Research Technical Completion Report

USE OF THE INDEX OF BIOTIC INTEGRITY TO ASSESS THE IMPACT OF LAND MANAGEMENT ACTIVITIES ON LOW ORDER STREAMS IN NORTHERN IDAHO

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WATER for IDAHO

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October, 1989

The research on which this report is based was financed in part by the United States Department of the Interior as authorized by the Water Research and Development Act of 1978 (P.L. 95-467).

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14-08-0001-G1419-06

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Submitted to

U.S. Geological Survey
United States Department of the Interior
Washington, D.C. 20242

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October, 1989

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ACKNOWLEDGMENTS

Thanks are extended to Ms. Cindy Robertson of the Idaho Department of Fish and Game, Coeur d'Alene; Dr. T. C. Bjornn, University of Idaho; and Mr. Bert Bowler of the Idaho Department of Fish and Game, Lewiston, for suggesting suitable study streams. Mr. Bert Bowler, and Drs. C. M. Falter, and T. C. Bjornn provided field equipment. Messrs. Bob Rainville, Harry Jagerman, Al Espinosa, Ed Lider, and others from the U.S. Forest Service provided information about study sites and data on land use activities. Dr. R. L. Wallace aided the identification of cottid species.

ABSTRACT

We adapted the Index of Biotic Integrity (IBI) to the faunal characteristics of northern Idaho headwater streams. Stream biota was sampled from June 1987 through September 1987. The original Index of Biotic Integrity, as developed for midwestern U.S. streams, was unsuitable for use in northern Idaho. Only four of the 12 metrics included in the original IBI reflected changes in the biotic integrity of northern Idaho streams. The original IBI, although significantly correlated with measures of stream quality, was too insensitive and classified lower quality streams as being in "good to excellent" health.

We modified the original IBI to contain eight metrics to reflect the health of the fish, amphibian, and aquatic macroinvertebrate communities. Also, expectation criteria of three metrics were adjusted for relative stream size. Our modified IBI seems to adequately assess the health of northern Idaho headwater streams. The modified IBI detected changes in stream health, as index scores were significantly correlated with road density and percent harvest of the drainages. Also, the modified IBI was more highly correlated with measures of impact and less significantly with the measures of stream size than Shannon diversity of fishes by biomass or numbers, the Index of Well Being, and Brillouin diversity of both fishes and aquatic macroinvertebrates.

The modified Index of Biotic Integrity offers managers a technique to evaluate stream health with limited vertebrate and invertebrate sampling. Because the index was developed from data collected in northern Idaho streams with generally nonerosive rock types, we do not know how well this index would classify stream health in other regions of Idaho or other streams in the Pacific Northwest.

INTRODUCTION

One principal goal of water resources management is to maintain the ecological integrity of aquatic systems. Although ecological integrity includes physical, chemical, and biological components, standards used to assess the quality of aquatic resources have been almost exclusively based on either monitoring concentrations of various contaminants or determining physical habitat quality. However, monitoring has limited application when dealing with non-point sources of pollution. Since an ability to sustain a balanced biotic community is probably the best indicator of watershed conditions, monitoring programs should assess the condition or "health" of biological communities.

Deteriorating water quality in Idaho streams is of primary concern to fisheries managers. Many headwater streams in Idaho have been affected by increased siltation rates and elevated temperatures caused primarily by human activities such as silviculture, agriculture, mining, and grazing. These streams are important for their productivity and maintaining downstream water quality. However, a method for monitoring these streams for non-point sources of degradation has not yet been established. Although studies have attributed poor insect and fish community conditions to high levels of sedimentation (Bjornn et al. 1977), no known method exists to predict the integrity of stream biota without employing extensive hydrological, riparian, and aquatic biota evaluation techniques.

Evaluating Biotic Integrity

The term "stream health" has been commonly used to describe the overall fitness of an aquatic system (Karr 1981). Previous attempts at evaluating stream health have taken one or more of five main approaches:

investigators have used indicator species; diversity indices; relative abundance of desirable species; biotic condition indices; and/or measures of physical habitat as indicators of biotic integrity. Numerous groups of organisms have been proposed as indicators of stream health, but none has emerged as being more commonly used or accepted than fishes (Hocutt 1981). Substantial evidence exists that fish communities can be used to assess human influence on the biological integrity of freshwater ecosystems and fisheries researchers have generally accepted fish as the most economical and practical group to use as biological indicators. Fish are large, relatively easy to capture and identify and are present in most freshwater systems from the headwaters to the mouth (Hocutt and Stauffer 1980). As a result, in parts of the United States fish have been used as indicators of stream health (Karr 1981).

Various indices have been proposed to evaluate stream health through the monitoring of fish communities. One such measure, the Index of Well Being (IWB), was proposed by Gammon (1976). The IWB incorporates measures of diversity and abundance estimates to asses fish assemblage quality. It has been used to assess biotic integrity on the Wabash River, Indiana (Gammon 1976), and the Willamette River, Oregon (Hughes and Gammon 1987). Other methods of evaluating stream health include use of diversity indices such as Shannon and Brillouin diversity (Pielou 1975). Both indices measure the number of taxa present (species richness) and the degree to which all species present are represented in the total community (species evenness). Another approach to the evaluation of biotic integrity is based on the relative abundance of desirable species present in a system as compared to the potential production of that system. Coble (1982) used the percentage of sport fishes present at a site to evaluate fish community responses to low dissolved oxygen in the Wisconsin River.

The Index of Biotic Integrity (IBI) was developed in the midwestern United States to assess the integrity of the stream fish community (Karr 1981). The health of the fish community is assumed to be a reflection of the biotic integrity of the stream system as a whole. By comparing communities from healthy and unhealthy streams, the IBI can be used to detect habitat alteration from chemical, physical, and hydrological impacts upon the watershed through the effect alteration has on the fish community. In streams of the upper midwest (Fausch et al. 1984; Karr et al. 1986), the Appalachians (Leonard and Orth 1986), and Oregon (Hughes and Gammon 1987), the IBI has proven to be a fast and inexpensive early warning system for detecting habitat alteration.

Fausch et al. (1984) found that IBI scores corresponded well with such disturbances as channelization, municipal sewage, and agricultural runoff in streams in Indiana, Illinois, South Dakota, Nebraska, Wisconsin, and Illinois. Leonard and Orth (1986) modified the original IBI to study the effects of municipal and industrial sewage and mining on West Virginia coolwater streams. They found a consistent relationship between water quality disturbances and IBI scores. Hughes and Gammon (1987) modified the IBI to reflect longitudinal changes in fish community structure in the Willamette River, Oregon. They found that the IBI reflected changes in fish community structure better than other commonly used indices.

The IBI measures the biotic integrity of a stream fish community through three main categories: species richness and composition; trophic composition; and fish abundance and condition (Karr 1981). The species richness and composition category assesses integrity through measures of the total number of species present, tolerant and intolerant species occurrences, and the relative abundance of major families of fishes, where each family has a different response to environmental perturbations. Intolerant species are highly sensitive to alteration of their food resources and habitats, while tolerant species are relatively insensitive (Karr et al. 1986). The trophic composition category assesses the biotic integrity of the stream through measures of the relative abundance of the insectivorous cyprinid, omnivore, and piscivore trophic guilds. Finally, the fish abundance and condition category evaluates population attributes such as total population, hybridization, and incidence of disease or other anomalies.

Previous studies have divided the categories of species richness and composition, abundance and condition, and trophic composition into 12 measures of the fish community, or metrics, which best reflect the response of the community to habitat alteration (Table 1; Karr et al. 1986). A rating of 1, 3, or 5 is assigned to each metric depending on whether the observed measure deviates strongly, somewhat, or not at all from the optimal condition (unimpacted stream). The twelve scores are summed for each site to yield an IBI score, which are then grouped into six classes: excellent; good; fair; poor; very poor; and no fish (Appendix A).

Fish collections are made from disturbed and undisturbed streams and evaluated in terms of the relative condition of each watershed, given that the streams are of approximately the same size and have similar hydrogeologic characteristics. Expectation criteria for each of the metrics are then established utilizing data from streams with the least amount of human disturbance. Since the expectation criteria for each metric vary most widely with stream size, the expectation criteria should

Table 1. Metrics used for the original Index of Biotic Integrity as developed for streams in the midwestern United States (Karr et al. 1986).

Category	Metric	Scoring criteria[1] 5	3	1
Species richness and composition	Number of fish species	high		low
	Number of darter species	high		low
	Number of sunfish species	high		low
	Number of sucker species	high		low
	Number of intolerant spp.	high		low
	Percent green sunfish	high		low
Trophic composition	Percent omnivores	low		high
	Percent insectivores	high		low
	Percent top carnivores	high		low
Fish abundance and condition	Number of fish	high		low
	Percent hybrids	low		high
	Percent anomalies	low		high

[1]Rating system:
Excellent = 5
Fair = 3
Poor = 1

be adjusted for stream size. Platts (1979) found that aquatic geomorphology and fish population composition of headwater streams in Idaho changed substantially with increasing stream order. Thus, the expectation criteria for Idaho streams should be adjusted for stream size.

The suitability of the Index of Biotic Integrity to assess stream health for low-order Idaho streams was unknown until the present study, since Idaho streams typically differ substantially in community structure from mid-western streams.

Objectives

The objectives of this study were to:

1. *Evaluate the suitability of the original Index of Biotic Integrity (IBI) to assess the health of Idaho headwater streams.*
2. *Develop and refine a modified Index of Biotic Integrity applicable to Idaho headwater streams.*
3. *Test the ability of the Index of Biotic Integrity to adequately assess the health of Idaho streams.*
4. *Compare evaluations of stream health using the IBI with those of other specific measures of biotic integrity.*

Objective 1: To evaluate the suitability of the original Index of Biotic Integrity (IBI) to assess the health of Idaho headwater streams.

The original Index of Biotic Integrity was first applied to Indiana streams (Karr 1981). Metrics used in the original index reflected aspects of the fish community which most likely show changes after perturbations (Table 1). For example, the category "number of darter species" is used because members of the Etheostominae group (family Percidae) are generally fast water, benthic fishes which show marked response to changes such as channelization and siltation (Karr et al. 1986). However, fish communities in Idaho differ substantially from those in midwestern streams. Darters are not distributed in the northwestern U.S. and several other metrics are not meaningful. Therefore, the suitability of the original IBI to assess stream health was evaluated. The original IBI was scored and correlated with measures of stream quality.

Methods

To evaluate the suitability of the original IBI to assess stream health, 49 headwater streams from four watersheds (Coeur d'Alene, St. Joe, Priest Lake, and North Fork of the Clearwater) were sampled from June 1987 to September 1987 (Figure 1; Appendix B). Streams ranged in size from second to fifth order. Streams were selected for size and accessibility from USDA Forest Service Forest Visitors Maps (Scale 1:126,720) after consultation with Idaho Department of Fish and Game Biologists in Regions I and II.

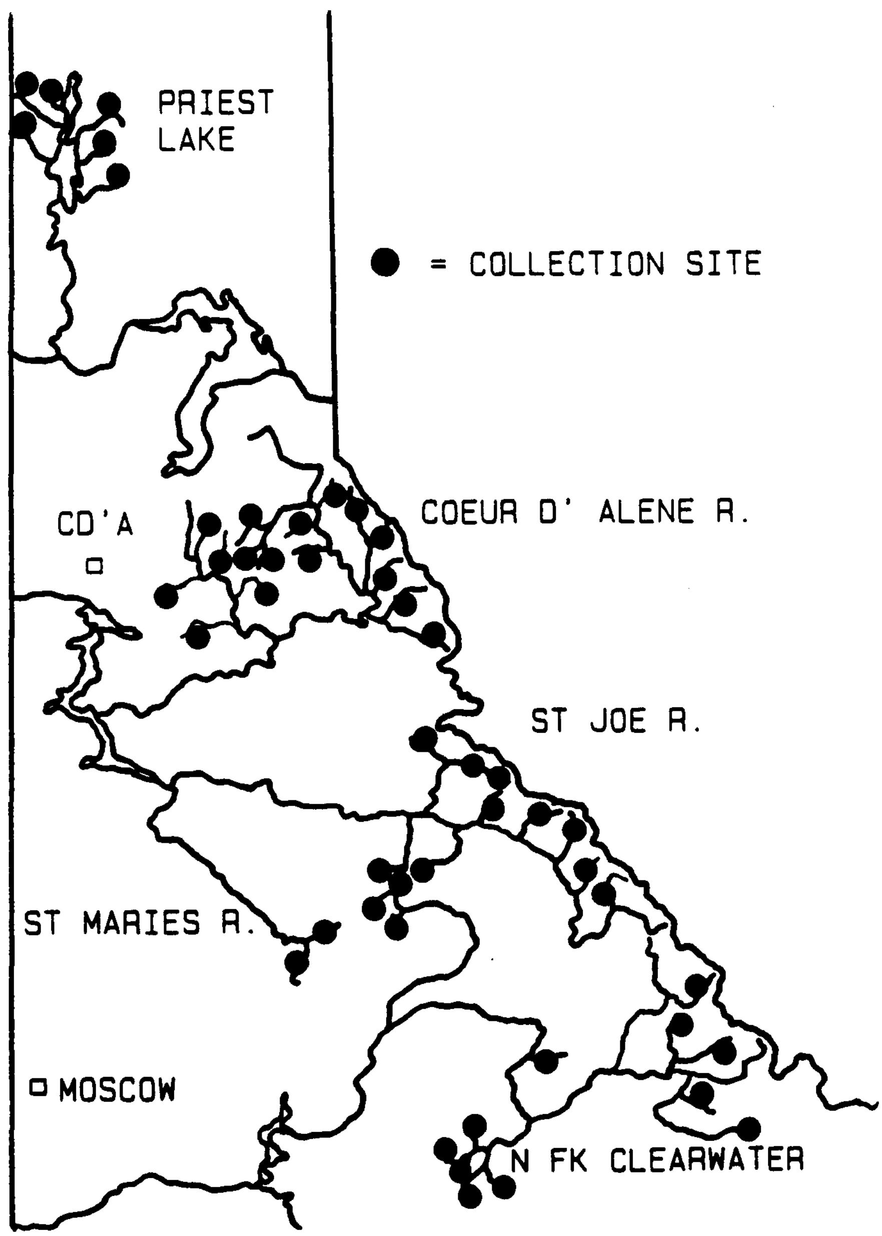

Figure 1. Location of collecting sites on headwater streams in northern Idaho. Abbreviations used were: CD'A - Coeur d'Alene; N.FK Clearwater - North Fork Clearwater River.

