle Chattahoochee River.

Location	# Species	# Individuals
Long Cane Cr.	24	452
Flat Shoals Cr.	28	1455
Mountain Oak Cr.	24	1411
Mulberry Cr.	23	1104
Standing Boy Cr.	17	820
Bull Cr.	22	2076
Upatoi Cr.	24	397
Total	**48**	**7715**

Table 5.
Species and Abundance of Fishes Sampled from 10/98 to 5/00 from the Mainstem of the Middle Chattahoochee River.

Location	# Species	# Individuals
West Point	19	733
Riverview Shoals	25	483
Bartlett's Ferry	19	429
Goat Rock	13	804
Oliver	13	763
Eagle-Phenix	21	310
above Bull Cr.	18	433
below Bull Cr.	25	480
above Upatoi Cr.	26	420
below Upatoi Cr.	25	467
above Mead	19	1692
below Mead	18	1308
Total	**43**	**8322**

Table 6. Index of Biotic Integrity of Fish Populations in Tributaries of the Middle Chattahoochee River

Site	Date	S	N	H	IBI
Long Cane Cr.	Fall 1998	12	79	2.080	16
	Spr 1999	11	47	1.630	18
	F/W 99-00	11	45	1.910	18
	Sum 2000	16	280	1.783	32
Flat Shoals Cr.	Fall 1998	13	74	2.048	34
	Spr 1999	17	184	1.832	38
	F/W 99-00	20	406	1.989	38
	Sum 2000	21	791	1.671	36
Mountain Oak Cr.	Fall 1998	17	164	2.213	42
	Spr 1999	17	423	1.876	40
	F/W 99-00	20	339	2.061	42
	Sum 2000	19	485	2.092	40
Mulberry Cr.	Fall 1998	11	120	1.565	28
	Spr 1999	15	154	1.893	30
	F/W 99-00	15	306	2.123	34
	Sum 2000	18	524	2.055	44
Standing Boy Cr.	Fall 1998	14	174	1.912	30
	Spr 1999	10	278	1.582	30
	F/W 99-00	11	85	2.065	28
	Sum 2000	13	283	2.020	32
Bull Cr.	Fall 1998	11	304	1.633	26
	Spr 1999	7	181	1.052	20
	F/W 99-00	15	1059	1.823	32
	Sum 2000	18	532	2.088	34
Upatoi Cr.	Fall 1998	13	111	2.102	28
	Spr 1999	11	83	1.533	22
	F/W 99-00	18	203	2.183	34
	Sum 2000		unavailable		

S = # of species
N = # of individuals
H = Shannon's Diversity index

Table 7. Physiographical Features and Land Use Patterns of Middle Chattahoochee River Tributary Drainage Basins

NAME	AREA (m^2)	Perimeter (m)	Order	DBA(mi^2)	% Forest	% Urban	% Agr	% Open
Standing Boy C.	120021635	72513	5	36	87.1	0.7	7.1	2.6
Mulberry C.	589227120	144221	6	177	84.5	0.4	8.9	3.9
Mountain Oak C.	178451366	78936	4	54	87.0	0.3	6.2	4.6
Upatoi C.	1164965373	220628	6	349	79.4	1.8	4.6	8.2
Bull C.	181649426	79713	5	54	60.6	31.3	7.1	0.8
Flat Shoals C.	570907090	154689	6	171	74.8	0.5	17.9	2.8
Long Cane C.	216586621	97217	5	65	70.7	6.8	15.8	1.0
Little Mtn. C.	14174929	16794	3	4	84.7	0.0	12.1	0.0
Mountain C.	99348960	59735	4	30	88.7	0.3	6.2	3.7
Barnes C.	12761188	18906	3	4	97.6	0.4	2.0	0.0
Blanton C.	9537849	15182	3	3	91.9	0.2	3.1	2.8