Stream sections from approximately 60 to 80 m long and incorporating at least two riffle--pool--run sequences were electrofished with 240V AC current supplied by a gas-powered Georator. Salt blocks, which typically raised the water conductivity to 100 μmohs/cm, were positioned at the head of each stream reach to increase the low water conductivity typically found in Idaho headwater streams. Two passes were made, the first pass was upstream, whereas the second was downstream. Fishes were identified to species, weighed (nearest g), measured (nearest mm), and returned alive to the stream. A few cottid fishes were preserved in 10% formalin solution for identification in the laboratory.

We used keys developed by Maughan (1972) and Eddy and Underhill (1984) to identify cottid fishes. Preserved sculpins were weighed and measured, and a length-weight regression (ln length vs. ln weight) was performed to back-calculate the weights of sculpins released in the field too small to register accurately on the field balance. Preserved weights were not adjusted for shrinkage. A similar length-weight regression was developed to back-calculate the weights of individuals of each species of salmonid less than 100 mm total length. Fishes were classified according to their tolerance to adverse environmental conditions (Table 2).

Stream health was evaluated from various physical-chemical determinations and from watershed activity information. Substrate embeddedness, or the percentage of the cobble and rocks of the stream bottom that were covered by fine sediment (Bjornn et al. 1977), was estimated by randomly sampling 50 rocks (one every 2 paces) and determining the amount of rock surface embedded in the sediments (0, 25, 50, 75, or 100%). Water conductivity was measured with a conductivity meter, total

Table 2. Relative tolerance to organic pollution, warm water, and sediment and trophic group of northern Idaho headwater fishes[1] (adapted from Hughes and Gammon 1987).

Family, species	Tolerance	Trophic guild
Salmonidae		
Brook trout	Intermediate	Insectivore[2]
Bull trout	Intolerant	Insectivore[3]
Cutthroat trout	Intolerant	Insectivore
Mountain whitefish	Intolerant	Insectivore
Rainbow trout	Intolerant	Insectivore
Cyprinidae		
Longnose dace	Intermediate	Insectivore
Northern squawfish	Tolerant	Piscivore
Redside shiner	Intermediate	Insectivore
Speckled dace	Intermediate	Insectivore
Catostomidae		
Largescale sucker	Tolerant	Omnivore/Herbivore
Mountain sucker	Intermediate	Herbivore
Cottidae		
Mottled sculpin	Intolerant	Insectivore
Shorthead sculpin	Intermediate	Insectivore[2]
Slimy sculpin	Intermediate	Insectivore[2]
Torrent sculpin	Intolerant	Insectivore

[1]occurrence of species from Moffitt and Bjornn (1984), Laumeyer (1976) and Maughan (1972)
[2]inferred from Scott and Crossman (1973)
[3]likely insectivorous to age II (R.L. Wallace, Professor, University of Idaho, personal communication)

alkalinity was measured with a Hach alkalinity kit, water temperature and air temperature were measured with a mercury field thermometer. The type of macrophytic growth, riparian zone plant community, percent instream cover, and riparian zone width were also estimated. Additional data gathered after field collecting included the amount of timber harvest and road density in the drainage. Percent timber harvest and road density of the drainage were determined through consultation with personnel from the U.S. Forest Service, Idaho Department of Lands, Plum Creek Timber Co., and Potlatch Industries.

Stream size was described by four parameters. Stream order is a dimensionless number system that describes stream size (Horton 1945). Shreve-Link number (Shreve 1967) is a numerical system in which all tributaries to a drainage are summed to provide the link number. We also used drainage area and stream discharge to describe stream size. Stream order, link number, elevation of the sample site, stream drainage area, and stream channel gradient were estimated from USGS topographical maps (scale 1:24,000 and 1:60,000).

We arbitrarily selected Shreve-Link number, discharge, and drainage area to reduce the number of variables needed to describe stream size. A multivariate cluster analysis, McQuitty's Similarity Analysis (Sarle 1982a), was performed using these three descriptors of stream size to separate the streams into size categories. Scoring criteria were then adjusted for stream size for those metrics influenced by size. If the mean of a metric varied significantly with stream size (Fisher's LSD Method; $P < 0.15$), separate scoring criteria were assigned to each metric. Thus, a metric may have multiple sets of expectation criteria depending on the stream size.

Two methods were used to assign scores to metrics. With continuous distributions, the range of values of metrics was divided into thirds to assign scores of 1, 3, or 5. For metrics with noncontinuous frequency distributions, natural separations were used to assign scores of 1, 3, or 5.

Expectation criteria for original IBI metrics were developed and means of original IBI metrics were compared between clusters of stream size. The metric density of fishes was adjusted for stream size. Metrics were then scored for all stations and an IBI score was determined by adding the scores of the individual metrics.

Results

A total of 1,949 fishes representing ten species and three families were sampled from 49 sections of 47 streams (Appendix D and E). Streams sampled ranged in elevation from 597 to 1,545 m, drainage areas ranged from 5 to 73 km^2, and estimated discharges ranged from 0.17 to 3.35 m^3/sec (Table 3; Appendix F). Three distinct clusters of stream size were found (Figure 2). Water conductivity ranged from 10 to 100 μmohs/cm. Road densities varied from 0 to 8.7 km/km^2, harvest areas ranged from 0 to 87%, and cobble embeddedness ranged from 8.5 to 55%. Streams contained from 1 to 6 fish species, 0 to 3 salmonid species, 0 to 2 cottid species, and 0 to 4 intolerant species (Table 4; Appendix G). Fish densities ranged from 2 to 31 fish/100 m^2.

Seven of the original 12 metrics, including number of fish species, number of intolerant species, percent insectivorous individuals, percent top carnivores (salmonids), density of fishes, percent hybrid individuals, and percent anomalies were applicable to Idaho headwater streams. No darters (Etheostominae), suckers (Catostomidae), sunfish (Centrarchidae), or other omnivores were found which precluded use of these metrics (Table 5).

Scoring of the criteria for the original IBI was established to separate the quality of northern Idaho streams (Table 6). The only metric that was significantly correlated with stream size was fish density, so scoring criteria for this metric were adjusted for stream size. The original IBI was significantly correlated with both road density and percent timber harvest ($P < 0.15$; Table 7). Scores for the original IBI ranged from 21-33; the lowest possible score was 7, while the highest was 35 (Figure 3). The original IBI classified most streams as being good to excellent health (Figure 4).

Table 3. Characteristics of headwater streams sampled in northern Idaho and their surrounding land areas.

	Mean	Median	Minimum	Maximum
Elevation (m)	1019	--	597	1545
Shreve link number	--	14	5	58
Stream order	--	3	2	5
Area collected (m^2)	330	--	174	717
Conductivity (μmohs/L)	40	--	10	100
Alkalinity (mg/L)	29.1	--	6.9	68.5
Temperature (°C)	13.8	--	10	19
Drainage Area (km^2)	30.48	--	5.18	73.48
Gradient (m/km)	27.8	--	11.1	61.5
Discharge (m^3/sec)	0.79	--	0.17	3.35
Road density (km/km^2)	2.3	--	0	8.7
Harvest area (% of drainage)	22.5	--	0	87
Cobble embeddedness (%)	23	--	8.5	55

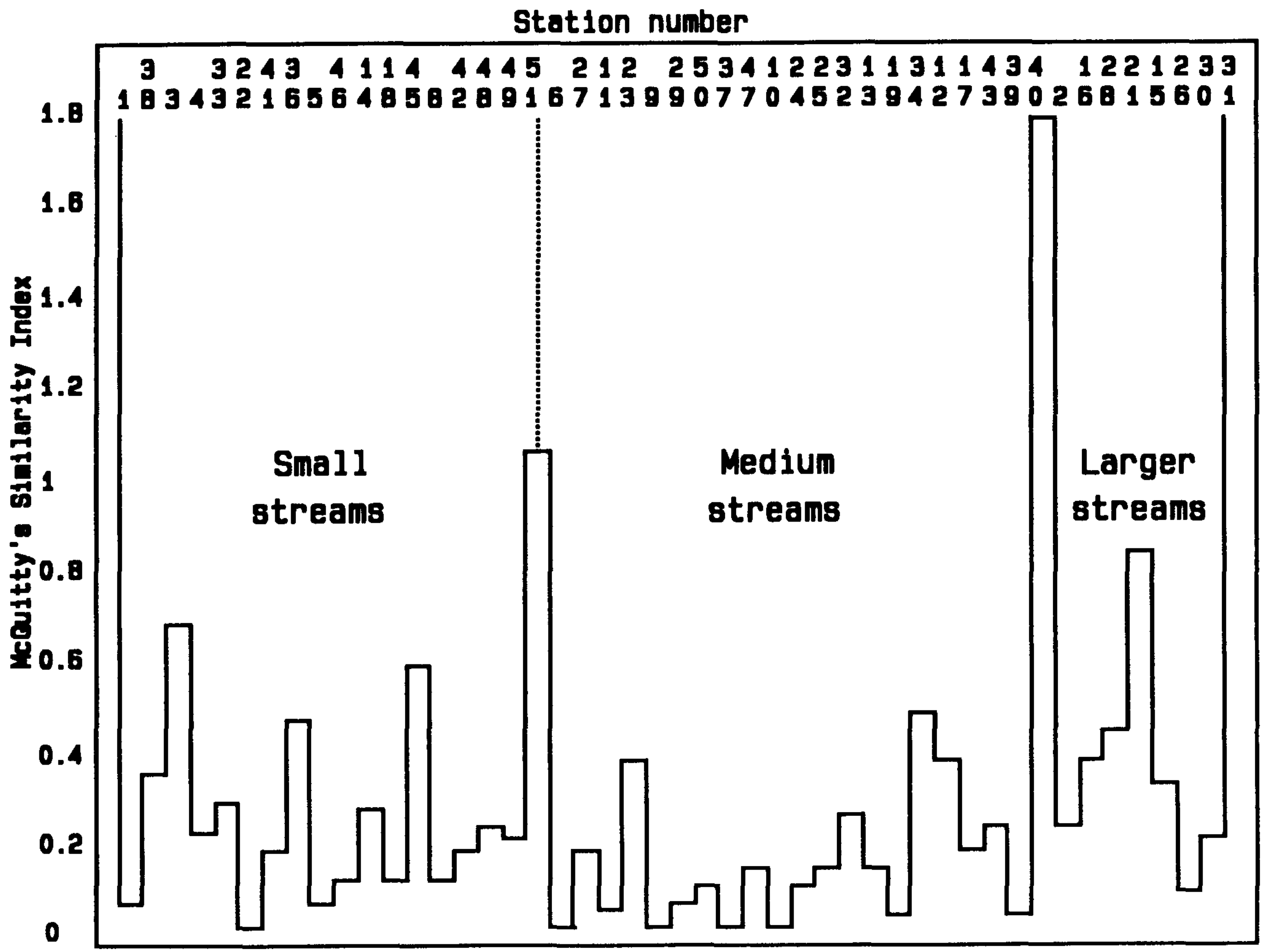

Figure 2. Distribution of size for northern Idaho headwater streams based on the McQuitty's Similarity Method.

Table 4. Fish composition and abundance collected from 49 northern Idaho headwater streams.

	Mean	Median	Minimum	Maximum
Number of salmonid species	--	2	0	3
Number of non-salmonid species	--	1	0	4
Number of Cottid species	--	1	0	2
Number of intolerant fish species	--	2	0	4
Number of introduced fish species	--	0	0	2
Percent introduced (fish) individuals	9.8	--	0	100
Percent salmonid individuals	50.5	--	0	100
Salmonid biomass ($g/100m^2$)	323	--	0	986
Non-salmonid biomass ($g/100m^2$)	29	--	0	178
Total biomass ($g/100m^2$)	352	--	33	990
Density of fishes ($No./100m^2$)	13	--	2	31
Density of salmonids ($No./100m^2$)	6	--	0	28
Density of non-salmonids ($No./100m^2$)	7	--	0	20

Table 5. Distribution of biotic variables from 49 Idaho headwater streams used for calculating the original Index of Biotic Integrity.

	Mean	Median	Minimum	Maximum
Number of fish and amphibian species	--	3	1	6
Number darter species	--	0	0	0
Number of sunfish species	--	0	0	0
Number of sucker species	--	0	0	0
Number of intolerant species	--	2	0	4
Percent green sunfish	0	--	0	0
Percent insectivores	100	--	100	100
Percent top carnivores (salmonid individuals)	50.5	--	0	100
Density of fishes (No./100m^2)	13	--	2	31
Percent hybrids	0.2	--	0	8
Percent anomalies	0.04	--	0	2

Table 6. Categories, metrics, and scoring criteria for the original IBI as adapted to Idaho headwater streams.

Category	Metric	Scoring criteria[1]		
		5	3	1
Species richness and composition	Number of fish species	>3	3	0-2
	Number of intolerant spp.	3+	2	0-1
Trophic composition	Percent insectivores	<100	100	100
	Percent top carnivores (Percent salmonids)	<30	31-70	770
Fish abundance and condition	Density of fishes[2]			
	Percent hybrids	>5	1-5	0-1
	Percent anomalies	>1	1	<1

[1]Rating system:
Excellent = 5
Fair = 3
Poor = 1

[2]Expectation criteria for fish densities are shown in Table 11.

Table 7. Correlation coefficients and probability values between the original IBI and measures of impact and stream size by Pearson Product-Moment Method.