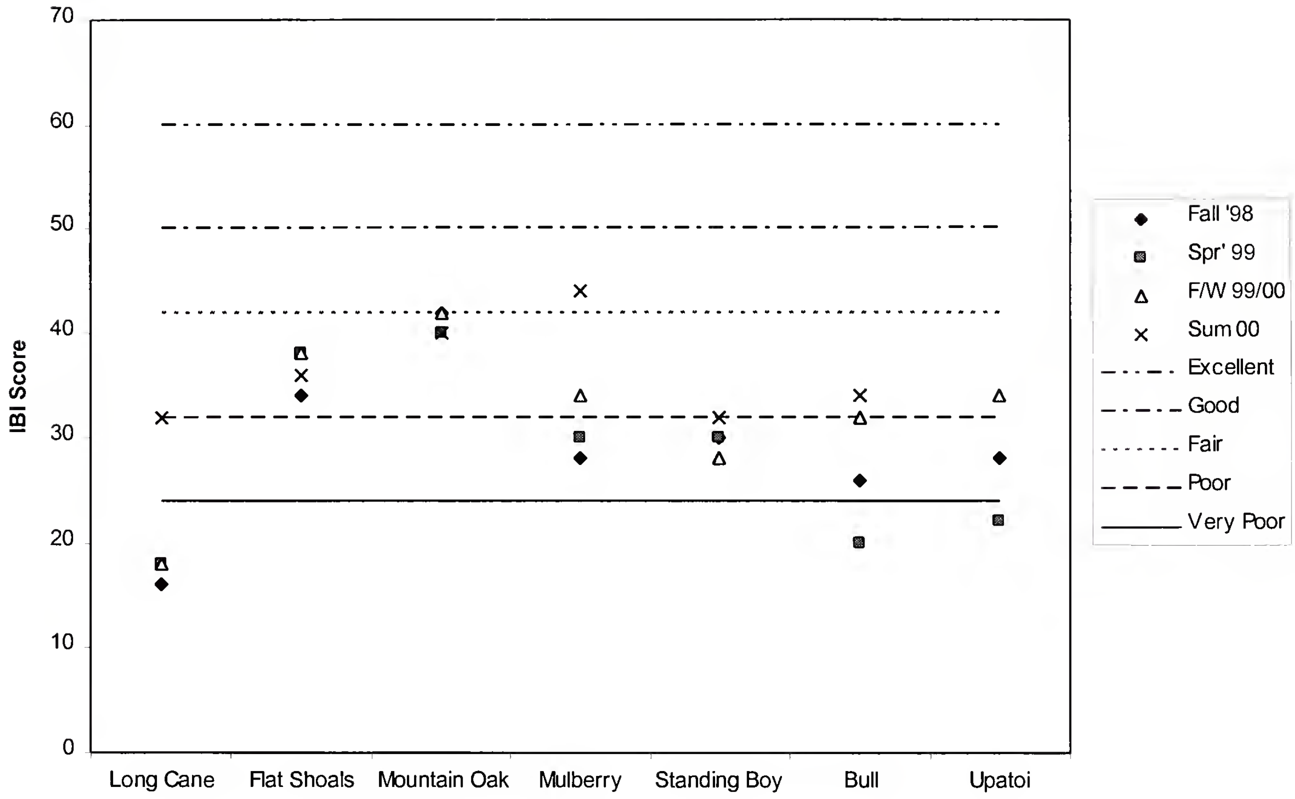

Figure 2. IBI Scores Plotted Within Integrity Classes

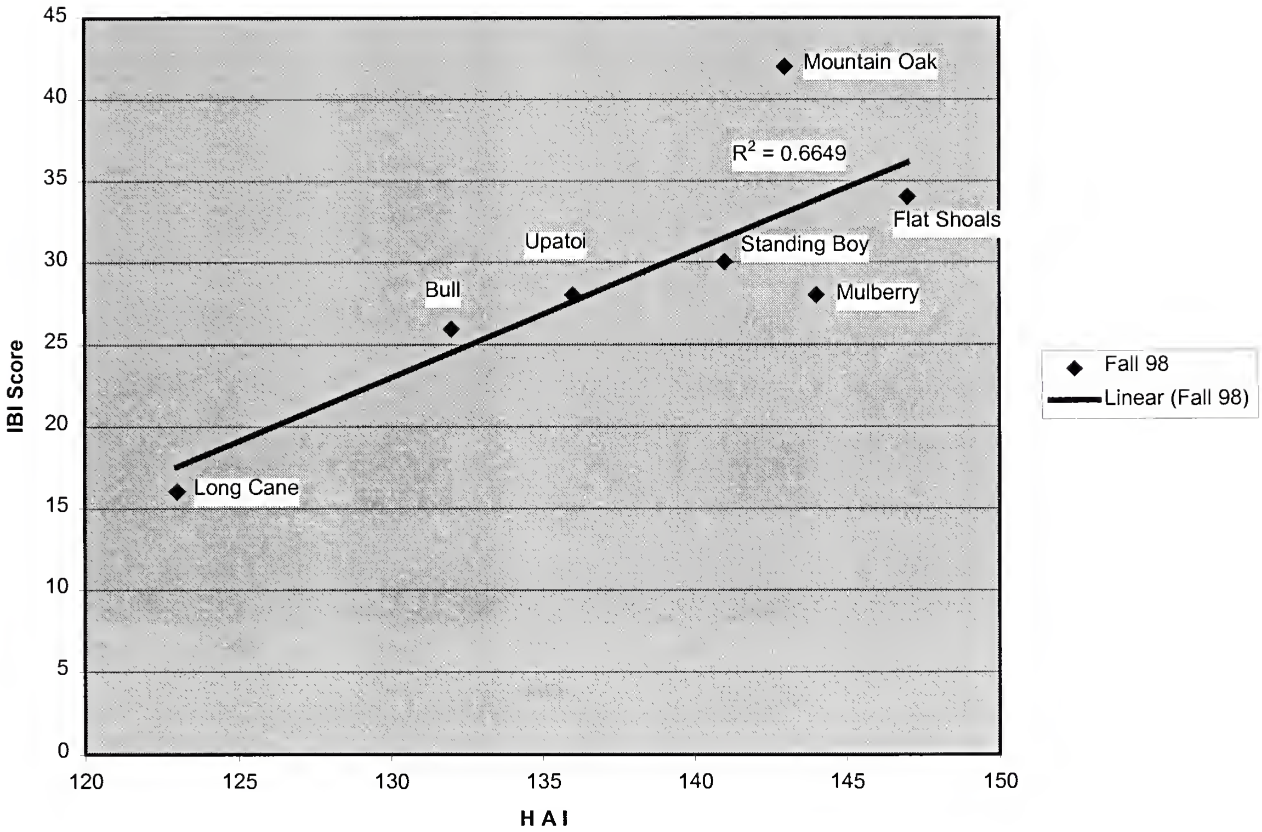

Figure 3. IBI vs Habitat Assessment Index, Fall 1998

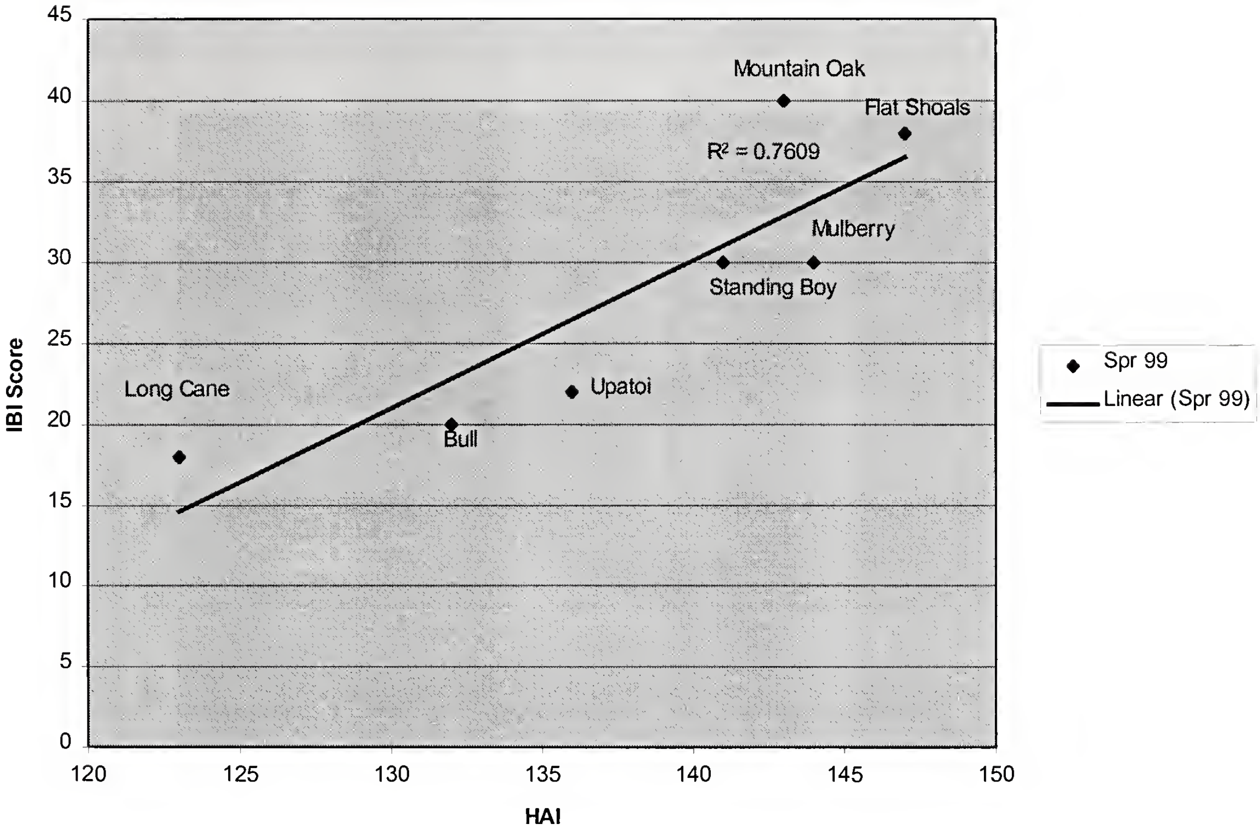

Figure 4. IBI vs Habitat Assessment Index, Spring 1999

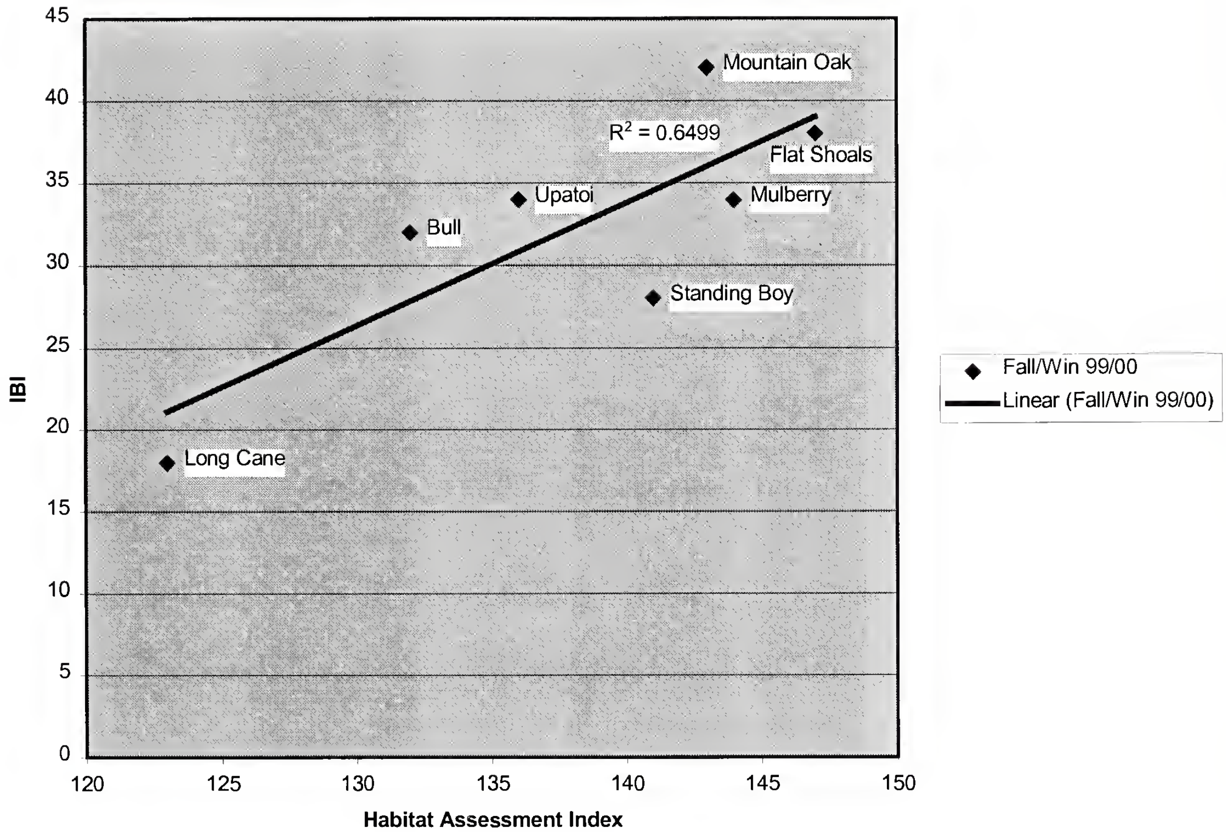

Figure 5. IBI vs Habitat Assessment Index, Fall/Win 1999/2000

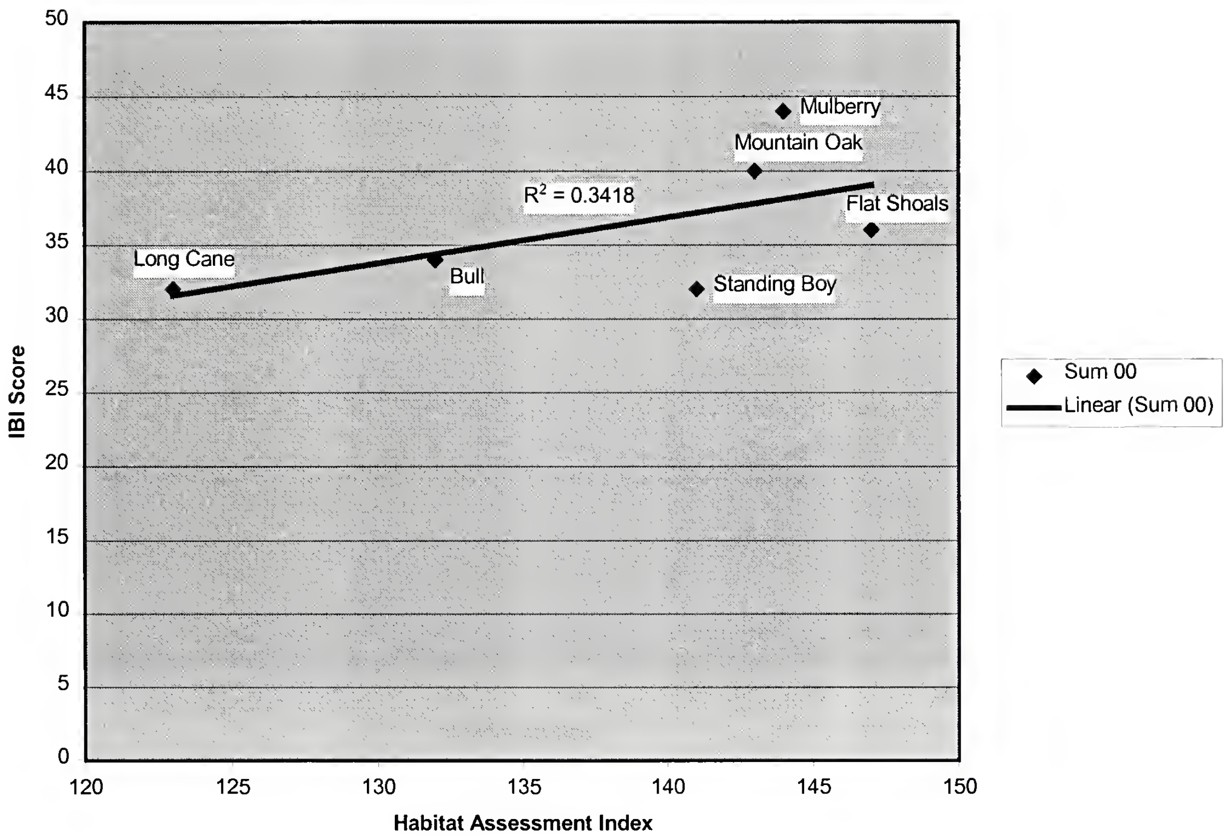

Figure 6. IBI vs Habitat Assessment Index, Sum 2000

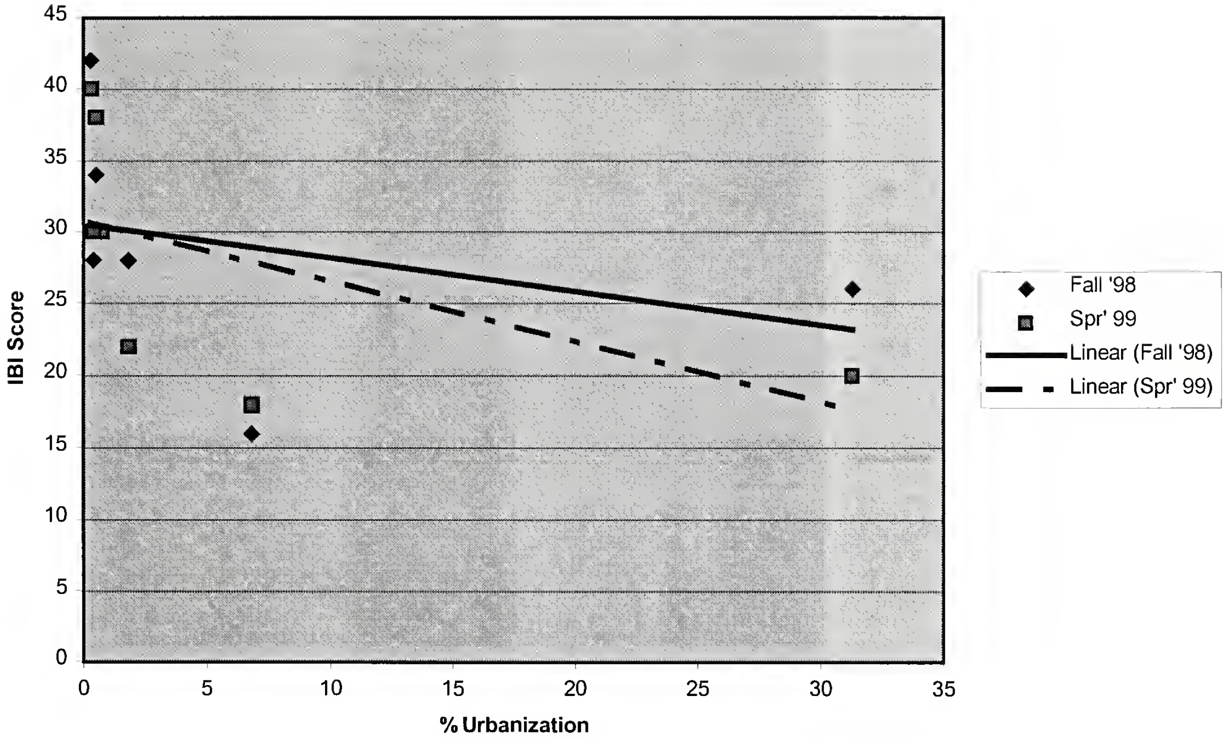

Figure 7. Relationship of IBI Score to Increasing Urbanization as Determined Using Spearman's Rank Correlation (trendlines for illustrative purpose only)

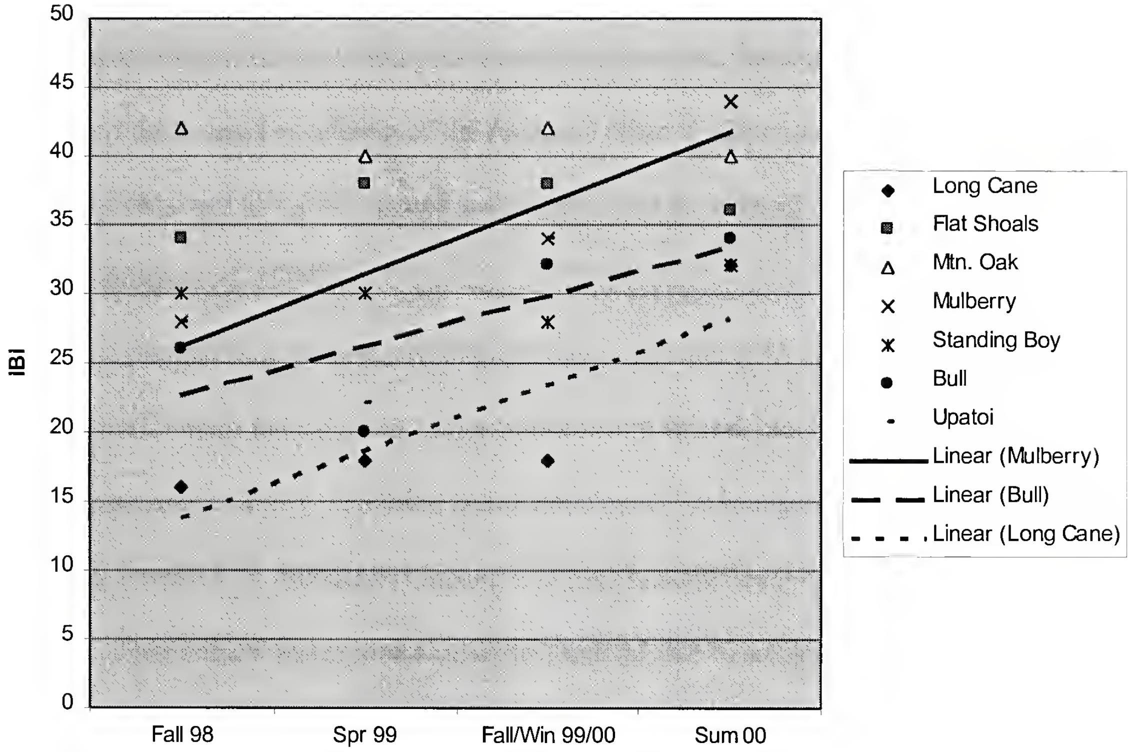

Figure 8. Distribution of Tributary Stream IBI Scores as Drought Progressed, Fall 1998 to Summer 2000

Discussion The absence of correlation between IBI scores and water chemistry data is not unexpected as the IBI is thought of as a 'robust' analytical method integrating the biological, physical, and chemical aspects of a water body and is subject to minimal effect by a single factor such as water chemistry (Oberdorf & Hughes 1992). Although many agencies still use chemical standards to assess aquatic life, chemical measures focus on only a single route of anthropogenic impact compared to the direct assessment of biological endpoints which integrates multiple physical, biological, and chemical criteria into the overall condition of the resource (Karr & Chu 1999). Also, chemical data are usually obtained as "grab" samples and might not be indicative of long-term water quality (Fausch *et al.* 1984).