Road density (n = 46)	Percent harvest (n = 45)	Cobble embeddedness (n = 47)
-0.382	-0.413	-0.101
0.009	0.005	0.729
Discharge (n = 47)	**Drainage area (n = 47)**	**Shreve link number (n = 47)**
0.142	-0.040	0.114
0.342	0.788	0.446

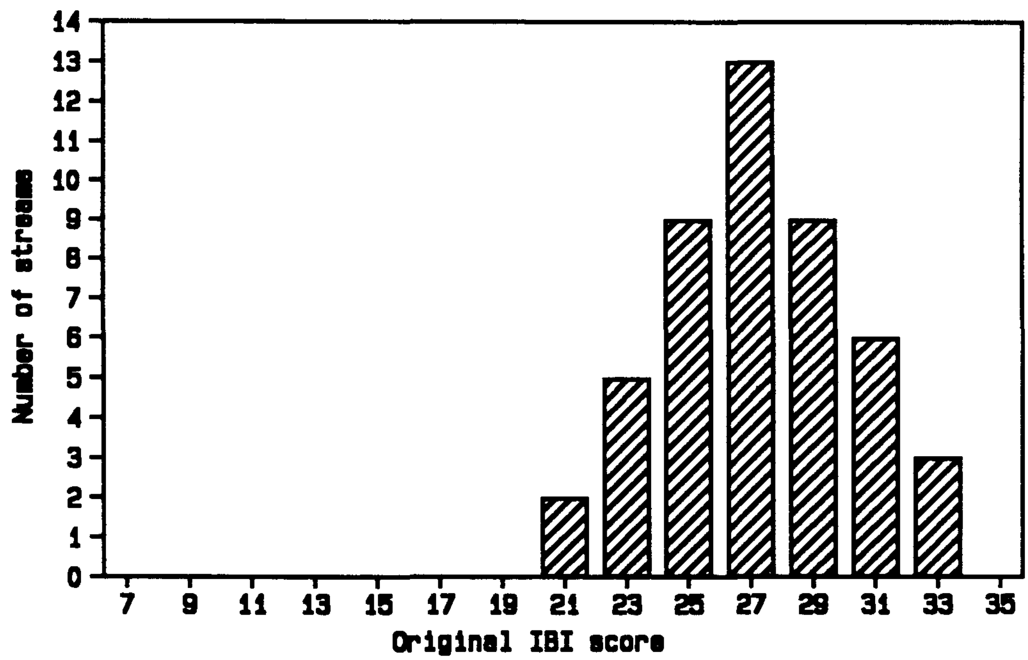

Figure 3. Frequency distribution of streams and scores using the original Index of Biotic Integrity.

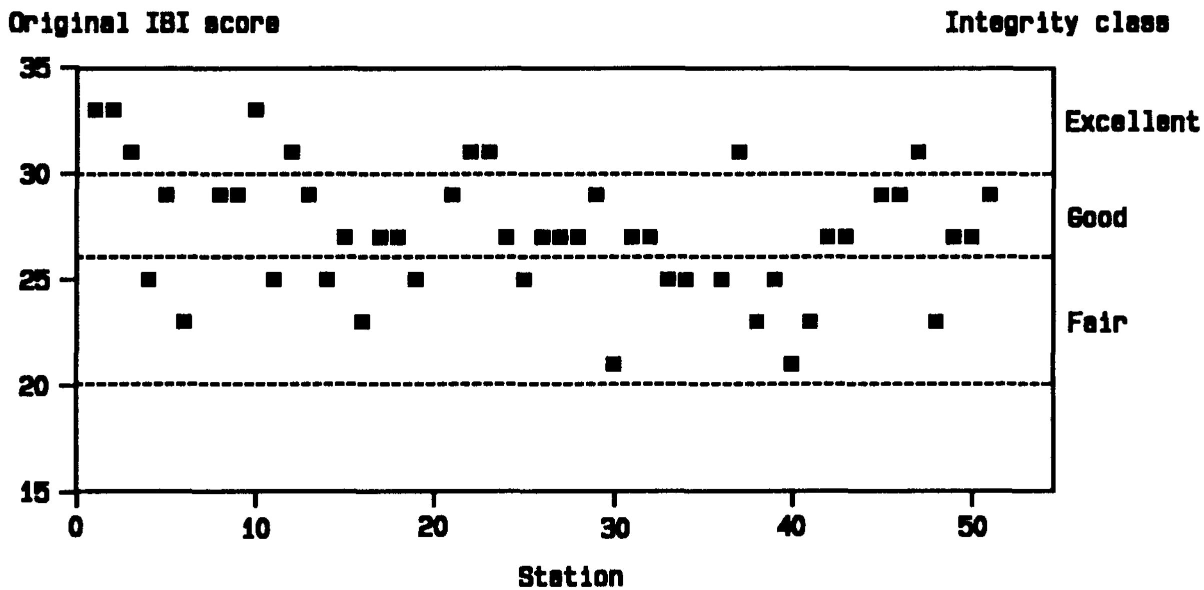

Figure 4. Stream quality based on the scores using the original Index of Biotic Integrity.

Objective 2: To develop and refine an Index of Biotic Integrity applicable to Idaho headwater streams.

Metrics included in the original Index of Biotic Integrity, as developed for midwestern streams, excluded components of the biotic community in Northwestern streams that respond to habitat alterations. Therefore, other components such as the presence of introduced species and abundance of other families of fishes, and amphibian and aquatic macroinvertebrate communities were included as possible metrics. Inclusion of amphibians was based on the work of Bury and Corn (1987) who found that stream amphibians were sensitive to habitat perturbations. Thus, the abundance of larval amphibians such as the tailed frog, *Ascaphus truei*, was examined in the study streams. Also, Winget and Mangum (1979) showed that aquatic macroinvertebrates exhibited marked changes in community structure following habitat alteration. Therefore, three aspects of the macroinvertebrate community: density of individuals, number of taxa, and diversity were evaluated as candidate metrics.

Methods

We replaced the metric for darter (Etheostominae) abundance by a metric reflecting sculpin (Cottidae) abundance, since these two families both possess a specificity for reproducing and feeding in benthic habitats (Karr et al. 1986). The metric, number of cottid species, as used by Hughes and Gammon (1987) was evaluated. The metric, percent common carp, was inappropriate, since carp are not found in northern Idaho (Simpson and

Wallace 1982). The metric reflecting occurrence of intolerant species known to occur in northern Idaho headwater streams was evaluated.

Because of the lack of fish species diversity in most Idaho headwater streams (Moffitt and Bjornn 1984; Laumeyer 1976; Maughan 1972), measures of other aquatic vertebrate and invertebrate communities were evaluated for inclusion in the modified IBI.

Amphibians and aquatic macroinvertebrates were sampled concurrently with the fish sampling in the study streams. Amphibians were collected with fishes by electroshocking, counted, and returned alive to the stream. Macroinvertebrates were sampled by taking four random Surber samples in a riffle, and preserved in FAA (formalin, alcohol, and acetic acid) for later laboratory identification. Most macroinvertebrates were identified to family or genus using Merritt and Cummins (1984). Plecoptera (stoneflies) were identified using Baumann et al. (1977) and Ephemeroptera (mayflies) were identified to species whenever possible with the key in Jensen (1966). Average weight of tailed frog larvae was determined by weighing approximately 50 tailed frog larvae collected in Surber samples. These larvae were similar in size to those collected by electrofishing.

The metrics in fish abundance and condition, number of individuals, percent hybrid individuals and percent anomalies were evaluated. Fish abundance expectation criteria were adjusted for stream size. We also evaluated the metrics of introduced individuals and total fish biomass used by Hughes and Gammon (1987; Appendix H).

Candidate metrics had to be significantly correlated ($P < 0.15$) with at least one of the three measures of physical disturbance (road density, percent harvest, and cobble embeddedness) to be included as a metric.

Thus, metrics that varied the most with habitat quality were chosen for inclusion in the IBI.

Once the list of candidate metrics was narrowed by correlation analysis, remaining metrics were more critically analyzed to assess their response to habitat quality. We clustered streams on three measures of habitat quality (road density, harvest area, and cobble embeddedness), and compared means of metrics among clusters using mean separation procedures such as Fisher's LSD, Tukey's W, and Scheffe's S statistics (Ott 1984). If the mean of a candidate metric differed significantly between at least two clusters, the metric was considered for inclusion in the IBI.

Once metrics were established for study streams, the scoring criteria for each metric were developed. The scoring criteria for metrics that were influenced by physical characteristics of the stream were adjusted for streams of similar hydrogeophysical character by establishing different scoring criteria in each of the clusters of stream size. For example, a first order, high gradient stream does not possess the same fish community as a fourth order, low gradient stream (Platts 1979). A McQuitty's similarity analysis was performed on the three measures of stream health, road density, percent harvest, and cobble embeddedness, to separate sample sites into clusters of stream quality. Metrics were then scored according to the criteria and metric scores were summed to yield an IBI score for each station. Expectation criteria for metrics that varied significantly with stream size clusters by Fisher's LSD Method (Ott 1984) were developed using the method described for the original IBI.

Results

A total of 1949 fish, 1230 amphibians, and 35,688 macroinvertebrates were collected. Macroinvertebrates collected represented 133 taxa, 45 families and 9 orders (Appendix I). Streams sampled contained from 1 to 6 species of fish and amphibians, 0 to 3 salmonid species, 0 to 2 cottid species, 0 to 4 intolerant species, and 16 to 35 invertebrate taxa. Fish densities ranged from 2 to 31/100 m^2, larval amphibian densities ranged from 0 to 87/100 m^2, and invertebrates ranged from 45 to 922/m^2.

Number of intolerant species, invertebrate density, number of salmonid species, salmonid density, fish density, and percent introduced individuals all were significantly correlated with one of the measures of impact ($P < 0.15$; Table 8). We found three distinct clusters of stream quality through McQuitty's Similarity Analysis (Figure 5). Number of species, number of salmonid species, density of tailed frog larvae, and invertebrate density had means that differed significantly with clusters of stream quality ($P < 0.05$). Table 9 includes the metrics that showed significant differences among stream quality clusters (LSD Method).

These eight metrics were then selected for inclusion in the modified IBI. Expectation criteria for metrics that did not vary significantly with stream size clusters were established by examining natural breaks in the distribution of the metrics or dividing the range into thirds. Metrics that varied significantly with stream size were number of non-salmonid species, density of fishes, density of salmonids, and density of tailed frog larvae (Table 9). Modified IBI metrics and scoring criteria are shown in Table 10. Adjusted scoring criteria by stream size are shown in Table 11.

Table 8. Ranked correlations and probability values between modified IBI metrics and measures of impact by Pearson Product-Moment Method (* = significant at α = 0.15).

Road density (n = 46)

Intolerant species	Invertebrate density	Salmonid density	Tailed frog density	Fish and amphib. species	Fish density	% introduced individuals	Salmonid species
-0.406	0.362	-0.263	-0.220	-0.152	0.144	-0.144	0.017
0.005*	0.013*	0.077*	0.141*	0.315	0.339	0.340	0.909

Percent harvest (n = 45)

Invertebrate density	Intolerant species	Salmonid species	Fish and amphib. species	Salmonid density	Fish density	Tailed frog density	% introduced individuals
0.495	-0.468	-0.360	-0.295	0.271	0.243	-0.218	0.152
0.0005*	0.001*	0.015*	0.049*	0.072*	0.108*	0.150*	0.317

Cobble embeddedness (n = 47)

Intolerant species	% introduced individuals	Salmonid density	Fish density	Salmonid species	Tailed frog density	Fish and amphib. species	Invertebrat density
-0.318	0.270	0.221	0.161	-0.072	-0.068	0.047	-0.024
0.030*	0.066*	0.135*	0.280	0.632	0.648	0.756	0.875

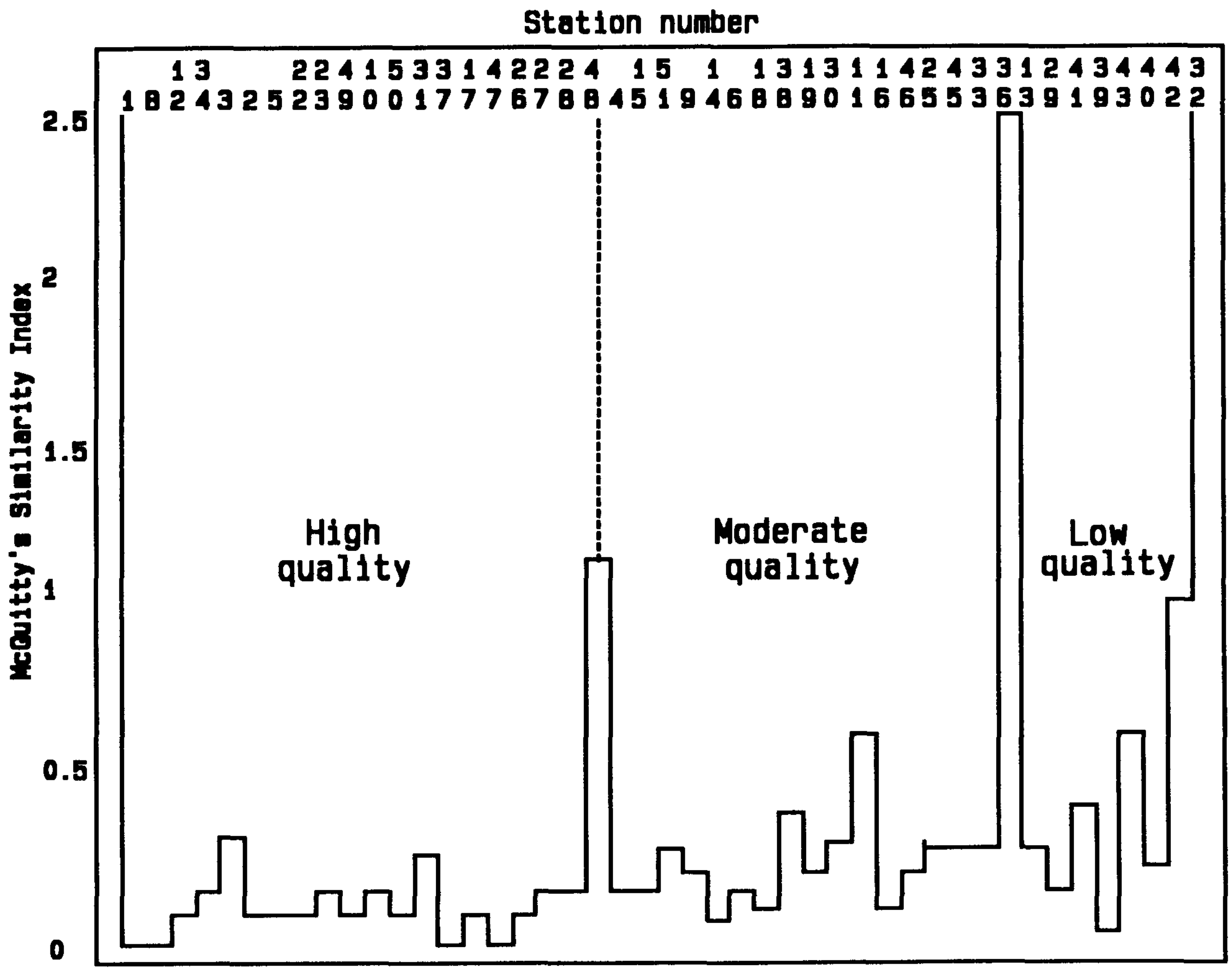

Figure 5. Distribution of quality for northern Idaho headwater streams based on the McQuitty's Similarity Method.

Table 9. Means of selected habitat measures and candidate IBI metrics within the three clusters of stream size for 47 northern Idaho headwater streams.

	Relative stream size		
	Small	Medium	Large
Drainage area (km^2)	16.5	33.7	60.1
Discharge (m^3/s)	0.55	0.77	1.47
Shreve link number	13	24	46.5
No. of fish and amphibian species	2.9	3.3	4
No. of non-salmonid species	1.48	1.61	2.5
Density of fishes (number/km^2)	157	130	103
Density of salmonid fishes (number/km^2)	90	46	34
Density of non-salmonid fishes (number/km^2)	66	57	96
Density of tailed frog larvae (number/100m^2)	15.1	4.5	2.3
Biomass of fish and amphibians (g/km^2)	341	308	480
Biomass of salmonid fishes (g/km^2)	320	280	427
Biomass of non-salmonid fishes (g/km^2)	21	28	53

Table 10. Categories, metrics, and scoring criteria for a modified IBI.

Category	Metric	Scoring criteria[1] 5	3	1
Species richness and composition	Number of species	>3	3	0-2
	Number of salmonid species	2+	1	0
	Number of intolerant spp.	3+	2	0-1
Fish abundance and condition				
	Percent introduced individuals	0	1-50	51-100
	Density of fishes/ $100m^2$ [2]			
	Density of salmonids/ $100m^2$			
Amphibian abundance	Density of tailed frog larvae/$100m^2$			
Aquatic invertebrate community	Density of invertebrates/m^2	0-126	127-161	161+

[1]Rating system:
Excellent = 5
Fair = 3
Poor = 1

[2]The criteria for these metrics varies with stream size. See Table 11.

Table 11. Scoring criteria for IBI metrics that vary significantly between streams of small, medium, and large size as defined by size clusters. Clusters were established by McQuitty's Similarity Method of multivariate cluster analysis, and numbers represent number of organisms per square meter of stream bottom.

Metric	Stream size cluster		
	Modified IBI Score		
	1	3	5
Small streams			
Fish density	>0.23	0.23-0.12	<0.12
Salmonid density	>0.15	0.15-0.05	<0.05
Tailed frog density	<10	10-40	>40
Medium streams			
Fish density	>0.16	0.16-0.08	<0.08
Salmonid density	>0.08	0.08-0.05	<0.05
Tailed frog density	<2.5	2.5-15	>15
Large streams			
Fish density	>0.14	0.14-0.08	<0.08
Salmonid density	>0.04	0.04-0.02	<0.02
Tailed frog density	<1	1-5	>5

Sensitivity ranges of the modified IBI metrics were inferred from the means of the metric scores on the three clusters of stream quality (Figure 5). Some metrics are sensitive to high levels of impact, some to low levels, and some are sensitive over the entire range (Figure 6).

The best possible score of the modified IBI is 40, since there are eight metrics, each with an maximum score of five (Table 12). The worst possible score is 0, if no vertebrates or macroinvertebrates were present. Therefore, the range of 0-40 was arbitrarily divided into five categories corresponding to the integrity classes of excellent, good, fair, poor, and very poor. Scores of 36-40 were classified as excellent; 30-34, good; 24-28, fair: 16-22, poor; 8-14, very poor, and 0-8, catastrophic (Table 12). The modified IBI scored most streams in the range from 20-36 (Figure 7). Modified IBI scores of streams sampled in northern Idaho ranged from 10-36 (Appendix J) and therefore most streams were in poor to good health as judged by the modified IBI (Figure 8).

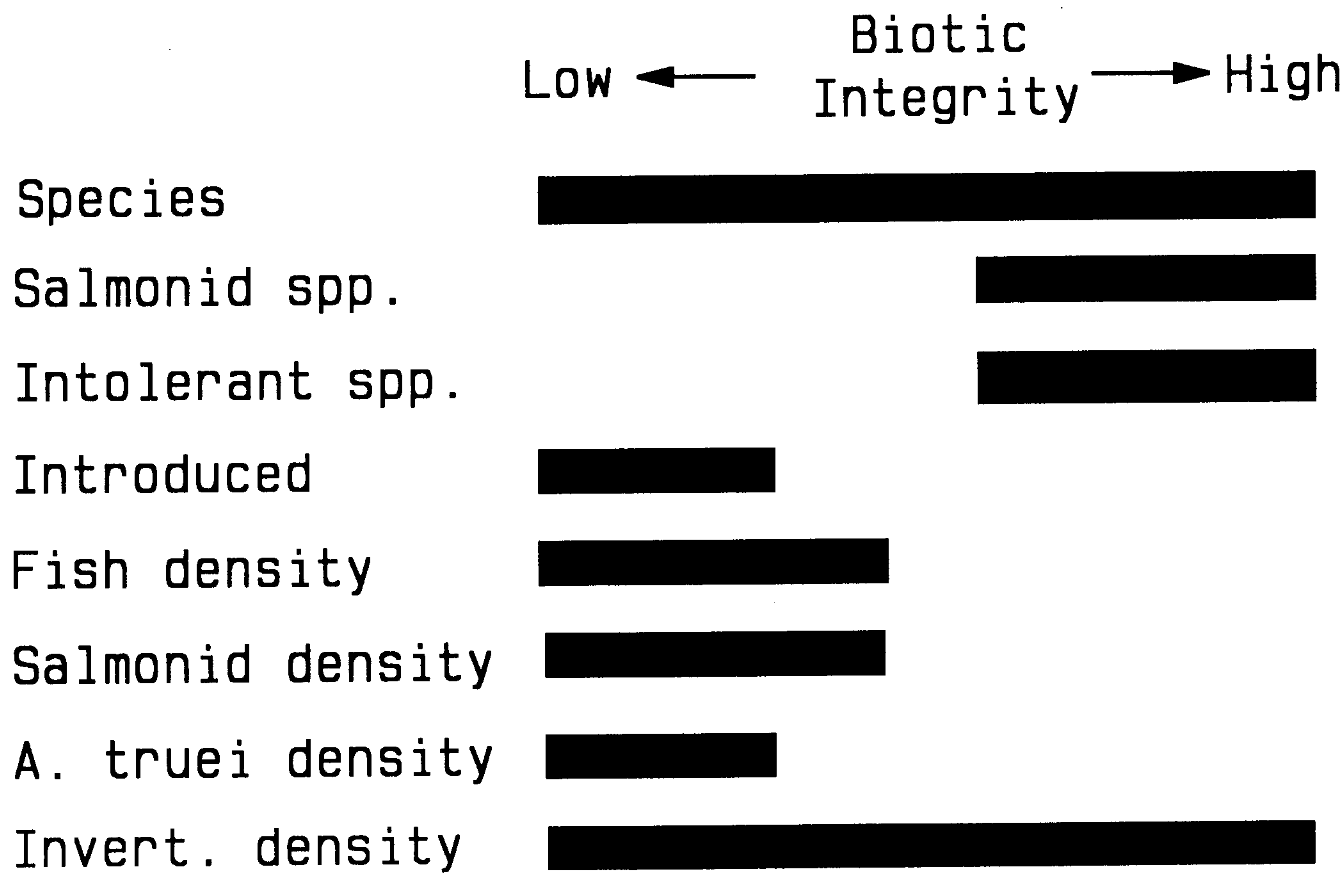

Figure 6. Sensitivity of modified IBI metrics to classification levels of biotic integrity. *A. truei* is the tailed frog larvae and Invert. is invertebrate. For example, the species category was sensitive over streams classified as having a low to high biotic integrity, while introduced fishes were sensitive over streams considered to be of a low biotic integrity.

Table 12. Integrity classes, class attributes, and IBI scores for the modified IBI.

Integrity class	Class attributes	IBI score
Excellent	Comparable to the best situations without human disturbance; all expected species including intolerants; amphibians abundant.	36-40
Good	Species richness lower, loss of some intolerants; less than optimum abundance.	30-34
Fair	Additional deterioration includes loss of most intolerants, fewer species, some introduced species present; lower diversity of salmonid species.	24-28
Poor	Few intolerant species present, introduced species abundant; amphibians rare, species richness low and abundance high.	16-22
Very poor	Mostly introduced fishes; amphibians absent, no intolerant species, only one fish species; high densities of small fishes.	8-14
Catastrophic	Repeated samplings find no fish or amphibians present; macroinvertebrates may or may not be present.	0-5

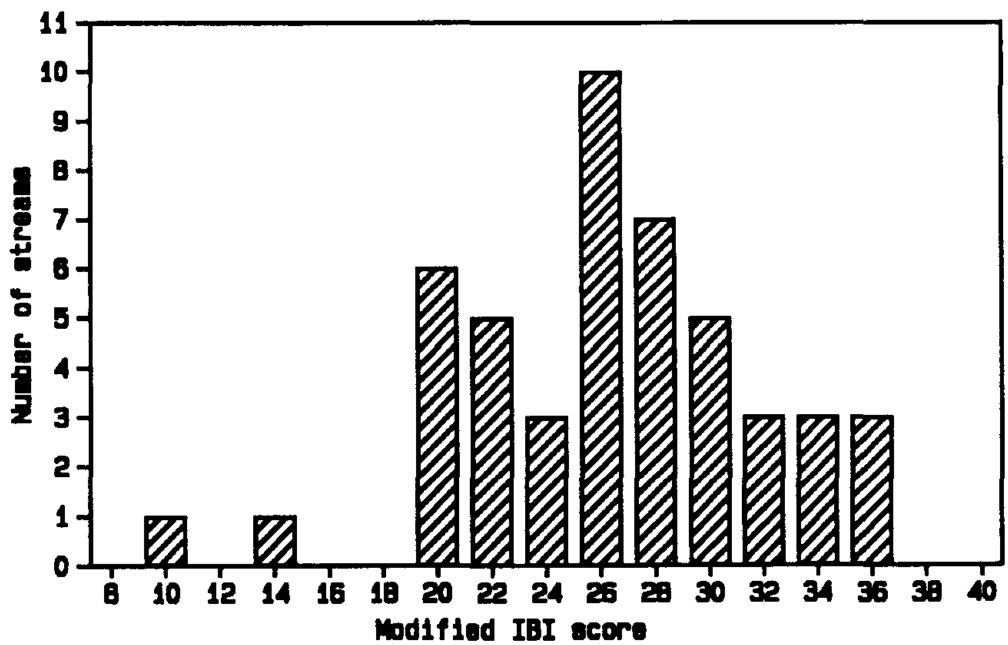

Figure 7. Frequency distribution of streams and scores using modified Index of Biotic Integrity.

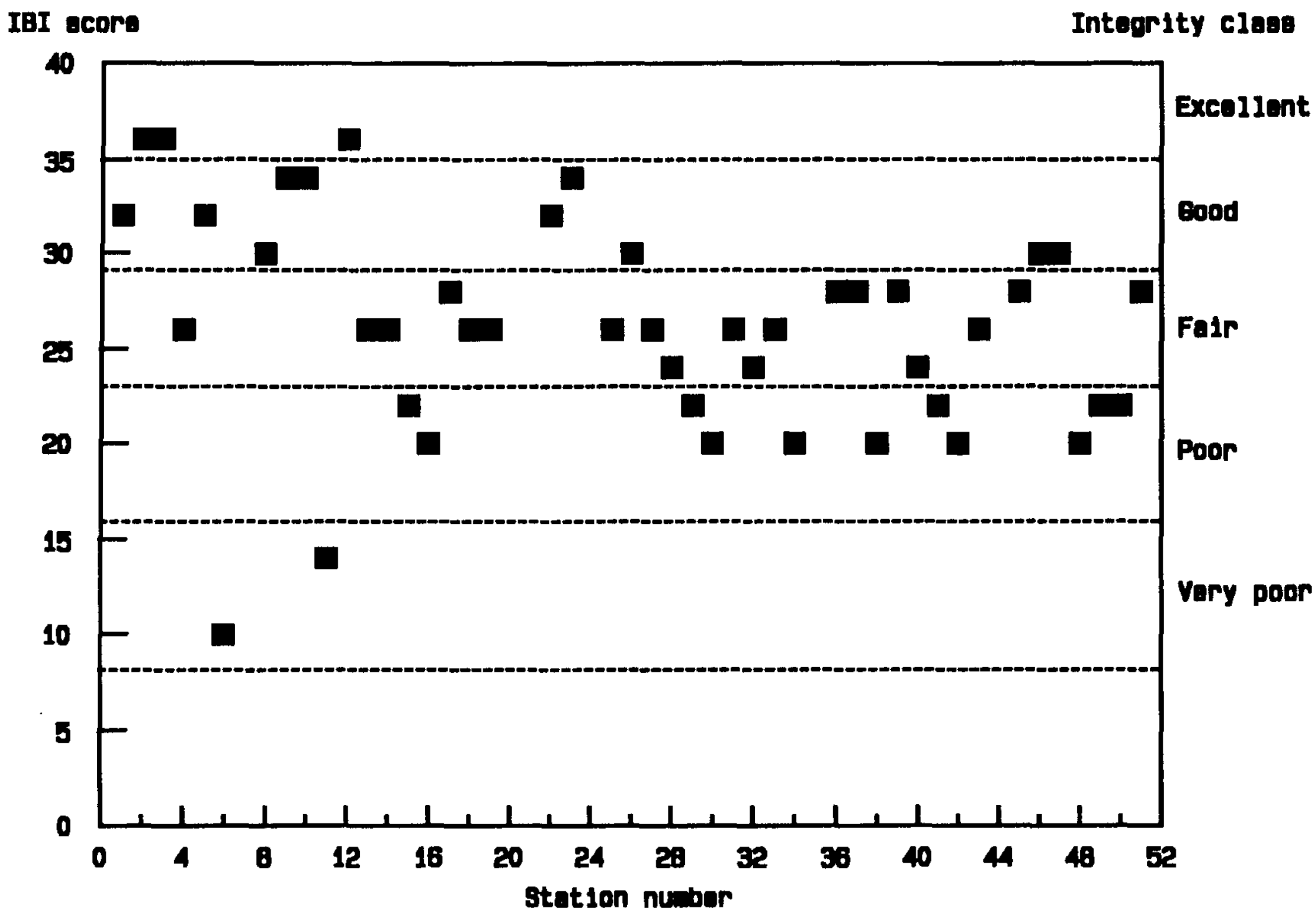

Figure 8. Stream quality based on the scores using the modified Index of Biotic Integrity.