The positive correlation exhibited between IBI and HAI scores indicates that the IBI score varies with the physical characteristics of a stream reach evaluated using the Habitat Assessment Index. A habitat index developed for low-gradient streams in Wisconsin revealed "a moderately strong and highly significant correlation with biotic integrity." That habitat index was similar to the HAI due to exclusion of watershed variables such as historical land use patterns outside the immediate riparian zone that may not always be related to the habitat quality of the stream (Wang *et al.* 1998).

The positive trend of IBI scores with the progressing drought offers a clue to the relationship between habitat quality and IBI score. Stream sampling was conducted during a period of prolonged drought in the Middle Chattahoochee drainage basin that may have had a positive effect on IBI scores. Low flow conditions may have aleviated some of the negative attributes of impacted streams such as siltation, nutrient loading, or chemical laden runoff. Surface waters in Florida and other southeastern states are thought to have received 80-95% of their heavy-metal load in runoff from parking lots, roads, and highways (TNDHE 1988). Other nonpoint-source pollutants found in runoff include improperly used pesticides and fertilizers, mishandled hazardous wastes, animal wastes, construction sediments, and septic tank leakage. Surface waters receive several times the organic and nutrient loads from nonpoint-sources compared to point-sources (TNDHE 1988). It could be inferred that reduced rainfall during the drought would result in less nonpoint-source pollution delivered to surface waters via runoff. The three streams that exhibited the greatest improvement in IBI score as the drought progressed are in watersheds with urban/suburban development that would be expected to suffer greater impact from storm-water runoff. Shields *et al.* (1995) suspected that large temporal variations in biotic integrity typical of degraded habitats may have confounded the relationship between physical habitat quality metrics and IBI scores in their study. Other researchers have documented a reduction in fish population diversity that accompanied urban land use (Schleiger 2000). It could be argued that the upward trend in IBI score in three of the lower scoring streams is indicative of improvements in habitat quality reflected by changes in the fish population structure, which would be expected to be most pronounced in the impacted streams. However, during drought, IBI scores may represent temporarily improved fish populations that have been colonized from less impacted tributaries where habitat quality remains higher during normal flow.

Further evidence of the positive effect of the drought can be found in the negative correlation of IBI scores with 'Percent Urbanization'. During the first two sessions of sampling, IBI scores were negatively correlated to the amount of urban development within the watershed. But during the second two sessions, as the drought progressed, IBI scores no longer reflected a significant effect from urbanization. This might be expected from fish populations within each watershed that no longer had to contend with the pollutant load delivered to the stream by storm-water runoff under normal flow conditions. This effect was observed most noticeably in Long Cane Creek where, by the fourth and final sample, the water no longer exhibited the foul odor and strange color it had in the earlier samples.

Conclusions No correlation could be detected between IBI score and chemical water quality. On the other hand, IBI scores exhibited significant positive correlation to physical stream habitat features as measured using the Habitat Assessment Index during three of the four sampling intervals. The only physiographic or land use feature that the IBI score appeared correlated with was urbanization, to which the IBI exhibited significant negative correlation during the first two sampling intervals. Finally, the IBI scores of three of the lower scoring streams trended positively with the progression of drought conditions, the positive trend in Mulberry Creek being most pronounced.

Streams with higher IBI scores exhibited low temporal variability in their scores while streams with lower IBI scores exhibited highly variable scores, as seen in Table 8. Karr *et al.* (1987) found that lower quality sites exhibited a greater degree of temporal IBI variation (Shields *et al.* 1995). It might be concluded that efforts toward habitat quality *protection* would be most effective in Mountain Oak, Standing Boy, and Flat Shoals Creeks whereas efforts toward habitat quality *improvement* would show more promise in Long Cane, Mulberry, Bull, and Upatoi Creeks. Several authors argue in favor of focusing conservation efforts on those high-quality habitats that retain intact, native communities or rich biodiversity (Lyons *et al.* 1995).

The conclusion was reached that fish community IBI scores are indicative of anthropogenic impacts to habitat quality with the caveat that climatic anomalies, such as drought, may lead to temporarily inflated IBI scores that do not accurately reflect true watershed health in the more impacted streams. Water quality was thought to be within acceptable levels due to the lack of physical anomalies (DELTs) observed in the sample populations (similar to conclusions reached by Shields *et al.* 1995).

Certainly, the aquatic systems in this study would benefit from further monitoring. The effects of drought on stream IBI scores might be more visible with data sets taken over an extended period of time. Also the lower scores may exhibit less variability and more validity if samples were taken over an extended period of normal flow conditions. Conclusions reached from analysis of sample data would have more validity if more than four replicates were available. The IBI has been validated as a monitoring tool for following temporal trends in biotic integrity and for identifying those aquatic systems in need of environmental protection or restoration activities (Lyons *et al.* 1995). Continued use of the IBI to assess local fish communities would facilitate the identification of threats to the biodiversity of regional watersheds.

Table 8. Variability of IBI Scores within each Tributary Stream

Site	F98	Sp99	F99	Su00	Standard Deviation	Variance ($S.D.^2$)
Long Cane	16	18	18	32	6.40	41
Mulberry	28	30	34	44	6.16	38
Bull	26	20	32	34	5.48	30
Upatoi	28	22	34		4.90	24
Flat Shoals	34	38	38	36	1.66	2.75
Standing Boy	30	30	28	32	1.41	2
Mountain Oak	42	40	42	40	0.94	1

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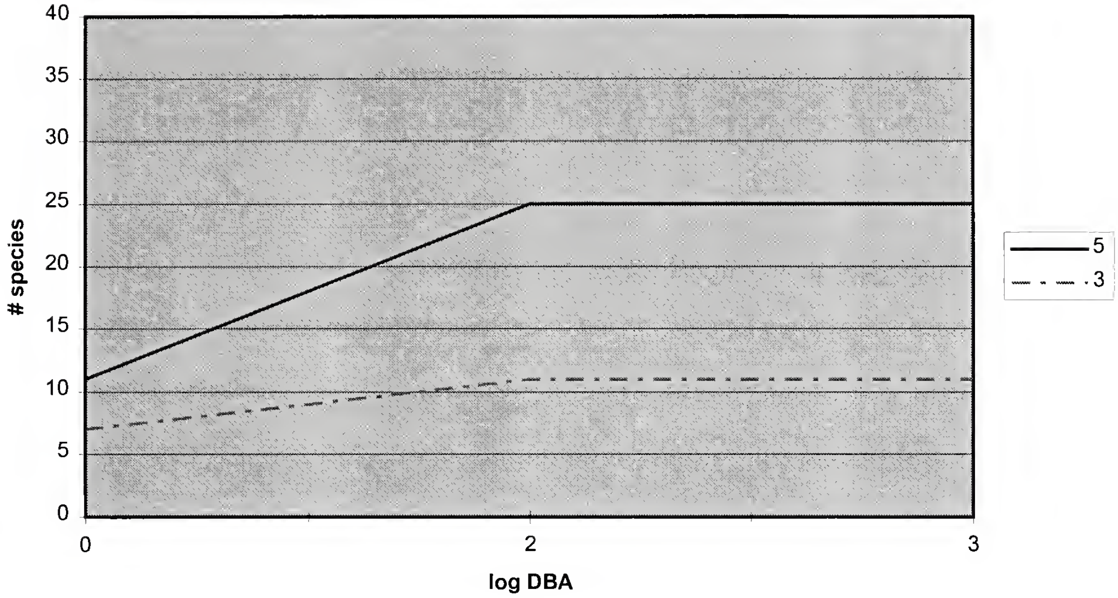
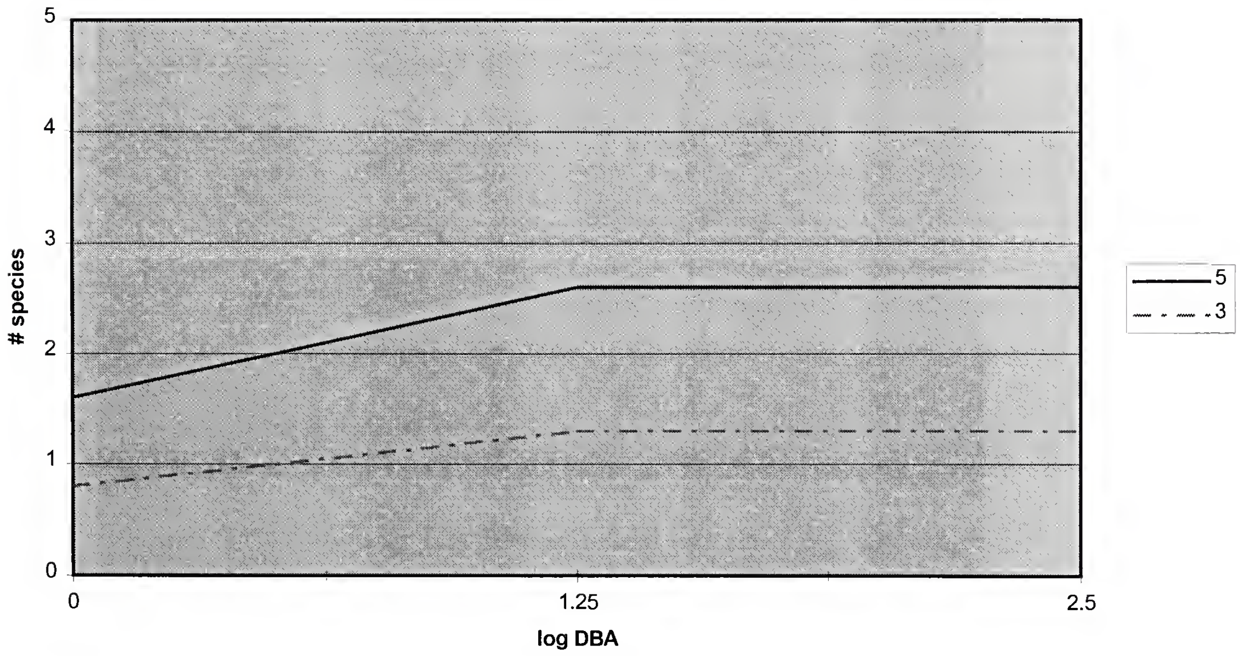
Appendices

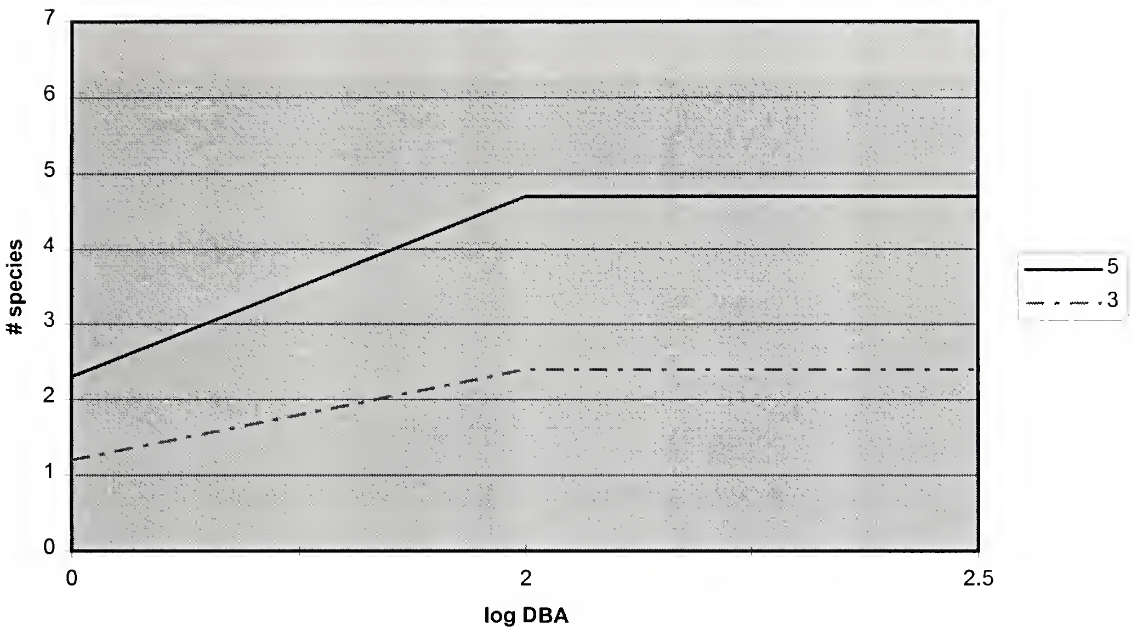
Appendix I. Metric 1, Total Number of Native Fish Species vs DBA for Apalachicola Basin (Maximum Species Richness Graph)