Objective 3: To test the ability of the modified Index of Biotic Integrity to adequately assess the health of Idaho streams.

Our modified Index of Biotic Integrity contains metrics which measure a larger segment of the aquatic biota than the original IBI for northern Idaho headwater streams. To evaluate the ability of the modified IBI to determine the biotic integrity of the study streams, we reexamined data from the streams sampled.

Methods

The relative importance of each metric in contributing to the overall IBI score was examined through principal component analysis (Sarle 1982b). The factor loadings of metrics on the significant principal components (eigenvalue >1) would be similar, if metrics contributed equally to the final IBI score. We also correlated the scores of individual metrics with the final IBI score to evaluate the relative contribution of each metric.

To determine whether metrics in the macroinvertebrate category are essential, modified IBI scores were computed without the macroinvertebrate metric. These scores were then correlated with measures of habitat impact and stream size to determine if removal of the macroinvertebrate metric adversely affected the ability of the modified IBI to assess stream health.

Correlation analysis was used to compare the final IBI scores from all sites against various measures of quality and stream size. If the modified IBI scores correlated significantly with timber harvest area, road density, and cobble embeddedness, the index was considered an effective measure of stream health.

Results

We found significant correlations between modified IBI scores and road density (Figure 9) and percent harvest of the drainage (Figure 10). Correlations between the modified IBI scores and percent harvest were higher than that for road density (Table 13).

All metrics except invertebrate density contributed significantly ($r > 0.40$) to at least one of the significant principal components (Table 14). Correlations of the metric scores with the overall modified IBI scores indicated the importance of each metric (Table 15). Scores of all eight metrics were significantly correlated ($P < 0.05$) with the modified IBI scores. The modified IBI scores as calculated without the macroinvertebrate density metric were correlated less significantly with road density ($r = -0.212$) and percent harvest ($r = -0.402$) than modified IBI scores calculated with the macroinvertebrate density metric (Table 13).

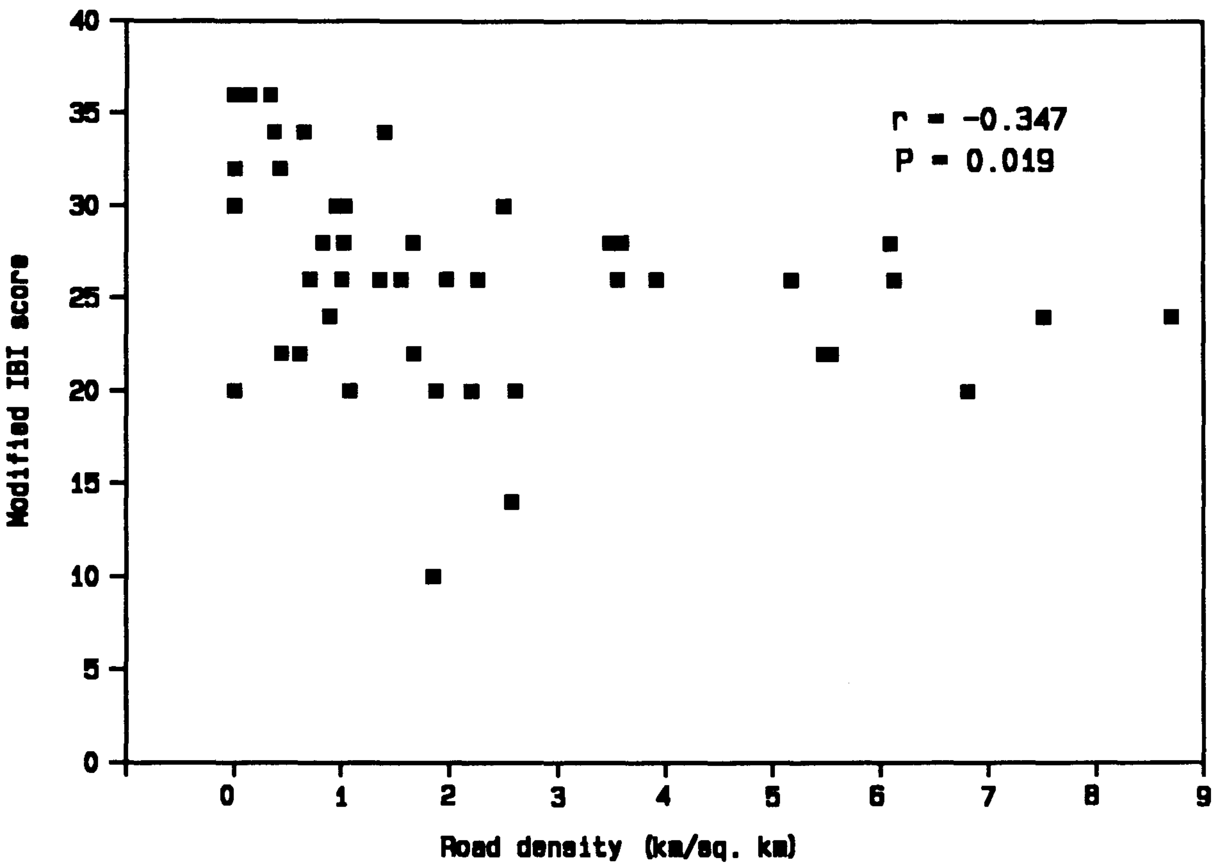

Figure 9. Relationship between modified Index of Biotic Integrity scores and road density for 47 headwater streams in northern Idaho.

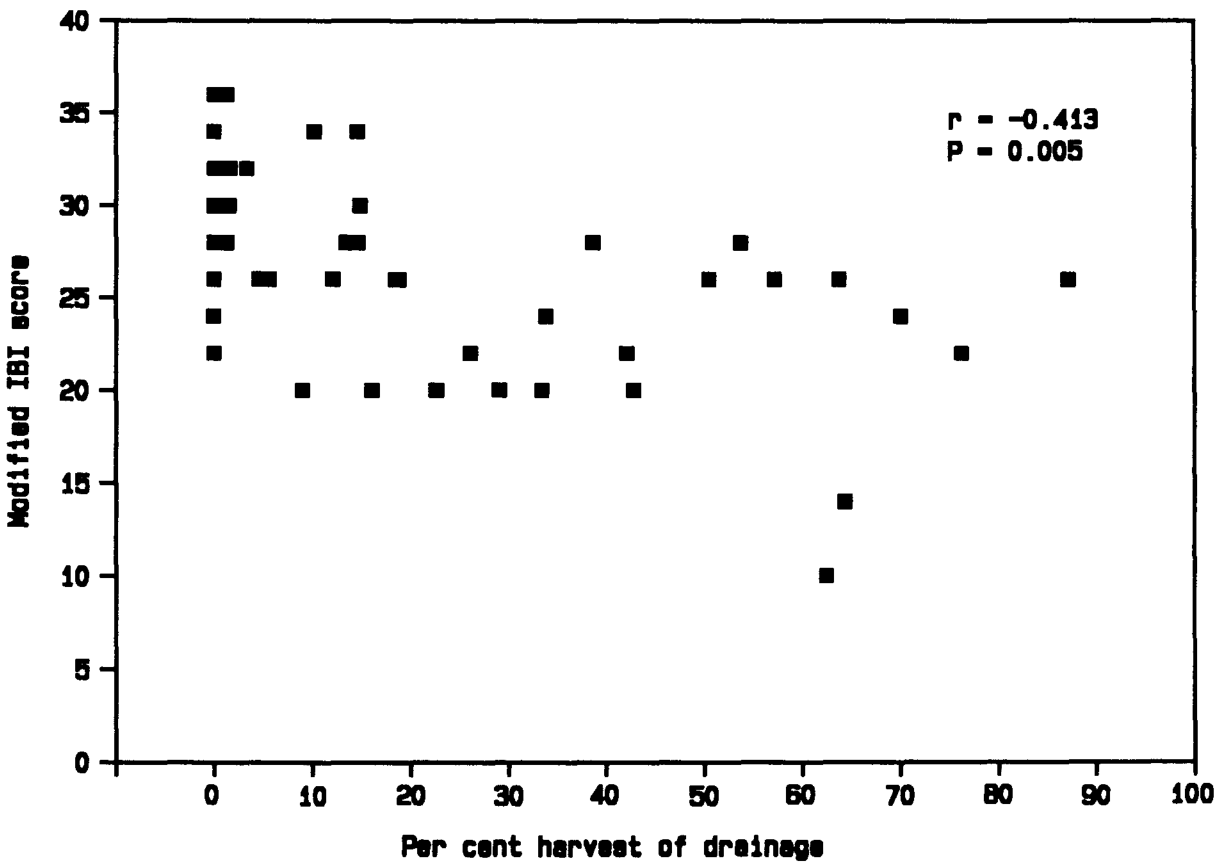

Figure 10. Relationship between modified Index of Biotic Integrity scores and proportion of drainage harvested by logging for 47 headwater streams in northern Idaho scores.

Table 13. Pearson Product-Moment correlation coefficients and probability values between the modified IBI calculated with and without the macroinvertebrate density metric and measures of impact and stream size.

	Modified IBI	IBI w/o inverts
Road density (n = 46)	-0.347 0.019	-0.212 0.105
Percent harvest (n = 45)	-0.521 0.0004	-0.402 0.006
Cobble embeddedness (n = 47)	-0.180 0.226	-0.200 0.189
Discharge (n = 47)	0.166 0.265	0.084 0.585
Drainage area (n = 47)	0.063 0.676	0.020 0.897
Shreve link number (n = 47)	-0.134 0.370	0.035 0.660

Table 14. Factor loadings of the modified IBI metrics on their first three principal components (Prin 1 through Prin 3; n = 47). Numbers represent relative significance of each metric in contributing to the overall modified IBI score; a loading of greater than 0.40 indicates significance.

Metric	Principal components		
	Prin 1	Prin 2	Prin 3
Tailed frog density	0.27	-0.12	0.58
Intolerant species	0.51	0.26	0.25
Fish and amphib. species	0.60	0.09	-0.13
Salmonid species	0.48	0.08	-0.44
Invertebrate density	0.24	-0.31	0.06
% introduced individuals	-0.06	0.39	0.59
Fish density	-0.14	0.54	-0.16
Salmonid density	-0.03	0.61	-0.11

Table 15. Correlations and probability values (P) between modified IBI metric scores and the modified IBI score by Pearson Product-Moment Method.

Metric	Correlation/P-value
Intolerant species	0.726 <0.0001
Fish and amphib. species	0.619 <0.0001
Salmonid species	0.502 0.0003
Salmonid density	0.441 0.0019
% introduced individuals	0.403 0.0066
Tailed frog density	0.391 0.0134
Fish density	0.358 0.0134
Invertebrate density	0.319 0.0289

Objective 4: To compare evaluations of stream health using the IBI with those of other specific measures of biotic integrity.

The effectiveness of any index will generally determine its widespread acceptance. As indicated earlier, the Index of Well Being (Gammon 1976), Shannon and Brillouin diversity indices (Pielou 1975), and abundance of desirable species (Coble 1982) all have been used to assess stream health. We compared these indices with the modified IBI to further assess the effectiveness of our index at discerning stream health.

Methods

For comparison with the IBI, five additional measures of biotic integrity were calculated for the study streams. First, Shannon diversity (H') was calculated for fish and amphibians by weight/km and by numbers/km. $H' = -\Sigma(\pi * \log_e \pi)$ where π is the proportion of the ith species from the sample (Pielou 1975). The Index of Well Being (IWB) (Hughes and Gammon 1987) which incorporates two measures of Shannon diversity (H'), and two measures of abundance, was calculated for fishes (numbers and biomass). The Index IWB $= 0.5 \log_e N + 0.5\log_e B + H'_N + H'_B$, where N is the number of individuals caught/km, B is the biomass of individuals caught/km, and H' is Shannon diversity. This composite index reflected the quality of fish communities better for an Oregon stream than any single measure of either diversity or abundance (Hughes and Gammon 1987).

The Brillouin Diversity Index (Pielou 1975) was calculated for both aquatic vertebrates (fish and amphibians) and invertebrates. Brillouin diversity (H) is a measure of both species richness and evenness which is similar to the Shannon diversity index (Pielou 1975):

$H = (1/N)\log_2(N!/n_i!+n_2!+...+n_s!)$, where N is the total number of individuals collected, n_i is the number of individuals within a species, and n_s is the number of species collected.

These five measures of biotic integrity were then compared with the modified IBI through correlations of various indices with measures of habitat alteration and stream size. We considered our IBI successful if correlations were higher with measures of stream quality, and lower with the measures of stream size, than Shannon diversity, the IWB, or Brillouin diversity.

Results

Shannon diversity of fish and amphibians by weight and numbers, the Index of Well Being, and the Brillouin diversity of both fishes and aquatic macroinvertebrates were significantly correlated with the three measures of impact and the three measures of stream size (Table 16). The modified IBI correlated better with percent harvest and cobble embeddedness than any other index. Only the original IBI correlated more highly with road density ($r = -0.382$) than the modified IBI ($r = -0.347$) although the difference was not significant. However, all indices except Shannon diversity of fishes by biomass and the Index of Well Being correlated more highly with discharge than the modified IBI, and all indices correlated better with drainage area and Shreve Link Number than the modified IBI. Thus, these other indices are more strongly influenced by stream size than the modified IBI, which was corrected for stream size.

Table 16. Pearson Product-Moment correlation coefficients and probability values between divestity indices and measures of impact and stream size. Abbreviations used are: IWB - Index of Well Being; H'-weight = Shannon diversity of fishes by biomass; H'-numbers = Shannon diversity of fishes by numbers.

Road density (n = 46)

H'-weight	IWB	H-fishes	H'-numbers	H-inverts
-0.259	-0.194	-0.161	-0.147	-0.033
0.082	0.196	0.286	0.330	0.828

Percent harvest (n = 45)

H'-weight	IWB	H-fishes	H'-numbers	H-inverts
-0.387	-0.313	-0.312	-0.295	-0.126
0.009	0.037	0.037	0.049	0.408

Cobble embeddedness (n = 47)

H'-weight	IWB	H-fishes	H'-numbers	H-inverts
-0.148	0.052	0.035	-0.007	0.0001
0.322	0.818	0.960	0.960	0.999

Discharge (n = 47)

H'-weight	IWB	H-fishes	H'-numbers	H-inverts
0.244	0.229	0.097	-0.049	-0.008
0.098	0.121	0.517	0.745	0.957

Drainage area (n = 47)

H'-weight	IWB	H-fishes	H'-numbers	H-inverts
0.389	0.370	0.289	-0.189	0.070
0.007	0.010	0.049	0.202	0.642

Shreve link number (n = 47)

H'-weight	IWB	H-fishes	H'-numbers	H-inverts
0.393	0.384	0.306	-0.169	0.125
0.006	0.008	0.036	0.256	0.404

DISCUSSION

Karr et al. (1986) suggested that caution should be used in applying the original IBI outside the midwestern United States. We recognized that species richness and composition of fishes, two important concepts of the original IBI, were highly different in northern Idaho than in the midwestern United States. Streams sampled for this study exhibited a range of sizes and impacts. Sampling limitations of transporting a heavy shocker assured that few streams were relatively unimpacted by human activities, and shocker effectiveness limited streams to those of fifth order or smaller. Our fish sampling was conducted with a Georator that was considered more effective than a backpack electroshocker. Extremely low conductivity of sample streams may have affected fish sampling, although sampling effectiveness would be relatively constant. A constant sampling error would not affect the final scores for these metrics since the IBI is calculated from relative, rather than absolute abundances.

Cobble embeddedness was weakly correlated with road density in the drainage ($r = 0.186$). This low correlation may be a result of inadequate sampling for embeddedness which may explain why most of the candidate metrics and measures of biotic integrity were weakly correlated with embeddedness.

The original IBI proved to be a reasonable indicator of biotic integrity, even though only four of the original twelve metrics reflected any change in integrity. Examination of the scores for individual metrics revealed that the metric percent insectivores did not vary and the metrics percent hybrids and percent anomalies deviated slightly from the optimum score of 5. Of the four remaining metrics, the metric percent salmonids was not highly correlated with any of the measures of quality, and thus, not considered important in describing the response of the fish community to habitat quality in the study streams.

The original IBI was more highly correlated with road density of the drainage than the modified IBI, and only slightly less correlated with harvest area and cobble embeddedness (Tables 7 and 13). However, the original IBI tended to score most stations in the higher integrity classes (Figure 4), and therefore, had little utility in practical classification of stream quality. The original IBI classified most of the stations as "excellent", and none as "fair", "poor", or "very poor" although stream quality was not consistently high based on our observations.

Seventeen measures of the fish, amphibian, and macroinvertebrate communities were evaluated as candidate metrics, which probably represent many of the traditional measures of stream health. Several metrics included in the modified IBI (Table 10), however, were dissimilar to metrics used in the original IBI. Metrics in the amphibian abundance and aquatic invertebrate community categories have not been used, as previous IBI's have dealt solely with the fish community. The metric percent introduced individuals was used by Hughes and Gammon (1987) for the Willamette River, Oregon. The metric density of salmonids has not been included in other known indices. The number of salmonid species represents abundance of the top trophic guild in all but one of the study streams, and may replace the metric percent top carnivores in the original IBI (Karr et al. 1986). The metrics number of species, number of intolerant species, and density of fishes, have been widely used (Karr 1981; Karr et al. 1986; Angermeier and Karr 1986; Fausch et al. 1984; Hughes and Gammon 1987; Leonard and Orth 1986). Metrics in the trophic composition category were not significantly correlated with stream quality, probably because all of the fish sampled are commonly classified as insectivores (Table 2).

Another difference between the modified IBI and the original IBI was in the adjustment for stream size. Our metrics influenced by stream size were scored within clusters of stream size. In contrast, Karr (1986) graphed the metric values against stream order and visually split the graph into three ranges. We believe the accuracy of the scores should increase by statistical clustering of stream sizes.

The inclusion of amphibian and aquatic macroinvertebrate categories may concern some fisheries biologists. Fishery managers may be reluctant to sample for these organisms with field crews which are generally trained only in fish identification. Since the relationship between amphibian populations and logging has been demonstrated (Bury and Corn 1987), we believed that increased sensitivity could be obtained by including them in a modified IBI. Because only three species of amphibians: the tailed frog (*Ascaphus truei*), Dunn's salamander (*Plethodon dunni*), and Pacific giant salamander (*Dicamptodon ensatus*) are commonly encountered in northern Idaho headwater streams (Bury and Corn 1987), identification is not likely to be a problem. Also, macroinvertebrate sampling, sorting, and enumeration, as required for the modified IBI, can be easily performed by personnel not trained in aquatic entomology.

The modified IBI represents a composite index of biotic integrity of fish, amphibian, and aquatic macroinvertebrate communities. Thus, it is an integration of several measures of integrity that have been used individually by fisheries managers and researchers. The modified IBI correlated well with our measures of physical disturbance (Table 13), and therefore, is probably a good measure of the effects of habitat alteration on the biotic community of streams. Our adjustments for stream size proved to be effective as the modified IBI was not correlated with measures of stream size (Table 13). This is a distinct advantage of the modified IBI over the Shannon and Brillioun diversity indices and the IWB, since they cannot be corrected for stream size. The modified IBI scored streams from 10 to 36, which is almost the entire range possible if fish were present. The modified IBI appears to have the ability to distinguish small differences in stream quality on the basis of differences in fish, amphibian, and macroinvertebrate communities. This gives it greater sensitivity and therefore an advantage over other measures of biotic integrity that incorporate only fish or macroinvertebrate community characteristics.

Other measures of biotic integrity used in this study, included the Shannon diversity of fish by numbers and biomass, the Index of Well Being, and Brillouin diversities of both fish and macroinvertebrates, did not correlate as well as the modified IBI with measures of stream quality (Tables 13 and 16). In our sample streams, the Shannon diversity of fishes by biomass and the Index of Well Being (Hughes and Gammon 1987) provided reasonable measures of stream quality. As predicted by the stream continuum concept (Vannote et al. 1980), Shannon diversity of fishes by biomass was highly correlated with stream size (Table 16), and therefore, may not be a good indicator of biotic integrity among streams of different sizes.

The relative contributions of the eight metrics to the overall IBI score were evaluated through principal component analysis (Table 14). The first principal component (Prin 1) heavily weights the metrics which dealt with numbers of species, the second component weights the two fish density metrics, and the third weights percent introduced individuals and density of tailed frog larvae. For this reason, we consider all metrics important in contributing to the final IBI score. Also, all metrics are significantly correlated with the IBI score ($P < 0.03$).

Comparison of modified IBI scores among the major river drainages sampled provides a general comparison of drainage quality (Figure 11). In general, rivers in the North Fork Clearwater and Coeur d'Alene drainages are different from each other ($P < = 0.15$). Based on our analyses, all of the "excellent" and "very poor" streams in this study were found in the North Fork Clearwater drainage. "Excellent" streams were located near the Bitterroot divide, whereas "very poor" streams were located in the Orogrande Creek drainage. Although headwaters in the St. Joe River sampled were impacted by human activities, the biotic integrity of these streams was less affected than the headwaters of the Coeur d'Alene River. Most streams in the Priest Lake drainage have less timber harvest and roads (Appendix C); however, these streams are located in the Idaho batholith, a highly erosive granitic substrate. Previous timber harvest (> 25 years ago) and fires (the 1969 Sundance burn) in the Priest Lake drainage may continue to effect stream quality.

We are cautiously optimistic about the ability of the modified IBI to assess stream health of low order streams in northern Idaho. Validation of this method is incomplete especially since the same streams were used to develop the index as were used to classify the streams. Complete validation is imperative, however, before widespread nonjudicious use occurs. We are confident application of the modified IBI to streams with relatively nonerosive rock types in northern Idaho will prove successful for biotic community classification but do not know how ubiquitous the application can be made to other areas in the Pacific Northwest.

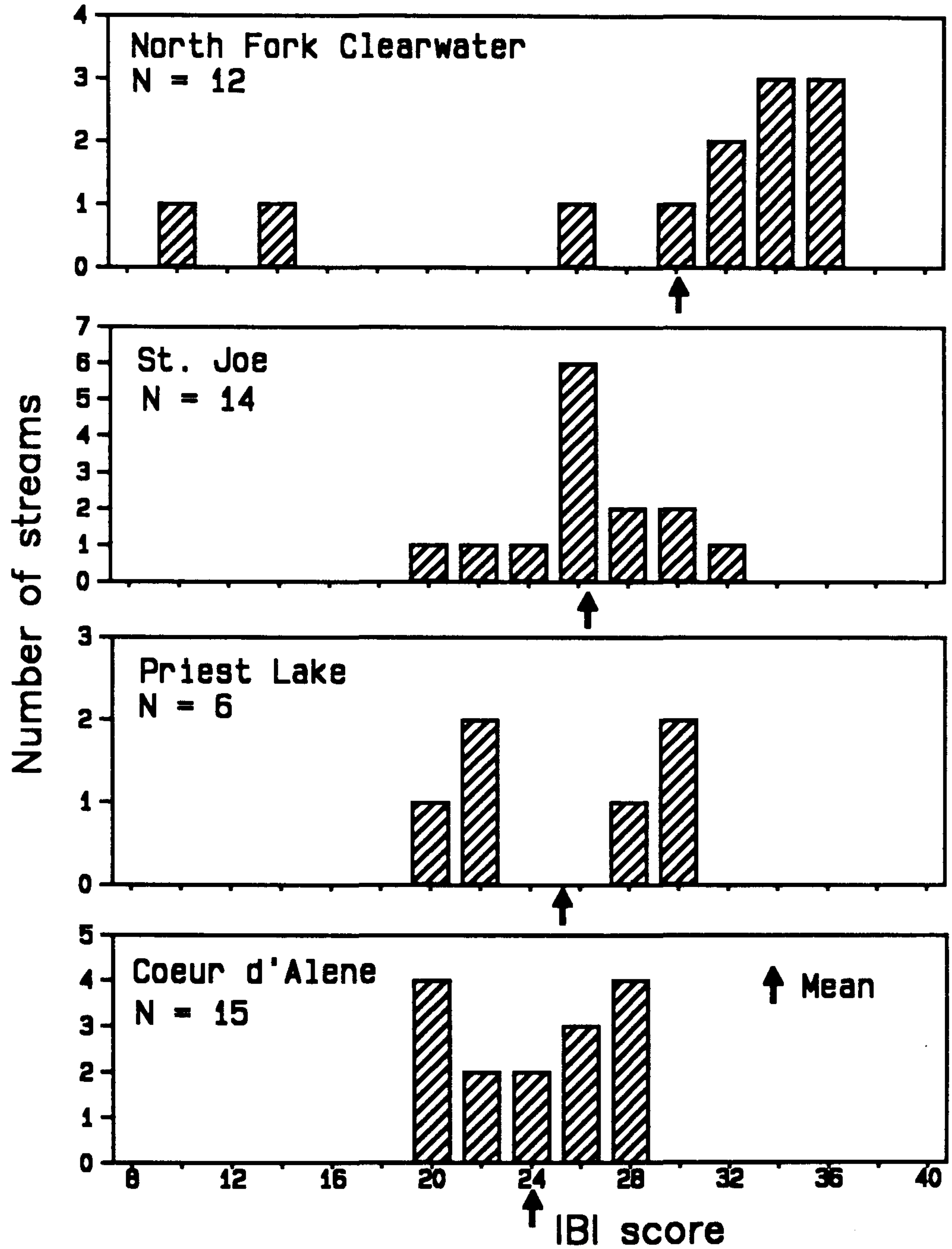

Figure 11. Comparison of modified Index of Biotic Integrity scores for headwater streams from four drainages in northern Idaho.

SUMMARY

1. Forty-nine low-order (2nd-5th order) streams were sampled in northern Idaho for fish, amphibians, and macroinvertebrates to relate their presence and abundance to stream condition or "health.". Several indices of stream health were evaluated with data collected.
2. The original Index of Biotic Integrity, developed for midwestern streams, was found unsuitable for northern Idaho streams. Only four of the 12 metrics included in the original IBI reflected changes in the biotic integrity of the study streams. The original IBI was too insensitive to changes in the biotic integrity and generally classified all streams in the "good" to "excellent" category, regardless of their quality.
3. A modified Index of Biotic Integrity containing eight metrics was developed from 17 candidate metrics. Expectation criteria of three metrics were adjusted for relative stream size.
4. The modified IBI correlated significantly with measures of physical disturbance and less with the measures of stream size than the Shannon diversity of fishes by biomass and numbers, the Index of Well Being, and Brillouin diversity of both fishes and aquatic macroinvertebrates and therefore, may be a better indicator of biotic integrity than these other indices.

5. We believe that the modified IBI has good potential to assess the biotic integrity of headwater streams with relatively nonerosive rock types in northern Idaho. The modified IBI has the sensitivity to detect changes in stream health, as changes not reflected in the fish community are apparently detected by the amphibian or aquatic macroinvertebrate metrics. Modified IBI scores were significantly correlated with road density and percent harvest of the drainages.