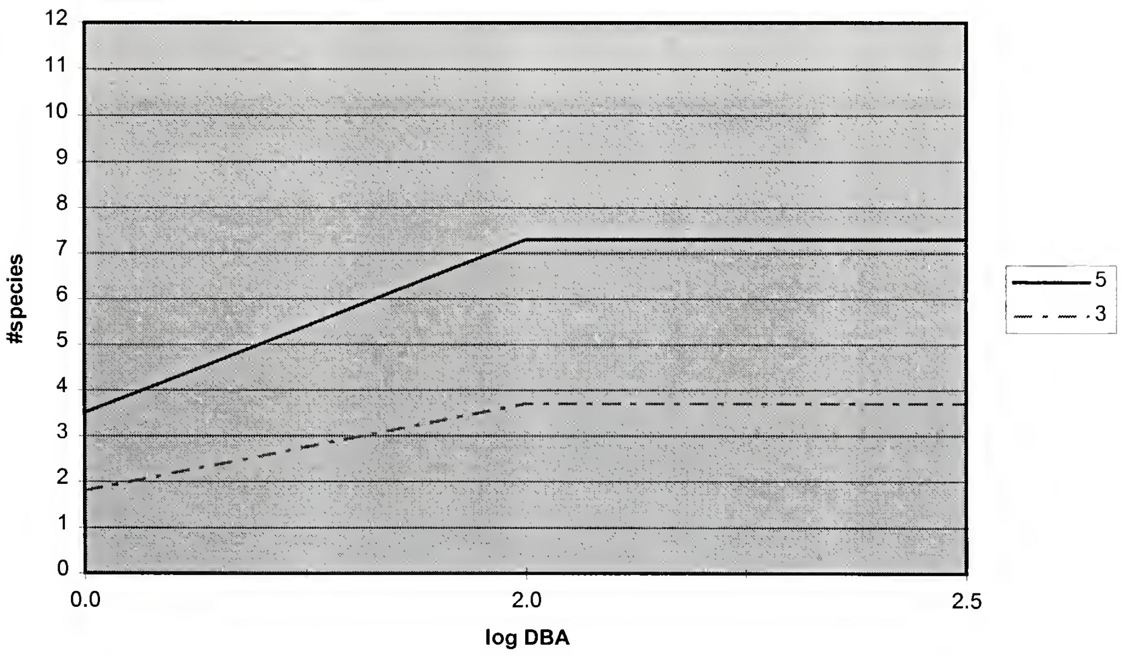
Appendix I. Metric 2, Total Number of Benthic Invertivore Species vs DBA for Apalachicola Basin (Maximum Species Richness Graph)



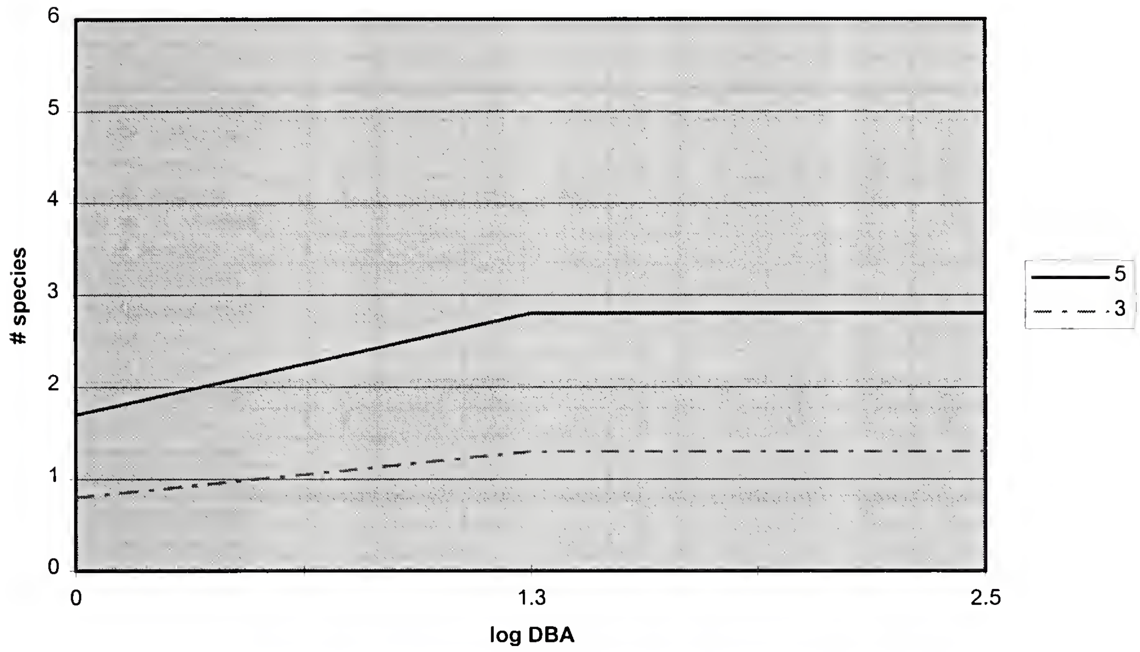
Appendix I. Metric 3, Total Number of Native Sunfish Species vs DBA for Apalachicola Basin (Maximum Species Richness Graph)



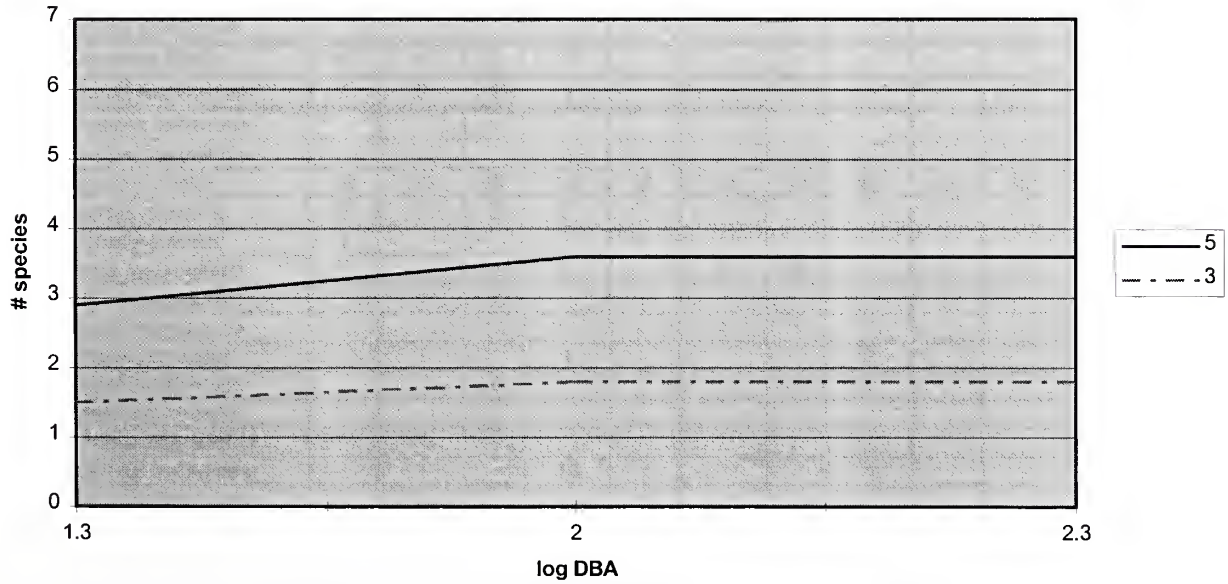
Appendix I. Metric 4, Total Number of Native Minnow Species vs DBA for the Apalachicola Basin (Maximum Species Richness Graph)



Appendix I. Metric 5, Total Number of Native Sucker Species vs DBA for Apalachicola Basin (Maximum Species Richness Graph)



Appendix I. Metric 6, Total Number of Intolerant Species vs DBA for Apalachicola Basin (Maximum Species Richness Graph)



Appendix 2.1 Species and Abundance of Fishes Sampled over a Two Year Period from Tributaries of the Middle Chattahoochee River. Page 1 of 3

Site	Long Cane Cr.				Flat Shoals Cr.				Mountain Oak Cr.			
Date	F '98	Sp '99	F/W	Su '00	F '98	Sp '99	F/W	Su '00	F '98	Sp '99	F/W	Su '00
Species												
Ichthyomyzon gagei	3	1	5	1					9	12	2	2
Redfin Pickerel				1								
Chain Pickerel						1						
Campostoma pauciradii			1		2	5	1	12			2	5
Cyprinella callitaenia					1			11	4			
Cyprinella venusta			1	7	24	95	193	448	17	121	12	50
Ericymba buccata	3		1	58		3	11	29	6	16	77	65
Hybopsis sp. cf. winchelli						3	9	4	1	2	8	4
Luxilus zonistius							2	2		21	9	12
Lythrurus atrapiculus					1							
Nocomis leptocephalus							1		9	9	18	12
Notropis baileyi					10	9	30	38	61	161	128	189
Notropis hypsilepis				7	1		2	1				
Notropis longirostris	1				11	9	12	75	10	27	26	47
Notropis texanus	2				1		12	7	2			
Opsopoeodus emiliae												
Semotilus thoreauianus												
Hypentelium etowanum					10	2	27	6	9	7	16	13
Minytrema melanops				10	2	3				1	1	1
Scartomyzon lachneri					6	14	27	12	16	4	6	
Moxostoma sp.								6	1			
Ameiurus brunneus	2	1	4	2		1	1	1		2	1	5
Ameiurus catus												
Ameiurus natalis											2	1
Ictalurus punctatus												
Noturus leptacanthus						2	1	5	4	8	3	10
Pirate Perch												
Esox americanus				1								
Esox niger						1						
Fundulus olivaceous												
Gambusia affinis	16	4	1	11						7	3	23
Labidesthes sicculus	7	2	1	1		3	9					
Ambloplites ariommus												
Centrarchus macropterus				2								
Lepomis auritus	19	25	17	112	2	19	17	62	5	3	4	12
Lepomis cyanellus	3		2	2								1
Lepomis gulosus	1											
Lepomis macrochirus	7	1		1		1	11		1	1	5	3
Lepomis megalotis		1										
Lepomis microlophus						1	1					
Lepomis punctatus		1		1				3				
Micropterus cataractae			4				3	4				
Micropterus coosae												
Micropterus punctulatus		1						1				
Micropterus salmoides		1		13				1				
Pomoxis nigromaculatus		3										
Perca flavescens									1		2	
Percina nigrofasciata	15	7	8	51	3	13	36	63	8	21	14	30
# of Species	12	12	11	16	13	17	20	21	17	17	20	19
# of Individuals	79	48	45	280	74	184	406	791	164	423	339	485

Appendix 2.1 Species and Abundance of Fishes Sampled over a Two Year Period from Tributaries of the Middle Chattahoochee River. Page 2 of 3