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Appendix A. Integrity classes and class attributes of the original Index of Biotic Integrity based on Karr (1981).

Integrity class	Class attributes
Excellent	The best situations without human disturbance; all expected species including intolerants, with a full array of age classes; balanced trophic structure.
Good	Species richness lower, loss of some intolerants; less than optimum abundance or sizes, trophic structure stressed.
Fair	Additional deterioration includes loss of most intolerants, fewer species, increasing tolerant species; older age classes of top predators rare.
Poor	Dominated by omnivores and pollution-tolerant forms, few top carnivores; growth rates and condition factors depressed; hybrids and diseased fish often present.
Very poor	Fewer fish, mostly introduced and tolerant fish; hybrids and diseased fish common.
No fish	Repeated samplings find no fish present.

Appendix B. Location of sampling sites for 49 northern Idaho headwater streams.

Station number	Drainage	Stream	Locality
1	N.Fk. Clearwater	Little Moose Ck.	80 m from mouth at Independence Ck. at br. on USFS Rd. 255
2		Toboggan Creek	Br. on USFS Rd. 581 1 km. from mouth at Cayuse Ck.
3		Cayuse Creek	500 m upstream fr. Br. on USFS Rd. 581
4		Osier Creek	USFS Rd. 737 at confluence with China Ck.
5		Goose Creek	USFS Trail No. 414, 200 m above mouth at Lake Ck.
6		Breakfast Creek	3 km upstream fr. Camp 57 on 57 Rd. (trib. Orogrande Ck.)
8		Larson Creek	200 m fr. mouth at N. Fk. Clearwater at br. on USFS Rd.700
9		French Creek	3 km upstream fr. jct. with Sylvan Ck.
10		Joy Creek	Br. on USFS Rd. 5216 100 m fr. mouth at Sylvan Ck.
11		Silver Creek	Br. on USFS Rd. 5054 at jct. with unnamed trib.
12		Little N. Fk. Clearwater	Br. on USFS Rd. 216 5 km downstream fr. Fish Lake
13	St. Joe River	E.Fk. Fishhook Ck.	Br. on USFS Rd. 201 10 km fr. source
14		Eagle Creek	5 km fr. mouth at St. Joe R. on USFS Rd. 1214
15		Quartz Creek	4 km fr. mouth at St. Joe R. on USFS Rd. 339.
16		Gold Creek	USFS Rd. 338 at Jct. with Berge Ck.
17		Red Ives Creek	3 km upstream fr. mouth at St. Joe R. on USFS Rd. 320
18		Bird Ck.	3 km upstream fr. mouth at St. Joe R. on USFS Rd. 338
19		Prospector Ck.	1 km fr. mouth at St. Joe R. on USFS Rd. 752
21		St. Maries R.	200 m upstream fr. jct. with Gold Center Ck.
22		Gold Center Ck.	5 km upstream fr. mouth at St. Maries R.
23	N. Fk. Clearwater	Little Lost L. Ck.	Br. on USFS Rd. 787
24	St. Joe River	Outlaw Ck.	Br. on USFS Rd. 1928 4 km fr. mouth at Fishhook Ck.
25		Sisters Ck.	Br. on USFS Rd. 2744
26		Loop Ck.	200 m upstream Fr. Jct. w/ Cliff Ck. on USFS Rd. 326
27		Allen Ck.	USFS Rd. 326 3 km upstream fr. mouth at Loop Ck.

Appendix B. (Continued)

Station number	Drainage	Stream	Locality
28	St. Joe River	N. Fk. St. Joe R.	Above jct. w/ Bullion Ck. on USFS Rd. 456
29	Coeur D'Alene R.	Falls Ck.	Br. on USFS Rd. 151 8 km fr. mouth at Shoshone Ck.
30		Shoshone Ck.	Br. on USFS Rd. 412 1 km upstream from jct. w/ Rampike Ck.
31		Lost Ck.	2 km fr. mouth at CD'A R. on USFS Rd. 442
32		Yellowdog Ck.	USFS Rd. 513 10 km fr. mouth on CD'A R.
33		Flat Ck.	Br. on USFS Rd. 400 at jct. w/ Svee Ck.
34		Cinnamon Ck.	Br. on USFS Rd. 208 1 km fr. mouth at CD'A R.
35		Teepee Ck.	Br. on Trail 451 at Jct. w/ Halsey Ck.
36		Teepee Ck.	Jct. w/ Little Elk Ck.
37		Prichard Ck.	Br. on USFS Rd. FH9 below jct. w/ Paragon Ck.
38		W. Fk. Eagle Ck.	USFS Rd. 152 5 km upstream fr. jct. w/ E. Fk. Eagle Ck.
39		Skookum Ck.	Br. on jeep trail 5km fr. mouth at N. Fk. CD'A R.
40		Cascade Ck.	USFS Rd. 534 3 km fr. mouth at N. Fk. CD'A R.
41		Burnt Cabin Ck.	USFS Rd. 206 1 km fr. jct. w/ Lone Cabin Ck.
42		Iron Ck.	USFS Rd. 794 10 km Fr. Mouth at N. Fk. CD'A R.
43		Big Elk Ck.	Br. on USFS Rd. 422 5 km Fr. mouth at Teepee Ck.
44		Trail Ck.	Br. on USFS Rd. 534 10 km fr. mouth at Teepee Ck.
45		Copper Ck.	Br. on USFS Rd. 3609 5 km fr. mouth at N. Fk. CD'A R.
46	Priest Lake	Kalispell Ck.	Br. on USFS Rd. 308 10 km fr. St. Rte. 57
47		S. Fk. Granite Ck.	Br. on USFS Rd. 319 at dead end
48		Beaver Ck.	Br. on USFS Rd. 1341 3 km fr mouth at Priest Lake
49		Soldier Ck.	Br. on Soldier Ck. Rd. at dead end
50		Hunt Ck.	Br. on Hunt Ck. Rd. 15 km fr. mouth at Priest Lake
51		Indian Ck.	Br. on Indian Ck. Rd. 1 km fr. jct. w/ S. Fk. Indian Ck.

Appendix C. Description of 49 northern Idaho sampling sites.

Station number	Stream name	Avg. depth (m)	Length (m)	Volume (m^3)	Area sampled (m^2)	Drainage area (km^2)	Road density (km/km^2)	Percent timber harvest	Shreve Link number
1	L MOOSE	0.44	80	175.49	395.5	48.86	0.00	0.00	24
2	TOBOGGAN	0.36	65	134.60	375.05	54.39	0.34	0.00	38
3	CAYUSE	0.41	65	229.37	560.95	43.20	0.14	0.00	18
4	OSIER	0.26	85	94.37	362.95	20.20	1.55	0.19	31
5	GOOSE	0.30	80	212.01	717.3	36.00	0.42	0.02	25
6	BREAKFAST	0.35	90	85.76	246.6	12.80	1.85	0.62	5
8	LARSON	0.25	65	111.47	438.1	28.36	0.00	0.00	20
9	FRENCH	0.22	80	79.47	357.6	22.65	1.40	0.15	17
10	HEM	0.26	85	109.45	415.65	19.19	0.65	0.10	11
11	SILVER	0.36	80	95.90	267.2	6.94	2.57	0.64	6
12	L N FK	0.22	65	46.48	211.25	7.74	0.00	0.01	17
13	FISHOOK	0.31	65	88.22	286.65	14.77	5.18	0.87	9
14	EAGLE	0.31	65	89.58	287.95	35.54	1.36	0.12	23
15	QUARTZ	0.47	65	230.78	493.35	64.69	1.67	0.26	48
16	GOLD	0.29	65	123.84	423.8	54.54	2.60	0.33	32
17	RED IVES	0.29	65	93.43	318.5	15.42	1.02	0.00	25
18	BIRD	0.29	65	90.58	317.2	38.99	2.26	0.18	34
19	PROSPECTO	0.30	65	59.78	201.5	14.37	1.97	0.05	12
21	ST MARIES	0.29	65	125.55	429.65	43.67	3.27	.	40
22	GOLD CENT	0.34	65	103.07	306.15	30.20	0.42	0.03	31
23	LLL	0.25	85	77.22	310.25	5.18	0.37	0.00	6
24	OUTLAW	0.38	75	130.52	346.5	18.36	1.12	.	10
25	SISTERS	0.28	65	62.22	224.9	19.13	3.53	0.57	13
26	LOOP	0.34	80	160.65	466.4	71.78	1.03	0.01	54
27	U LOOP	0.19	65	41.33	212.55	12.04	1.01	0.00	5
28	N FK ST J	0.32	75	169.31	527.25	53.60	0.89	0.00	46
29	FALLS	0.26	65	67.90	264.55	22.15	5.48	0.42	17
30	SHOSHONE	0.35	55	128.73	370.15	73.48	1.87	0.23	56
31	LOST	0.30	65	88.46	290.55	64.81	0.71	0.06	58
32	YELLOWDOG	0.28	80	82.66	295.2	21.05	8.70	0.70	9
33	FLAT	0.21	75	80.94	393.75	24.27	3.91	0.50	26
34	CINNAMON	0.19	65	41.86	224.25	15.10	0.00	0.09	14
35	L TEEPEE	0.38	75	183.09	476.25	81.34	2.62	0.19	83
36	U TEEPE	0.28	65	65.93	232.7	25.11	3.47	0.13	32
37	PRICHARD	0.23	65	57.03	252.85	22.21	0.83	0.15	13
38	W FK EAGL	0.27	85	92.79	345.1	50.71	2.20	0.29	25
39	SKOOKUM	0.23	55	40.68	174.35	16.53	6.09	0.54	18
40	CASCADE	0.22	60	39.07	175.8	16.07	7.51	0.34	20
41	B CABIN	0.26	65	55.12	209.3	29.57	5.55	0.76	31
42	IRON	0.30	65	55.40	183.3	25.90	6.81	0.43	18
43	B ELK	0.20	100	54.43	267.7	19.53	6.13	0.64	23
44	TRAIL	0.25	65	98.59	392.6	54.18	4.49	0.12	86
45	COPPER	0.23	65	71.76	312	36.62	3.59	0.39	32
46	KALISPELL	0.25	65	99.56	391.3	37.78	2.50	0.15	26

Appendix C. (Continued)

Station number	Stream name	Avg. depth (m)	Length (m)	Volume (m^3)	Area sampled (m^2)	Drainage area (km^2)	Road density (km/km^2)	Percent timber harvest	Shreve Link number
47	GRANITE	0.29	65	98.96	337.35	22.52	0.96	0.00	12
48	BEAVER	0.22	65	52.14	234.65	29.06	1.08	0.16	16
49	SOLDIER	0.33	65	95.34	291.85	34.12	0.44	0.00	15
50	HUNT	0.23	65	92.07	408.2	21.94	0.62	0.00	15
51	INDIAN	0.36	65	135.10	378.77	31.34	1.66	0.01	10

Appendix D. Number of fish and amphibians collected from 49 northern Idaho headwater streams.

Stream	Species											
	Mountain whitefish	Cutthroat trout	Rainbow trout	Cutthroat-Rainbow hybrid	Brook trout	Bull trout	Longnose dace	Speckled dace	Slimy sculpin	Shorthead sculpin	Torrent sculpin	Tailed Frog larvae
1 L MOOSE	1	3	2				2			6	1	
2 TOBOGGAN		7				3				9		7
3 CAYUSE		2				2				14		4
4 OSIER		11								43		15
5 GOOSE		6	3			1				68		50
6 BREAKFAST					70							
8 LARSON			12									22
9 FRENCH		11		1						12		87
10 HEM		24	1									167
11 SILVER					57					10		1
12 L N FK		12				2				24		183
13 FISHOOK		25										5
14 EAGLE		36								27		61
15 QUARTZ		21								38		17
16 GOLD		11								30		
17 RED IVES		17								42		23
18 BIRD		35								21		72
19 PROSPECTOR		33								26		126
21 ST MARIES	3	19					1	2		24	2	
22 GOLD CENTER		17								24	3	35
23 LLL		19				2				24		83
24 OUTLAW		44										51
25 SISTERS		25								27		43
26 LOOP		12			10					60	2	50
27 U LOOP		16								21		1
28 N FK ST JOE		5	4		21		1			46		1
29 FALLS		20										10
30 SHOSHONE										44		7
31 LOST			7				8			35	11	1

Appendix D. (Continued)

Stream	Species: Mountain whitefish	Cutthroat trout	Rainbow trout	Cutthroat-Rainbow hybrid	Brook trout	Bull trout	Longnose dace	Speckled dace	Slimy sculpin	Shorthead sculpin	Torrent sculpin	Tailed Frog larvae
32 YELLOWDOG		35	2	1						54		11
33 FLAT		7								44		30
34 CINNAMON		12								21		
35 L TEEPEE		3								8	1	
36 U TEEPE		5								17		2
37 PRICHARD		10			13							45
38 W FK EAGLE		16			15					44		
39 SKOOKUM		5			1					35		12
40 CASCADE		6								15		
41 B CABIN		2								12		
42 IRON		9								3		
43 B ELK		4								17		5
44 TRAIL		1					1			15	3	
45 COPPER		2			2					15		3
46 KALISPELL		3			1		1		4			
47 GRANITE		9			2	1			8			
48 BEAVER		13			9				16			
49 SOLDIER		4			19							
50 HUNT		37										
51 INDIAN		17			8							

Appendix E. Scientific names of fishes collected from 49 northern Idaho headwater streams.

Scientific name	Common name
Salmonidae	
Prosopium williamsoni	mountain whitefish
Salmo clarki lewisi	westslope cutthroat trout
Salmo gairdneri	rainbow trout
Salvelinus fontinalis	brook trout
Salvelinus malma	bull trout
Cyprinidae	
Rhinichthys cataractae	longnose dace
Rhinichthys osculus	speckled dace
Cottidae	
Cottus cognatus	slimy sculpin
Cottus confusus	shorthead sculpin
Cottus rhotheus	torrent sculpin

Appendix F. Physical and habitat data for 49 northern Idaho headwater streams.