Site	Mulberry Cr.				Standing Boy Cr.				Bull Cr.			
Date	F '98	Sp '99	F/W	Su '00	F '98	Sp '99	F/W	Su '00	F '98	Sp '99	F/W	Su '00
Species												
Ichthyomyzon gagei												
Redfin Pickerel												
Chain Pickerel												
Campostoma pauciradii	2	2	12		3	5	3	11			4	18
Cyprinella callitaenia												
Cyprinella venusta	57	66	82	169	47	20	17	25	79	125	176	27
Ericymba buccata		6	53	16	47	83	2	50				
Hybopsis sp. cf. winchelli	6	3		3	1				23	4	67	40
Luxilus zonistius	1	1										
Lythrurus atrapiculus												
Nocomis leptocephalus	1	1	3									
Notropis baileyi												
Notropis hypsilepis		2	1	5								
Notropis longirostris	6	4	55	85	32	118	20	55	53		191	193
Notropis texanus	1	13	8	30	16	15	12	6	116		397	63
Opsopoeodus emiliae												
Semotilus thoreauianus												1
Hypentelium etowanum												
Minytrema melanops				1			1					
Scartomyzon lachneri	4	18	19	43	1					17	6	
Moxostoma sp.				17								
Ameiurus brunneus		2									7	3
Ameiurus catus											1	
Ameiurus natalis				3					1			7
Ictalurus punctatus												
Noturus leptacanthus												
Pirate Perch												
Esox americanus												
Esox niger												
Fundulus olivaceous												
Gambusia affinis			2	3	3	9	2	15	5	9	76	40
Labidesthes sicculus									1			
Ambloplites ariommus												
Centrarchus macropterus												
Lepomis auritus	7	11	29	88	9	14	13	72	12	23	21	71
Lepomis cyanellus			3		2			2	3			1
Lepomis gulosus				1				2				3
Lepomis macrochirus	3		14	15	3	1	6	36	9		86	40
Lepomis megalotis									2			10
Lepomis microlophus								2			21	
Lepomis punctatus												
Micropterus cataractae		1	3	1								
Micropterus coosae			2	1								
Micropterus punctulatus												
Micropterus salmoides		1		3	1	1	3	1		2	3	6
Pomoxis nigromaculatus					1					1	1	1
Perca flavescens												4
Percina nigrofasciata	32	23	20	40	8	12	6	6			2	4
# of Species	11	15	15	18	14	10	11	13	11	7	15	18
# of Individuals	120	154	306	524	174	278	85	283	304	181	1059	532

Appendix 2.1 Species and Abundance of Fishes Sampled over a Two Year Period from Tributaries of the Middle Chattahoochee River. Page 3 of 3

Site	Upatoi Cr.											
Date	F '98	Sp '99	F/W	Su '00	F '98	Sp '99	F/W	Su '00	F '98	Sp '99	F/W	Su '00
Species												
Ichthyomyzon gagei			1									
Redfin Pickerel												
Chain Pickerel												
Campostoma pauciradii			4									
Cyprinella callitaenia		3										
Cyprinella venusta	39	5	65									
Ericymba buccata			25									
Hybopsis sp. cf. winchelli	3	1	3									
Luxilus zonistius												
Lythrurus atrapiculus												
Nocomis leptocephalus												
Notropis baileyi												
Notropis hypsilepis												
Notropis longirostris	8	15	38									
Notropis texanus	15	45	7									
Opsopoeodus emiliae	5		2									
Semotilus thoreauianus			1									
Hypentelium etowanum												
Minytrema melanops												
Scartomyzon lachneri	1											
Moxostoma sp.												
Ameiurus brunneus	1											
Ameiurus catus												
Ameiurus natalis												
Ictalurus punctatus	6	4	6									
Noturus leptacanthus	9	1	3									
Pirate Perch												
Esox americanus												
Esox niger												
Fundulus olivaceous		1	5									
Gambusia affinis												
Labidesthes sicculus												
Ambloplites ariommus			2									
Centrarchus macropterus												
Lepomis auritus	7	6	18									
Lepomis cyanellus												
Lepomis gulosus												
Lepomis macrochirus			3									
Lepomis megalotis	6	1										
Lepomis microlophus			9									
Lepomis punctatus												
Micropterus cataractae			1									
Micropterus coosae												
Micropterus punctulatus												
Micropterus salmoides	1											
Pomoxis nigromaculatus												
Perca flavescens		1										
Percina nigrofasciata	10		10									
# of Species	13	11	18									
# of Individuals	111	83	203									

Appendix 2.2 Species and Abundance of Fishes Sampled over a Two Year Period from Near-shore Habitat of the Mainstem of the Middle Chattahoochee River. Page 1 of 4

Site	below Eagle-Phenix Dam				below Oliver Dam				below Goat Rock Dam			
Date	F '98	Su '99	F '99	Sp '00	F '98	Su '99	F '99	Sp '00	F '98	Su '99	F '99	Sp '00
Species												
Lepisosteus oculatus												
Lepisosteus osseus				3								
Amia calva												
Anguilla rostrata						1		1				
Dorosoma cepedianum		5	5	15								
Dorosoma petenense												
Cyprinella callitaenia	3	4										
Cyprinella venusta		5	3	1								
Cyprinus carpio			2	1								
Hybopsis sp. cf. winchelli									91			9
Notemigonus crysoleucas												
Notropis hypsilepis												
Notropis texanus			3					1	37		17	22
Opsopoeodus emiliae												
Carpoides cyprinus				1*								
Minytrema melanops									11		1	2
Scartomyzon lachneri												
Moxostoma sp.												
Ameiurus brunneus								1				
Ameiurus catus				1								
Ameiurus serracanthus												
Ictalurus furcatus												
Ictalurus punctatus				2								
Noturus leptacanthus												
Strongylura marina												
Fundulus olivaceous												
Labidesthes sicculus	1		2	2		7		2	2	2	11	1
Morone chrysops x saxatilis												
Lepomis auritus	36	13	16	26	101	60	108	132	31	27	27	62
Lepomis cyanellus				2		1	4	2	2		3	4
Lepomis gulosus				2					3		1	1
Lepomis macrochirus	13	35	13	20	84	85	34	67	77	21	75	91
Lepomis megalotis		1		2								
Lepomis microlophus	1	10	12	7		4	2	6	66	17	17	28
Lepomis punctatus												
Micropterus cataractae	6	2		1	2		2					
Micropterus punctulatus	2	8	2	2	10	7	5	6		2	5	6
Micropterus salmoides		6	5	1	8	3	8	7	7	1	4	2
Pomoxis nigromaculatus		1		4						1		
Perca flavescens				2				1	2			15
Percina nigrofasciata					1							
# of Species	7	11	10	19	6	8	7	11	11	7	10	12
# of Individuals	62	90	63	95	206	168	163	226	329	71	161	243

* = lesions

Appendix 2.2 Species and Abundance of Fishes Sampled over a Two Year Period from Near-shore Habitat of the Mainstem of the Middle Chattahoochee River. Page 2 of 4

Site	below Bartletts Ferry Dam				below Riverview Shoals				below West Point Dam			
Date	F '98	Su '99	F '99	Sp '00	F '98	Su '99	F '99	Sp '00	F '98	Su '99	F '99	Sp '00
Species												
Lepisosteus oculatus												
Lepisosteus osseus				8		2	1					
Amia calva								2	1	1		2
Anguilla rostrata												
Dorosoma cepedianum		4					1	4				
Dorosoma petenense	3								205			
Cyprinella callitaenia							4					
Cyprinella venusta												
Cyprinus carpio				26	1			5				2
Hybopsis sp. cf. winchelli			1				76					
Notemigonus crysoleucas				1							1	
Notropis hypsilepis							1					
Notropis texanus							9	1				
Opsopoeodus emiliae												
Carpoides cyprinus												
Minytrema melanops	1				1	1	1					1
Scartomyzon lachneri							1		2			
Moxostoma sp.					2			2		1		
Ameiurus brunneus							1		1			
Ameiurus catus				1					1			
Ameiurus serracanthus												
Ictalurus furcatus												
Ictalurus punctatus				1								
Noturus leptacanthus												
Strongylura marina												
Fundulus olivaceous												
Labidesthes sicculus	8	2	5	2			15		26	6	331	3
Morone chrysops x saxatilis								2				
Lepomis auritus	18	20	7	114	41	14	54	27	16	7	31	18
Lepomis cyanellus	1		1	8	1		2	1			4	
Lepomis gulosus				3	1	1	3				1	
Lepomis macrochirus	17	48	22	57	26	21	61	42	7	5	22	13
Lepomis megalotis												
Lepomis microlophus		1	2			4	5	6	1			1
Lepomis punctatus							1					
Micropterus cataractae												
Micropterus punctulatus	3	6	2	12	2	4	6	7	2	4	1	
Micropterus salmoides	6		5	7,1*	2	2	1	2	6	1	3	4
Pomoxis nigromaculatus						1						1
Perca flavescens	2		2			1		1	1			
Percina nigrofasciata			1		7		1	2				
# of Species	9	6	10	12	10	10	19	14	12	7	8	9
# of Individuals	59	81	48	241	84	51	244	104	269	25	394	45

* = lesions

Appendix 2.2 Species and Abundance of Fishes Sampled over a Two Year Period from Near-shore Habitat of the Mainstem of the Middle Chattahoochee River. Page 3 of 4

Site	below Mead outflow				above Mead outflow				below Upatoi Cr. outflow			
Date	F '98	Su '99	F '99	Sp '00	F '98	Su '99	F '99	Sp '00	F '98	Su '99	F '99	Sp '00
Species												
Lepisosteus oculatus												1
Lepisosteus osseus										1		1
Amia calva												
Anguilla rostrata												
Dorosoma cepedianum	9	3	1	9	8		8	5	7	5		26
Dorosoma petenense	960	1			1300					4		42
Cyprinella callitaenia					1				10	2		14
Cyprinella venusta		4	4	1		1			8	4	2	2
Cyprinus carpio				2						1		1
Hybopsis sp. cf. winchelli							7					
Notemigonus crysoleucas												
Notropis hypsilepis												
Notropis texanus	1				6		16		5			11
Opsopoeodus emiliae	1				5		1					
Carpoides cyprinus												
Minytrema melanops	2		1			1	2	4		4		1
Scartomyzon lachneri												1
Moxostoma sp.							1			2		
Ameiurus brunneus												
Ameiurus catus												
Ameiurus serracanthus												
Ictalurus furcatus												
Ictalurus punctatus		1						1		1		1
Noturus leptacanthus												
Strongylura marina				1								
Fundulus olivaceous												1
Labidesthes sicculus		8				1			8			
Morone chrysops x saxatilis												1
Lepomis auritus	6	1	2	3	15	1	6	2	7	24	12	27
Lepomis cyanellus		3		1								1
Lepomis gulosus				1			1					2
Lepomis macrochirus	86	15	71	33	46	46	80	47	33	40	23	66
Lepomis megalotis	6				5	2	5	1	1	2	2	6
Lepomis microlophus	14	9	21	7	10	8	9	12	12	6		12
Lepomis punctatus												
Micropterus cataractae												
Micropterus punctulatus		7		1		5	1	1	2	1	1	5
Micropterus salmoides	2	2		8	2		1	15,1*		3		1
Pomoxis nigromaculatus												
Perca flavescens							1	1				3
Percina nigrofasciata											5	3
# of Species	10	11	6	11	10	8	14	10	10	15	6	23
# of Individuals	1087	54	100	67	1398	65	139	90	93	100	45	229

* = lesions

Appendix 2.2 Species and Abundance of Fishes Sampled over a Two Year Period from Near-shore Habitat of the Mainstem of the Middle Chattahoochee River. Page 4 of 4

Site	above Upatoi Cr. outflow				below Bull Cr. outflow				above Bull Cr. Outflow			
Date	F '98	Su '99	F '99	Sp '00	F '98	Su '99	F '99	Sp '00	F '98	Su '99	F '99	Sp '00
Species												
Lepisosteus oculatus												
Lepisosteus osseus		1						1				
Amia calva	1											
Anguilla rostrata												
Dorosoma cepedianum	7	1		28	50	4		5		7		7
Dorosoma petenense				1								
Cyprinella callitaenia	7	1		2	18		11		30			
Cyprinella venusta	5		1		12				10	1		
Cyprinus carpio	2			3		1	1	1		2		
Hybopsis sp. cf. winchelli												
Notemigonus crysoleucas												
Notropis hypsilepis												
Notropis texanus				2			8					3
Opsopoeodus emiliae												
Carpoides cyprinus				1				3				
Minytrema melanops			1	4*			1	2				3
Scartomyzon lachneri			1								1	1
Moxostoma sp.				1*			2					
Ameiurus brunneus												
Ameiurus catus								1				
Ameiurus serracanthus								1				
Ictalurus furcatus							1	2				1
Ictalurus punctatus								1				
Noturus leptacanthus				1								
Strongylura marina												
Fundulus olivaceous												
Labidesthes sicculus	10				8							
Morone chrysops x saxatilis			1	1								
Lepomis auritus	12	6	49	19	6	5	51	32	68	3	27	62
Lepomis cyanellus							1					6
Lepomis gulosus				1			1	2				
Lepomis macrochirus	49	78	25	35	24	17	113	20	36	12	51	55
Lepomis megalotis	1	1	3	8			5	5			1	
Lepomis microlophus	3	1	15	8	3	8	35	3	9	2	4	6
Lepomis punctatus												
Micropterus cataractae			1				1		3			1
Micropterus punctulatus	1	3	2	2	1	2	3	2	2	3	1	3
Micropterus salmoides	3		2	2	3				2	3	1	2
Pomoxis nigromaculatus				1				2				
Perca flavescens		1		1								1
Percina nigrofasciata			4				1		1		2	
# of Species	12	9	12	19	9	6	15	16	9	8	8	13
# of Individuals	101	93	105	121	125	37	235	83	161	33	88	151

* = lesions

Appendix 3.1 IBIs of Fish Communities Sampled from Long Cane Creek
Drainage Basin Area = 65 sq. mi. Reach = 120m

Calculations for IBI, Fall 1998

Metric	# or %	Score
1	12	1
2	1	1
3	3	3
4	3	1
5	0	1
6	0	1
7	83.71%	1*
8	37.97%	3
9	7.59%	1
10	1.27%	1
11	100	1
12	24.05%	1
DELTs		
	IBI =	16

* N<100

Calculations for IBI, Spr 1999

Metric	# or %	Score
1	11	1
2	1	1
3	4	3
4	0	1
5	0	1
6	0	1
7	68.31%	1*
8	58.33%	1
9	0	1
10	8.33%	5
11	71.7	1
12	14.58%	1
DELTs		
	IBI =	18

* N<100

Calculations for IBI, F/W 99-00

Metric	# or %	Score
1	11	1
2	1	1
3	1	1
4	3	1
5	0	1
6	1	1
7	79.67%	1*
8	42.22%	3
9	4.44%	1
10	8.89%	5
11	70	1
12	20.00%	1
DELTs		
	IBI =	18

* N<100

Calculations for IBI, Sum 2000

Metric	# or %	Score
1	16	3
2	1	1
3	4	3
4	3	1
5	1	1
6	2	3
7	64.30%	3
8	42.14%	3
9	25.71%	3
10	5.00%	5
11	445	3
12	45.00%	3
DELTs		
	IBI =	32

Appendix 3.2 IBIs of Fish Communities Sampled from Flat Shoals Creek
Drainage Basin Area = 171 sq. mi. Reach = 250m

Calculations for IBI, Fall 1998

Metric	# or %	Score
1	11	1
2	1	1
3	1	1
4	7	3
5	3	5
6	4	5
7	79.86%	1*
8	2.70%	5
9	66.22%	5
10	0	1
11	51.2	1
12	59.46%	5
DELTs		
	IBI =	34

* N<100

Calculations for IBI, Spr 1999

Metric	# or %	Score
1	16	3
2	2	3
3	3	3
4	5	3
5	3	5
6	2	3
7	64.66%	3
8	0	5
9	64.67%	5
10	0	1
11	140	1
12	30.43%	3
DELTs		
	IBI =	38

Calculations for IBI, F/W 99-00

Metric	# or %	Score
1	19	3
2	2	3
3	3	3
4	9	5
5	2	3
6	3	3
7	66.41%	3
8	7.14%	5
9	67.00%	5
10	0.74%	1
11	300.8	1
12	38.42%	3
DELTs		
	IBI =	38

Calculations for IBI, Sum 2000

Metric	# or %	Score
1	19	3
2	2	3
3	2	1
4	9	5
5	3	5
6	4	5
7	54.89%	1
8	8.22%	5
9	77.75%	5
10	1.48%	1
11	293.6	1
12	29.84%	1
DELTs		
	IBI =	36

Appendix 3.3 IBIs of Fish Communities Sampled from Mountain Oak Creek
Drainage Basin Area = 54 sq. mi. Reach = 100m

Calculations for IBI, Fall 1998

Metric	# or %	Score
1	15	3
2	2	3
3	2	1
4	7	5
5	3	5
6	2	3
7	78.09%	5
8	3.66%	5
9	61.59%	5
10	0.61%	1
11	204	1
12	68.29%	5
DELTs		
	IBI =	42

Calculations for IBI, Spr 1999

Metric	# or %	Score
1	16	3
2	2	3
3	2	1
4	6	3
5	3	5
6	2	3
7	66.20%	3
8	0.95%	5
9	82.27%	5
10	0	1
11	510	3
12	61.47%	5
DELTs		
	IBI =	40

Calculations for IBI, F/W 99-00

Metric	# or %	Score
1	18	3
2	2	3
3	2	1
4	7	5
5	3	5
6	2	3
7	68.81%	3
8	2.65%	5
9	76.70%	5
10	0.59%	1
11	408	3
12	84.07%	5
DELTs		
	IBI =	42

Calculations for IBI, Sum 2000

Metric	# or %	Score
1	18	3
2	2	3
3	2	1
4	7	5
5	2	3
6	1	1
7	71.05%	5
8	3.30%	5
9	75.67%	5
10	0	1
11	542	3
12	74.43%	5
DELTs		
	IBI =	40

Appendix 3.4 IBIs of Fish Communities Sampled from Mulberry Creek
Drainage Basin Area = 177 sq. mi. Reach = 165m

Calculations for IBI, Fall 1998

Metric	# or %	Score
1	11	1
2	1	1
3	2	1
4	7	5
5	1	1
6	1	1
7	65.27%	3
8	8.33%	5
9	59.11%	5
10	0	1
11	145.5	1
12	40.83%	3
DELTs		
	IBI =	28

Calculations for IBI, Spr 1999

Metric	# or %	Score
1	15	1
2	1	1
3	1	1
4	9	5
5	1	1
6	3	3
7	69.90%	3
8	7.14%	5
9	61.69%	5
10	1.30%	1
11	186.7	1
12	37.01%	3
DELTs		
	IBI =	30

Calculations for IBI, F/W 99-00

Metric	# or %	Score
1	15	1
2	1	1
3	2	1
4	7	5
5	1	1
6	3	3
7	78.40%	5
8	15.03%	5
9	65.03%	5
10	1.63%	1
11	364.8	3
12	48.37%	3
DELTs		
	IBI =	34

Calculations for IBI, Sum 2000

Metric	# or %	Score
1	18	3
2	1	1
3	3	3
4	6	5
5	3	5
6	4	5
7	71.10%	5
8	19.85%	5
9	58.78%	5
10	1.15%	1
11	627.9	3
12	40.08%	3
DELTs		
	IBI =	44

Appendix 3.5 IBIs of Fish Communities Sampled from Standing Boy Creek
Drainage Basin Area = 36 sq. mi. Reach = 150m

Calculations for IBI, Fall 1998

Metric	# or %	Score
1	14	3
2	1	1
3	2	1
4	6	3
5	1	1
6	1	1
7	72.47%	5
8	8.05%	5
9	82.18%	5
10	1.15%	1
11	225.3	1
12	51.15%	3
DELTs		
	IBI =	30

Calculations for IBI, Spr 1999

Metric	# or %	Score
1	10	1
2	1	1
3	2	1
4	5	3
5	0	1
6	0	1
7	68.70%	3
8	5.40%	5
9	84.89%	5
10	0.36%	1
11	358.7	3
12	76.62%	5
DELTs		
	IBI =	30

Calculations for IBI, F/W 99-00

Metric	# or %	Score
1	11	1
2	1	1
3	2	1
4	5	3
5	1	1
6	1	1
7	86.11%	1*
8	22.35%	5
9	60.00%	5
10	3.53%	5
11	110.7	1
12	34.12%	3
DELTs		
	IBI =	28

* N<100

Calculations for IBI, Sum 2000

Metric	# or %	Score
1	13	3
2	1	1
3	4	3
4	5	3
5	0	1
6	0	1
7	78.75%	5
8	40.28%	3
9	48.06%	5
10	1.06%	1
11	354.7	3
12	39.22%	3
DELTs		
	IBI =	32

Appendix 3.6 IBIs of Fish Communities Sampled from Bull Creek
Drainage Basin Area = 54 sq.mi. Reach = 180m

Calculations for IBI, Fall 1998

Metric	# or %	Score
1	11	1
2	0	1
3	3	3
4	4	3
5	0	1
6	0	1
7	68.10%	3
8	8.55%	5
9	89.14%	5
10	0%	1
11	332.2	1
12	25.33%	1
DELTs		
	IBI =	26

Calculations for IBI, Spr 1999

Metric	# or %	Score
1	7	1
2	0	1
3	1	1
4	2	1
5	1	1
6	1	1
7	54.07%	1
8	12.71%	5
9	71.27%	5
10	1.66%	1
11	191.1	1
12	11.60%	1
DELTs		
	IBI =	20

Calculations for IBI, F/W 99-00

Metric	# or %	Score
1	15	3
2	1	1
3	3	3
4	5	3
5	1	1
6	1	1
7	67.32%	3
8	12.09%	5
9	78.47%	5
10	0.38%	1
11	1092.2	5
12	25.12%	1
DELTs		
	IBI =	32

Calculations for IBI, Sum 2000

Metric	# or %	Score
1	17	3
2	1	1
3	4	3
4	5	3
5	0	1
6	0	1
7	72.26%	5
8	23.50%	5
9	60.71%	5
10	1.88%	1
11	540	3
12	44.55%	3
DELTs		
	IBI =	34

Appendix 3.7 IBIs of Fish Communities Sampled from Upatoi Creek
Drainage Basin Area = 349 sq.mi. Reach = 150m

Calculations for IBI, Fall 1998

Metric	# or %	Score
1	13	1
2	2	3
3	2	1
4	5	3
5	1	1
6	1	1
7	81.96%	5
8	11.71%	5
9	63.06%	5
10	0.90%	1
11	148	1
12	19.82%	1
DELTs		
	IBI =	28

Calculations for IBI, Spr 1999

Metric	# or %	Score
1	10	1
2	1	1
3	2	1
4	5	3
5	0	1
6	1	1
7	63.91%	1*
8	8.43%	5
9	83.13%	5
10	1.20%	1
11	109.3	1
12	19.28%	1
DELTs		
	IBI =	22

* N<100

Calculations for IBI, F/W 99-00

Metric	# or %	Score
1	18	3
2	2	3
3	4	3
4	7	3
5	0	1
6	2	1
7	75.52%	5
8	15.76%	5
9	68.97%	5
10	1.48%	1
11	269.3	1
12	37.44%	3
DELTs		
	IBI =	34

Calculations for IBI, Sum 2000

Metric	# or %	Score
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
DELTs		
	IBI =	

APPENDIX 4.1 HABITAT ASSESSMENT FIELD DATA SHEET - HIGH GRADIENT STREAMS (FRONT)

STREAM NAME: *MOUNTAIN OAK CREEK*	SITE #: @ *HWY 219*
LAT: *32° 47' 46.2"* LONG: *85° 01' 27.7"*	
INVESTIGATORS: *Columbus State University*	
FORM COMPLETED BY: *TRACY FERRING*	DATE: *12/22/00* TIME: *1145* **AM** PM
REASON FOR SURVEY: Ecoregions Reference Site Project	

HABITAT PARAMETER	CONDITION CATEGORY: OPTIMAL	SUBOPTIMAL	MARGINAL	POOR
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags submerged logs, undercut banks, cobble, and other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of new-fall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desireable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 14	20 19 18 17 16	15 **14** 13 12 11	10 9 8 7 6	5 4 3 2 1
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE 17	20 19 18 **17** 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
3. Velocity/depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is <0.3 m/s, deep is >0.5 m).	Only three of the four regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only two of the four habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by one velocity/depth regime (usually slow-deep).
SCORE 14	20 19 18 17 16	15 **14** 13 12 11	10 9 8 7 6	5 4 3 2 1
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand, or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand, or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate depostion of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 15	20 19 18 17 16	**15** 14 13 12 11	10 9 8 7 6	5 4 3 2 1
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 17	20 19 18 **17** 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

APPENDIX 4.1 HABITAT ASSESSMENT FIELD DATA SHEET - HIGH GRADIENT STREAMS (BACK)

HABITAT PARAMETER	CONDITION CATEGORY			
	OPTIMAL	SUBOPTIMAL	MARGINAL	POOR
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e. dredging (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40-80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 17	20 19 18 **17** 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
7. Frequency of Riffles (or bends)	Occurance of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams were riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by width of the stream is a ratio of >25.
SCORE 8	20 19 18 17 16	15 14 13 12 11	10 9 **8** 7 6	5 4 3 2 1
8. Bank Stability (score each bank) Note: Determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion, mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 6 (LB)	Left Bank 10 9	8 7 **6**	5 4 3	2 1 0
SCORE 6 (RB)	Right Bank 10 9	8 7 **6**	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; Vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of streambank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; Vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 8 (LB)	Left Bank 10 9	**8** 7 6	5 4 3	2 1 0
SCORE 6 (RB)	Right Bank 10 9	8 7 **6**	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone is >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted riparian zone.	Width of riparian zone is 12-18 meters; human activities have impacted riparian zone only minimally.	Width of riparian zone is 6-12 meters; human activities have impacted riparian zone a great deal.	Width of riparian zone is < 6 meters; little or no riparian vegetation due to human activities.
SCORE 7 (LB)	Left Bank 10 9	8 **7** 6	5 4 3	2 1 0
SCORE 8 (RB)	Right Bank 10 9	**8** 7 6	5 4 3	2 1 0

TOTAL SCORE 143

APPENDIX 4.2 HABITAT ASSESSMENT FIELD DATA SHEET - LOW GRADIENT STREAMS (FRONT)

STREAM NAME: *UPATOI CREEK*		SITE #: *@ S. Lumpkin Rd.*	
LAT: *32⁰ 24' 47.0"* LONG: *84⁰ 49' 11.6"*			
INVESTIGATORS: *Columbus State University*			
FORM COMPLETED BY: *TRACY FERRING*	DATE: *12/28/00* TIME: *1330* AM **PM**	REASON FOR SURVEY: Ecoregions Reference Site Project	

HABITAT PARAMETER	**CONDITION CATEGORY**			
	OPTIMAL	**SUBOPTIMAL**	**MARGINAL**	**POOR**
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags submerged logs, undercut banks, cobble, and other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well suited for full colonization potential; adequate habitat for maintenanceof populations; presence of additional substrate in the form of new-fall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desireable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 8	20 19 18 17 16	15 14 13 12 11	10 9 **8** 7 6	5 4 3 2 1
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or sand or clay bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE 8	20 19 18 17 16	15 14 13 12 11	10 9 **8** 7 6	5 4 3 2 1
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools are large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE 14	20 19 18 17 16	15 14 **13** 12 11	10 9 8 7 6	5 4 3 2 1
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand, or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand, or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate depostion of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 13	20 19 18 17 16	15 14 **13** 12 11	10 9 8 7 6	5 4 3 2 1
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 18	20 19 **18** 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

APPENDIX 2.2 HABITAT ASSESSMENT FIELD DATA SHEET - LOW GRADIENT STREAMS (BACK)

HABITAT PARAMETER	CONDITION CATEGORY			
	OPTIMAL	SUBOPTIMAL	MARGINAL	POOR
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e. dredging (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40-80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 15	20 19 18 17 16	**15** 14 13 12 11	10 9 8 7 6	5 4 3 2 1
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note- channel braiding is considered normal in coastal plains and low-lying areas. This parameter is not easily rated in these areas).	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a lond distance.
SCORE 12	20 19 18 17 16	15 14 13 **12** 11	10 9 8 7 6	5 4 3 2 1
8. Bank Stability (score each bank) Note: Determine leftor right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion, mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE <u>8</u> (LB)	Left Bank 10 9	**8** 7 6	5 4 3	2 1 0
SCORE <u>8</u> (RB)	Right Bank 10 9	**8** 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; Vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of streambank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; Vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE <u>8</u> (LB)	Left Bank 10 9	**8** 7 6	5 4 3	2 1 0
SCORE <u>8</u> (RB)	Right Bank 10 9	**8** 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone is >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted riparian zone.	Width of riparian zone is 12-18 meters; human activities have impacted riparian zone only minimally.	Width of riparian zone is 6-12 meters; human activities have impacted riparian zone a great deal.	Width of riparian zone is < 6 meters; little or no riparian vegetation due to human activities.
SCORE <u>8</u> (LB)	Left Bank 10 9	**8** 7 6	5 4 3	2 1 0
SCORE <u>8</u> (RB)	Right Bank 10 9	**8** 7 6	5 4 3	2 1 0

TOTAL SCORE <u>136</u>

APPENDIX 2.3 HABITAT ASSESSMENT FIELD DATA SHEET - HIGH GRADIENT STREAMS (FRONT)

STREAM NAME: *BULL CREEK*	SITE #: *@ HWY 280*	
LAT: *32° 25' 46.4"* LONG: *84° 57' 06.0"*		
INVESTIGATORS: *Columbus State University*		
FORM COMPLETED BY: *TRACY FERRING*	DATE: *01/05/01* TIME: *1615* AM **PM**	REASON FOR SURVEY: Ecoregions Reference Site Project

HABITAT PARAMETER	CONDITION CATEGORY			
	OPTIMAL	**SUBOPTIMAL**	**MARGINAL**	**POOR**
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags submerged logs, undercut banks, cobble, and other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well suited for full colonization potential; adequate habitat for maintenanceof populations presence of additional substrate in the form of new-fall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desireable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 9	20 19 18 17 16	15 14 13 12 11	10 **9** 8 7 6	5 4 3 2 1
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE 17	20 19 18 **17** 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
3. Velocity/depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is <0.3 m/s, deep is >0.5 m).	Only three of the four regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only two of the four habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by one velocity/depth regime (usually slow-deep).
SCORE 12	20 19 18 17 16	15 14 13 **12** 11	10 9 8 7 6	5 4 3 2 1
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand, or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand, or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate depostion of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 9	20 19 18 17 16	15 14 13 12 11	10 **9** 8 7 6	5 4 3 2 1
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 17	20 19 18 **17** 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

APPENDIX 4.3 HABITAT ASSESSMENT FIELD DATA SHEET - HIGH GRADIENT STREAMS (BACK)

HABITAT PARAMETER	CONDITION CATEGORY			
	OPTIMAL	SUBOPTIMAL	MARGINAL	POOR
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e. dredging (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40-80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 17	20 19 18 **17** 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
7. Frequency of Riffles (or bends)	Occurance of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams were riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by width of the stream is a ratio of >25.
SCORE 5	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	**5** 4 3 2 1
8. Bank Stability (score each bank) Note: Determine leftor right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion, mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 8 (LB)	Left Bank 10 9	**8** 7 6	5 4 3	2 1 0
SCORE 7 (RB)	Right Bank 10 9	8 **7** 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; Vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of streambank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; Vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 8 (LB)	Left Bank 10 9	**8** 7 6	5 4 3	2 1 0
SCORE 8 (RB)	Right Bank 10 9	**8** 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone is >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted riparian zone.	Width of riparian zone is 12-18 meters; human activities have impacted riparian zone only minimally.	Width of riparian zone is 6-12 meters; human activities have impacted riparian zone a great deal.	Width of riparian zone is < 6 meters; little or no riparian vegetation due to human activities.
SCORE 7 (LB)	Left Bank 10 9	8 **7** 6	5 4 3	2 1 0
SCORE 5 (RB)	Right Bank 10 9	8 7 6	**5** 4 3	2 1 0

TOTAL SCORE 132

APPENDIX 4.4 HABITAT ASSESSMENT FIELD DATA SHEET - HIGH GRADIENT STREAMS (FRONT)

STREAM NAME: *FLAT SHOALS CREEK*	SITE #: *@ HWY 18*
LAT: *32° 52' 53.5"* LONG: *85° 04' 40.2"*	
INVESTIGATORS: *Columbus State University*	
FORM COMPLETED BY: *TRACY FERRING*	DATE: *12/20/00* TIME: *n/a* AM PM
REASON FOR SURVEY: Ecoregions Reference Site Project	

HABITAT PARAMETER	CONDITION CATEGORY			
	OPTIMAL	**SUBOPTIMAL**	**MARGINAL**	**POOR**
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags submerged logs, undercut banks, cobble, and other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well suited for full colonization potential; adequate habitat for maintenanceof populations presence of additional substrate in the form of new-fall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desireable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 16	20 19 18 17 **16**	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE 11	20 19 18 17 16	15 14 13 12 **11**	10 9 8 7 6	5 4 3 2 1
3. Velocity/depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is <0.3 m/s, deep is >0.5 m).	Only three of the four regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only two of the four habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by one velocity/depth regime (usually slow-deep).
SCORE 12	20 19 18 17 16	15 14 13 **12** 11	10 9 8 7 6	5 4 3 2 1
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand, or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand, or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate depostion of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 17	20 19 18 **17** 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 19	20 **19** 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

APPENDIX 4.4 HABITAT ASSESSMENT FIELD DATA SHEET - HIGH GRADIENT STREAMS (BACK)

HABITAT PARAMETER	CONDITION CATEGORY			
	OPTIMAL	SUBOPTIMAL	MARGINAL	POOR
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e. dredging (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40-80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 18	20 19 **18** 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
7. Frequency of Riffles (or bends)	Occurance of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams were riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by width of the stream is a ratio of >25.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 **6**	5 4 3 2 1
8. Bank Stability (score each bank) Note: Determine leftor right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion, mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 9 (LB)	Left Bank 10 **9**	8 7 6	5 4 3	2 1 0
SCORE 7 (RB)	Right Bank 10 9	8 **7** 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; Vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of streambank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; Vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 8 (LB)	Left Bank 10 9	**8** 7 6	5 4 3	2 1 0
SCORE 8 (RB)	Right Bank 10 9	**8** 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone is >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted riparian zone.	Width of riparian zone is 12-18 meters; human activities have impacted riparian zone only minimally.	Width of riparian zone is 6-12 meters; human activities have impacted riparian zone a great deal.	Width of riparian zone is < 6 meters; little or no riparian vegetation due to human activities.
SCORE 8 (LB)	Left Bank 10 9	**8** 7 6	5 4 3	2 1 0
SCORE 8 (LB)	Right Bank 10 9	**8** 7 6	5 4 3	2 1 0

TOTAL SCORE 147

APPENDIX 4.5 HABITAT ASSESSMENT FIELD DATA SHEET - LOW GRADIENT STREAMS (FRONT)

STREAM NAME: *LONG CANE CREEK*	SITE #: *@ Old West Point Rd.*	
LAT: *32° 59' 56.9"* LONG: *85° 05' 32.0"*		
INVESTIGATORS: *Columbus State University*		
FORM COMPLETED BY: *TRACY FERRING*	DATE: *12/20/00* TIME: *0905* **AM** PM	REASON FOR SURVEY: Ecoregions Reference Site Project

HABITAT PARAMETER	CONDITION CATEGORY			
	OPTIMAL	**SUBOPTIMAL**	**MARGINAL**	**POOR**
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags submerged logs, undercut banks, cobble, and other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well suited for full colonization potential; adequate habitat for maintenanceof populations presence of additional substrate in the form of new-fall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desireable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 10	20 19 18 17 16	15 14 13 12 11	**10** 9 8 7 6	5 4 3 2 1
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation persent.	All mud or sand or clay bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE 8	20 19 18 17 16	15 14 13 12 11	10 9 **8** 7 6	5 4 3 2 1
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools are large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE 14	20 19 18 17 16	15 **14** 13 12 11	10 9 8 7 6	5 4 3 2 1
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand, or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand, or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate depostion of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 12	20 19 18 17 16	15 14 13 **12** 11	10 9 8 7 6	5 4 3 2 1
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 19	20 **19** 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

APPENDIX 4.5 HABITAT ASSESSMENT FIELD DATA SHEET - LOW GRADIENT STREAMS (BACK)

HABITAT PARAMETER	CONDITION CATEGORY: OPTIMAL	SUBOPTIMAL	MARGINAL	POOR
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e. dredging (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40-80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 12	20 19 18 17 16	15 14 13 **12** 11	10 9 8 7 6	5 4 3 2 1
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note- channel braiding is considered normal in coastal plains and low-lying areas. This parameter is not easily rated in these areas).	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a lond distance.
SCORE 8	20 19 18 17 16	15 14 13 12 11	10 9 **8** 7 6	5 4 3 2 1
8. Bank Stability (score each bank) Note: Determine leftor right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion, mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 9 (LB)	Left Bank 10 **9**	8 7 6	5 4 3	2 1 0
SCORE 9 (RB)	Right Bank 10 **9**	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; Vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of streambank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; Vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 9 (LB)	Left Bank 10 **9**	8 7 6	5 4 3	2 1 0
SCORE 9 (RB)	Right Bank 10 **9**	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone is >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted riparian zone.	Width of riparian zone is 12-18 meters; human activities have impacted riparian zone only minimally.	Width of riparian zone is 6-12 meters; human activities have impacted riparian zone a great deal.	Width of riparian zone is < 6 meters; little or no riparian vegetation due to human activities.
SCORE 7 (LB)	Left Bank 10 9	8 **7** 6	5 4 3	2 1 0
SCORE 2 (RB)	Right Bank 10 9	8 7 6	5 4 3	**2** 1 0

TOTAL SCORE 123

APPENDIX 4.6 HABITAT ASSESSMENT FIELD DATA SHEET - HIGH GRADIENT STREAMS (FRONT)

STREAM NAME: *MULBERRY CREEK*	SITE #: *@ Hamilton-Mulberry Grove Rd.*	
LAT: *32⁰ 42' 10.2"* LONG: *84⁰ 57' 28.5"*		
INVESTIGATORS: *Columbus State University*		
FORM COMPLETED BY: *TRACY FERRING*	DATE: *12/20/00* TIME: *1510* AM **PM**	REASON FOR SURVEY: Ecoregions Reference Site Project

HABITAT PARAMETER	CONDITION CATEGORY			
	OPTIMAL	SUBOPTIMAL	MARGINAL	POOR
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags submerged logs, undercut banks, cobble, and other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well suited for full colonization potential; adequate habitat for maintenanceof populations; presence of additional substrate in the form of new-fall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desireable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 14	20 19 18 17 16	15 **14** 13 12 11	10 9 8 7 6	5 4 3 2 1
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE 17	20 19 18 **17** 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
3. Velocity/depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is <0.3 m/s, deep is >0.5 m).	Only three of the four regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only two of the four habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by one velocity/depth regime (usually slow-deep).
SCORE 11	20 19 18 17 16	15 14 13 12 **11**	10 9 8 7 6	5 4 3 2 1
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand, or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand, or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate depostion of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 14	20 19 18 17 16	15 **14** 13 12 11	10 9 8 7 6	5 4 3 2 1
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 18	20 19 **18** 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

APPENDIX 4.6 HABITAT ASSESSMENT FIELD DATA SHEET - HIGH GRADIENT STREAMS (BACK)

HABITAT PARAMETER	CONDITION CATEGORY			
	OPTIMAL	**SUBOPTIMAL**	**MARGINAL**	**POOR**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e. dredging (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40-80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 17	20 19 18 **17** 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
7. Frequency of Riffles (or bends)	Occurance of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams were riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by width of the stream is a ratio of >25.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 **6**	5 4 3 2 1
8. Bank Stability (score each bank) Note: Determine leftor right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion, mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 9 (LB)	Left Bank 10 **9**	8 7 6	5 4 3	2 1 0
SCORE 8 (RB)	Right Bank 10 9	**8** 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; Vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of streambank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; Vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 9 (LB)	Left Bank 10 **9**	8 7 6	5 4 3	2 1 0
SCORE 7 (RB)	Right Bank 10 9	8 **7** 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone is >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted riparian zone.	Width of riparian zone is 12-18 meters; human activities have impacted riparian zone only minimally.	Width of riparian zone is 6-12 meters; human activities have impacted riparian zone a great deal.	Width of riparian zone is < 6 meters; little or no riparian vegetation due to human activities.
SCORE 9 (LB)	Left Bank 10 **9**	8 7 6	5 4 3	2 1 0
SCORE 5 (RB)	Right Bank 10 9	8 7 6	**5** 4 3	2 1 0

TOTAL SCORE 144

APPENDIX 4.7 HABITAT ASSESSMENT FIELD DATA SHEET - HIGH GRADIENT STREAMS (FRONT)

STREAM NAME: *STANDING BOY CREEK*	SITE #: *@ Fortson Rd.*	
LAT: *32° 38' 30.8"* LONG: *84° 57' 11.2"*		
INVESTIGATORS: *Columbus State University*		
FORM COMPLETED BY: *TRACY FERRING*	DATE: *12/20/00* TIME: *1540* AM **PM**	REASON FOR SURVEY: Ecoregions Reference Site Project

HABITAT PARAMETER	CONDITION CATEGORY			
	OPTIMAL	SUBOPTIMAL	MARGINAL	POOR
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags submerged logs, undercut banks, cobble, and other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well suited for full colonization potential; adequate habitat for Maintenanceof populations presence of additional substrate in the form of new-fall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desireable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 10	20 19 18 17 16	15 14 13 12 11	**10** 9 8 7 6	5 4 3 2 1
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE 16	20 19 18 17 **16**	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
3. Velocity/depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is <0.3 m/s, deep is >0.5 m).	Only three of the four regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only two of the four habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by one velocity/depth regime (usually slow-deep).
SCORE 14	20 19 18 17 16	15 **14** 13 12 11	10 9 8 7 6	5 4 3 2 1
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand, or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand, or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate depostion of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 13	20 19 18 17 16	15 14 **13** 12 11	10 9 8 7 6	5 4 3 2 1
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 17	20 19 18 **17** 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

APPENDIX 4.7 HABITAT ASSESSMENT FIELD DATA SHEET - HIGH GRADIENT STREAMS (BACK)

HABITAT PARAMETER	CONDITION CATEGORY			
	OPTIMAL	SUBOPTIMAL	MARGINAL	POOR
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e. dredging (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40-80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 18	20 19 **18** 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
7. Frequency of Riffles (or bends)	Occurance of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams were riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by width of the stream is a ratio of >25.
SCORE 10	20 19 18 17 16	15 14 13 12 11	**10** 9 8 7 6	5 4 3 2 1
8. Bank Stability (score each bank) Note: Determine leftor right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion, mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 6 (LB)	Left Bank 10 9	8 7 **6**	5 4 3	2 1 0
SCORE 7 (RB)	Right Bank 10 9	8 **7** 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; Vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of streambank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; Vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 5 (LB)	Left Bank 10 9	8 7 6	**5** 4 3	2 1 0
SCORE 7 (RB)	Right Bank 10 9	8 **7** 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone is >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted riparian zone.	Width of riparian zone is 12-18 meters; human activities have impacted riparian zone only minimally.	Width of riparian zone is 6-12 meters; human activities have impacted riparian zone a great deal.	Width of riparian zone is < 6 meters; little or no riparian vegetation due to human activities.
SCORE 9 (LB)	Left Bank 10 **9**	8 7 6	5 4 3	2 1 0
SCORE 9 (RB)	Right Bank 10 **9**	8 7 6	5 4 3	2 1 0

TOTAL SCORE 141

Appendix 5

X^2 Test of Independence Between Two Samples (Habitat Assessment Index & IBI)

		LC	FS	MO	Mu	SB	Bull	Up	row totals	
IBI (Fall 98)	obs.	16	34	42	28	30	26	28	204	row 1
	exp.	24.24	31.56	32.26	29.99	29.82	27.55	28.59		
HAI (Fall 00)	obs.	123	147	143	144	141	132	136	966	row 2
	exp.	114.76	149.44	152.74	142.01	141.18	130.45	135.41		
column totals		139	181	185	172	171	158	164	1170	grand total

(obs - exp)^2/exp

IBI (Fall 98)	2.80	0.19	2.94	0.13	0.00	0.09	0.01	6.16
HAI (Fall 00)	0.59	0.04	0.62	0.03	0.00	0.02	0.00	1.30

X^2= 7.46

Critical Value for *a* =.05 at d.f. of 6 is 12.6

Critical Value (12.6) > X^2 (7.46) so fail to reject Ho

Dist. A (IBI) = Dist. B (HAI)

X^2 Test of Independence Between Two Samples (Habitat Assessment Index & IBI)

		LC	FS	MO	Mu	SB	Bull	Up	row totals	
IBI (Spr 99)	obs.	18	38	40	30	30	20	22	198	row 1
	exp.	23.98	31.47	31.13	29.60	29.09	25.86	26.88		
HAI (Fall 00)	obs.	123	147	143	144	141	132	136	966	row 2
	exp.	117.02	153.53	151.87	144.4	141.91	126.14	131.12		
column totals		141	185	183	174	171	152	158	1164	grand total

(obs - exp)^2/exp

IBI (Spr 99)	1.49	1.36	2.53	0.01	0.03	1.33	0.88	7.62
HAI (Fall 00)	0.31	0.28	0.52	0.00	0.01	0.27	0.18	1.56

X^2= 9.18

Critical Value for *a* =.05 at d.f. of 6 is 12.6

Critical Value (12.6) > X^2 (9.18) so fail to reject Ho

Dist. A (IBI) = Dist. B (HAI)

Appendix 5
(cont)

X^2 Test of Independence Between Two Samples (Habitat Assessment Index & IBI)

		LC	FS	MO	Mu	SB	Bull	Up	row totals	
IBI (Fall 99)	obs.	18	38	42	34	28	32	34	226	row 1
	exp.	26.73	35.08	35.08	33.75	32.04	31.09	32.23		
HAI (Fall 00)	obs.	123	147	143	144	141	132	136	966	row 2
	exp.	114.27	149.92	149.92	144.25	136.96	132.91	137.77		
column totals		141	185	185	178	169	164	170	1192	grand total

$(obs - exp)^2/exp$

IBI (Fall 99)	2.85	0.24	1.37	0.00	0.51	0.03	0.10	5.10
HAI (Fall 00)	0.67	0.06	0.32	0.00	0.12	0.01	0.02	1.19

$X^2 = 6.29$

Critical Value for *a* =.05 at d.f. of 6 is 12.6
Critical Value (12.6) > X^2 (6.29) so fail to reject Ho
Dist. A (IBI) = Dist. B (HAI)

X^2 Test of Independence Between Two Samples (Habitat Assessment Index & IBI)

		LC	FS	MO	Mu	SB	Bull	row totals	
IBI (Sum 00)	obs.	32	36	40	44	32	34	218	row 1
	exp.	32.24	38.07	38.07	39.11	35.99	34.53		
HAI (Fall 00)	obs.	123	147	143	144	141	132	830	row 2
	exp.	122.76	144.93	144.93	148.89	137.01	131.47		
column totals		155	183	183	188	173	166	1048	grand total

$(obs - exp)^2/exp$

IBI (Sum 00)	0.00	0.11	0.10	0.61	0.44	0.01	1.27
HAI (Fall 00)	0.00	0.03	0.03	0.16	0.12	0.00	0.33

$X^2 = 1.61$

Critical Value for *a* =.05 at d.f. of 5 is 11.1
Critical Value (11.1) > X^2 (1.61) so fail to reject Ho
Dist. A (IBI) = Dist. B (HAI)

Appendix 6 Spearman's Rank Correlation between IBI and Increasing Urbanization

Fall 98	**MO**	**MU**	**FS**	**SB**	**Up**	**LC**	**Bull**	
Urb.rank	1	2	3	4	5	6	7	
IBI rank	1	4.5	2	3	4.5	7	6	
d	0	2.5	1	1	0.5	1	1	
d^2	0	6.25	1	1	0.25	1	1	10.5

$r_s = 1 - (6 \times \text{sum } d^2 / n^3 - n) = 0.813$ 0.8125

Critical Value at n =6, *a* =.05, (0.786) < r_s (0.813) so reject Ho of no correlation.

Spr 99	**MO**	**MU**	**FS**	**SB**	**Up**	**LC**	**Bull**	
Urb.rank	1	2	3	4	5	6	7	
IBI rank	1	3.5	2	3.5	5	7	6	
d	0	1.5	1	0.5	0	1	1	
d^2	0	2.25	1	0.25	0	1	1	5.5

$r_s = 1 - (6 \times \text{sum } d^2 / n^3 - n) = 0.902$ 0.901786

Critical Value at n =6, *a* =.05, (0.786) < r_s (0.902) so reject Ho of no correlation.

Fall 99	**MO**	**MU**	**FS**	**SB**	**Up**	**LC**	**Bull**	
Urb.rank	1	2	3	4	5	6	7	
IBI rank	1	3.5	2	6	3.5	7	5	
d	0	1.5	1	2	1.5	1	2	
d^2	0	2.25	1	4	2.25	1	4	14.5

$r_s = 1 - (6 \times \text{sum } d^2 / n^3 - n) = 0.741$ 0.741071

Critical Value at n =6, *a* =.05, (0.786) > r_s (0.741) so fail to reject Ho of no correlation.

Sum 00	**MO**	**MU**	**FS**	**SB**	**LC**	**Bull**	
Urb.rank	1	2	3	4	5	6	
IBI rank	2	1	3	5.5	5.5	4	
d	1	1	0	1.5	0.5	2	
d^2	1	1	0	2.25	0.25	4	8.5

$r_s = 1 - (6 \times \text{sum } d^2 / n^3 - n) = 0.757$ 0.757143

Critical Value at n =6, *a* =.05, (0.886) > r_s (0.757) so fail to reject Ho of no correlation.

Appendix 7

X2 Test of Independence Between Multiple Samples

		LC	FS	MO	Mu	SB	Bull	row totals	
Fall 98	obs.	16	34	42	28	30	26	176	row 1
	exp.	19.40	33.72	37.88	31.41	27.72	25.87		
Spring 99	obs.	18	38	40	30	30	20	176	row 2
	exp.	19.40	33.72	37.88	31.41	27.72	25.87		
Fall 99	obs.	18	38	42	34	28	32	192	row 3
	exp.	21.17	36.79	41.32	34.27	30.24	28.22		
Summer 00	obs.	32	36	40	44	32	34	218	row 4
	exp.	24.03	41.77	46.92	38.91	34.33	32.04		
column totals		84	146	164	136	120	112	762	grand total

$(obs - exp)^2/exp$

Fall 98	0.60	0.00	0.45	0.37	0.19	0.00	1.61
Spring 99	0.10	0.54	0.12	0.06	0.19	1.33	2.35
Fall 99	0.47	0.04	0.01	0.00	0.17	0.51	1.20
Summer 00	2.64	0.80	1.02	0.67	0.16	0.12	5.40

$X^2 = 10.55$

Critical Value for *a* =.05 at d.f. of 15 is 25.0

Critical Value (25.0) > X^2 (10.55) so fail to reject Ho

Dist. A (Fall 98) = Dist. B (Spr 99) = Dist. C (Fall 99) = Dist. D (Spr 00)