Station	Stream name	Temp. (C)	Flow (m/s) (1Mohs/L)	Conduc- tivity (mg/L)	Alkalin- ity ness	Substrate embedded-	Stream percent cover	Stream Order (m)	Stream elevation (m/km)	Avg. gradient (m)	Avg. width pool
1	L MOOSE	16	0.43	85	59.4	21.5	20	3	981	31.72	4.9
2	TOBOGGAN	15	0.64	35	25.7	11.5	30	3	1055	19.95	5.7
3	CAYUSE	13	0.53	25	19.0	8.5	40	4	1545	18.52	8.6
4	OSIER	13	0.73	65	45.9	27	10	4	1097	40.61	4.2
5	GOOSE	13	0.32	88	61.4	9.5	20	3	1280	37.06	8.9
6	BREAKFAST	14	0.24	30	22.3	42.5	5	3	1164	11.43	2.7
8	LARSON	18	0.50	20	15.6	24.5	70	3	597	61.46	6.7
9	FRENCH	12	0.68	30	22.3	34	60	3	1177	16.87	4.4
10	HEM	13	0.62	20	15.6	10.5	5	3	1213	28.35	4.8
11	SILVER	12	0.46	35	25.7	33.5	10	2	1158	20.49	3.3
12	L N FK	14	0.72	20	13.7	24.5	30	3	1411	35.61	3.2
13	FISHOOK	17	0.55	25	20.5	37	20	3	1260	16.09	4.4
14	EAGLE	11	0.83	65	47.9	13.5	70	3	914	36.08	4.4
15	QUARTZ	13	0.94	50	44.5	25.5	40	3	927	29.37	7.5
16	GOLD	12	0.52	50	35.8	20	40	3	1109	21.14	6.5
17	RED IVES	13	0.94	50	41.1	18.5	10	3	1128	26.38	4.9
18	BIRD	14	0.82	100	68.5	23.5	40	3	853	33.16	4.8
19	PROSPECTO	15	0.39	20	20.5	16	50	3	866	56.04	3.1
21	ST MARIES	18	0.59	30	20.5	30	35	3	927	19.55	6.6
22	GOLD CENT	19	0.34	30	6.8	31	5	4	939	40.06	4.7
23	LLL	14	0.41	20	13.7	25	30	3	1402	55.76	3.6
24	OUTLAW	14.5	0.40	20	13.7	25	15	3	1128	31.07	4.6
25	SISTERS	14	0.39	20	20.5	34.5	30	3	1247	27.11	3.4
26	LOOP	14	0.72	70	47.9	11.5	25	5	975	12.48	5.8
27	U LOOP	12	0.53	38	27.4	13.5	50	4	1250	30.10	3.2
28	N FK ST J	19	0.46	65	47.9	22	5	5	963	14.11	7.0
29	FALLS	11	0.94	47	34.2	11	50	4	1021	37.39	4.0
30	SHOSHONE	17	0.76	38	27.4	12.5	10	4	896	12.88	6.7
31	LOST	17	0.53	47	34.2	29.5	25	4	756	16.19	4.4
32	YELLOWDOG	15	0.58	24	17.1	24.5	60	4	872	31.26	3.6
33	FLAT	13	0.70	65	47.9	29	40	4	914	29.62	5.2
34	CINNAMON	13.5	0.61	47	34.2	25.5	70	4	853	42.16	3.4
35	L TEEPEE	17	0.26	47	34.2	27.5	10	5	927	7.77	6.3
36	U TEEPE	17.5	0.30	56	41.1	17.5	40	3	942	11.14	3.5
37	PRICHARD	13.5	0.39	20	13.7	21	30	4	1036	47.99	3.8
38	W FK EAGL	15	0.55	.	.	22.5	10	4	853	18.65	4.0
39	SKOOKUM	13	0.55	10	13.7	28	65	3	866	30.56	3.1
40	CASCADE	13	0.26	45	34.2	29.5	75	4	878	30.13	2.9
41	B CABIN	14	0.38	35	20.5	16	50	3	914	19.58	3.2
42	IRON	15	0.32	53	34.2	20	25	3	975	26.08	2.8
43	B ELK	11	0.40	30	22.3	17	50	3	972	12.61	2.6
44	TRAIL	17	0.25	30	22.3	14	5	4	966	8.62	6.0
45	COPPER	11	0.28	20	15.6	32	5	4	744	12.38	4.8
46	KALISPELL	10	0.58	35	25.7	55	30	4	829	12.25	6.0
47	GRANITE	10.5	0.44	75	52.7	18.5	20	3	1067	19.11	5.1
48	BEAVER	11.5	0.44	20	15.6	19	70	3	799	39.40	3.6
49	SOLDIER	13	0.52	15	12.2	19	60	3	963	36.77	4.4
50	HUNT	11	0.52	10	8.9	11.5	10	3	1085	20.20	6.2
51	INDIAN	11.5	0.57	.	.	17.5	25	3	1097	28.93	5.8

Appendix G. Biological data for 49 northern Idaho headwater streams.

Station	Stream name	No. of fish species	No. fish & amphib. species	Fish density ($\#/m^2$)	Salmonid density ($\#/m^2$)	Non-salmonid den. ($\#/m^2$)	Number salmonid species	Number other species	Salmonid biomass ($g/100m^2$)	Other Spp. biomass ($g/100m^2$)	Station biomass ($g/100m^2$)
1	L MOOSE	6	6	0.038	0.015	0.023	3	3	216	19	104
2	TOBOGGAN	3	4	0.051	0.027	0.024	2	2	986	4	417
3	CAYUSE	3	4	0.032	0.007	0.025	2	2	354	9	108
4	OSIER	2	3	0.149	0.030	0.118	1	2	324	55	195
5	GOOSE	4	5	0.109	0.014	0.095	3	2	268	32	91
6	BREAKFAST	1	1	0.284	0.284	0.000	1	0	454	0	289
8	LARSON	1	2	0.027	0.027	0.000	1	1	180	0	64
9	FRENCH	3	4	0.067	0.034	0.034	2	2	116	8	59
10	HEM	2	3	0.060	0.060	0.000	2	1	264	0	100
11	SILVER	2	3	0.251	0.213	0.037	1	2	169	6	106
12	L N FK	3	4	0.180	0.066	0.114	2	2	215	24	184
13	FISHOOK	1	2	0.087	0.087	0.000	1	1	190	0	104
14	EAGLE	2	3	0.219	0.125	0.094	1	2	560	88	394
15	QUARTZ	2	3	0.120	0.043	0.077	1	2	422	23	158
16	GOLD	2	2	0.097	0.026	0.071	1	1	230	28	113
17	RED IVES	2	3	0.185	0.053	0.132	1	2	302	20	169
18	BIRD	2	3	0.177	0.110	0.066	1	2	463	29	258
19	PROSPECTO	2	3	0.293	0.164	0.129	1	2	236	44	228
21	ST MARIES	6	6	0.119	0.051	0.067	2	4	413	58	209
22	GOLD CENT	3	4	0.144	0.056	0.088	1	3	672	44	388
23	LLL	3	4	0.145	0.068	0.077	2	2	418	33	245
24	OUTLAW	1	2	0.127	0.127	0.000	1	1	638	0	289
25	SISTERS	2	3	0.231	0.111	0.120	1	2	406	20	303
26	LOOP	4	5	0.180	0.047	0.133	2	3	573	56	249
27	ALLEN	2	3	0.174	0.075	0.099	1	2	279	38	244
28	N FK ST J	5	6	0.146	0.057	0.089	3	3	736	31	250
29	FALLS	1	2	0.076	0.076	0.000	1	1	553	0	328
30	SHOSHONE	1	2	0.119	0.000	0.119	0	2	0	44	44
31	LOST	4	5	0.210	0.024	0.186	1	4	58	178	210
32	YELLOWDOG	4	5	0.312	0.129	0.183	2	3	816	69	503
33	FLAT	2	3	0.130	0.018	0.112	1	2	271	62	170
34	CINNAMON	2	2	0.147	0.054	0.094	1	1	236	38	203
35	L TEEPEE	3	3	0.025	0.006	0.019	1	2	55	6	176
36	U TEEPE	2	3	0.095	0.021	0.073	1	2	51	22	57
37	PRICHARD	2	3	0.091	0.091	0.000	2	1	409	0	254
38	W FK EAGL	3	3	0.217	0.090	0.127	2	1	324	67	214
39	SKOOKUM	3	4	0.235	0.034	0.201	2	2	280	84	337
40	CASCADE	2	2	0.119	0.034	0.085	1	1	183	39	203
41	B CABIN	2	2	0.067	0.010	0.057	1	1	11	28	36
42	IRON	2	2	0.065	0.049	0.016	1	1	306	14	276
43	B ELK	2	3	0.078	0.015	0.064	1	2	12	21	28
44	TRAIL	4	4	0.051	0.003	0.048	1	3	8	42	45
45	COPPER	3	4	0.061	0.013	0.048	2	2	28	17	31
46	KALISPELL	3	4	0.023	0.010	0.013	2	2	45	7	26
47	GRANITE	3	4	0.059	0.036	0.024	3	1	143	8	75
48	BEAVER	2	3	0.162	0.094	0.068	2	1	219	15	162
49	SOLDIER	2	2	0.079	0.079	0.000	2	0	287	0	154
50	HUNT	1	1	0.091	0.091	0.000	1	0	400	0	154
51	INDIAN	2	2	0.066	0.066	0.000	2	0	456	0	189

Appendix G. (Continued)

Station	Stream name	A. truei density (#/100m²)	Invert. density (#/m²)	No. of introduced species	% introduced individs.	No. of intoler. species	No. of cottid species	Percent salmonid individs.	No. of invert. taxa	% hybrid individs.
1	L MOOSE	0.00	205.9	0	0.00	4	2	0.40	34	0.00
2	TOBOGGAN	1.87	57.2	0	0.00	3	1	0.53	24	0.00
3	CAYUSE	0.71	89.6	0	0.00	3	1	0.22	26	0.00
4	OSIER	4.13	186.5	0	0.00	2	1	0.20	30	0.00
5	GOOSE	6.97	230.4	0	0.00	4	1	0.13	34	0.00
6	BREAKFAST	0.00	172.8	1	100.00	0	0	1.00	27	0.00
8	LARSON	5.02	16.7	0	0.00	2	0	1.00	16	0.00
9	FRENCH	24.33	135.3	0	0.00	2	1	0.50	24	0.04
10	HEM	40.18	139.4	0	0.00	3	0	1.00	25	0.00
11	SILVER	0.37	149.4	1	85.07	1	1	0.85	24	0.00
12	L N FK	86.63	72.1	0	0.00	3	1	0.37	23	0.00
13	FISHOOK	1.74	124.5	0	0.00	2	0	1.00	27	0.00
14	EAGLE	21.18	104.8	0	0.00	2	1	0.57	26	0.00
15	QUARTZ	3.45	219.6	0	0.00	2	1	0.36	35	0.00
16	GOLD	0.00	215.2	0	0.00	2	1	0.27	33	0.00
17	RED IVES	7.22	94.4	0	0.00	3	1	0.29	31	0.00
18	BIRD	22.70	72.1	0	0.00	2	1	0.63	25	0.00
19	PROSPECTO	62.53	58.3	0	0.00	2	1	0.56	27	0.00
21	ST MARIES	0.00	191.8	0	0.00	3	2	0.43	26	0.00
22	GOLD CENT	11.43	39.4	0	0.00	3	2	0.39	23	0.00
23	LLL	26.75	118.5	0	0.00	3	1	0.47	34	0.00
24	OUTLAW	14.72	67.3	0	0.00	2	0	1.00	24	0.00
25	SISTERS	19.12	114.1	0	0.00	2	1	0.48	28	0.00
26	LOOP	10.72	79.5	1	11.90	3	2	0.26	17	0.00
27	ALLEN	0.47	44.6	0	0.00	2	1	0.43	28	0.00
28	N FK ST J	0.19	45.7	2	32.47	2	1	0.39	17	0.00
29	FALLS	3.78	165.4	0	0.00	2	0	1.00	23	0.00
30	SHOSHONE	1.89	238.6	0	0.00	1	1	0.00	35	0.00
31	LOST	0.34	117.1	1	11.48	3	2	0.11	33	0.00
32	YELLOWDOG	3.73	263.1	1	2.17	3	1	0.41	31	0.01
33	FLAT	7.62	301.7	0	0.00	2	1	0.14	34	0.00
34	CINNAMON	0.00	230.0	0	0.00	2	1	0.36	34	0.00
35	L TEEPEE	0.00	256.0	0	0.00	2	2	0.25	37	0.00
36	U TEEPE	0.86	123.7	0	0.00	2	1	0.23	32	0.00
37	PRICHARD	17.80	86.6	1	56.52	2	0	1.00	25	0.00
38	W FK EAGL	0.00	95.9	1	20.00	1	1	0.41	23	0.00
39	SKOOKUM	6.88	111.9	1	2.44	2	1	0.15	29	0.00
40	CASCADE	0.00	47.9	0	0.00	1	1	0.29	26	0.00
41	B CABIN	0.00	192.9	0	0.00	1	1	0.14	31	0.00
42	IRON	0.00	160.5	0	0.00	1	1	0.75	22	0.00
43	B ELK	1.87	342.6	0	0.00	2	1	0.19	23	0.00
44	TRAIL	0.76	90.3	0	0.00	2	2	0.05	26	0.00
45	COPPER	0.00	174.7	1	10.53	2	1	0.21	28	0.00
46	KALISPELL	0.00	75.4	1	11.11	1	1	0.44	26	0.00
47	GRANITE	0.00	138.6	1	10.00	2	1	0.60	31	0.00
48	BEAVER	0.00	95.9	1	23.68	1	1	0.58	29	0.00
49	SOLDIER	0.00	75.1	1	82.61	1	0	1.00	32	0.00
50	HUNT	0.00	157.2	0	0.00	1	0	1.00	28	0.00
51	INDIAN	0.00	58.0	0	0.00	2	0	1.00	22	0.00

Appendix H. IBI metrics and scoring criteria for the Willamette River, Oregon (Hughes and Gammon 1987).

Category	Metric	Scoring criteria IBI excellent<----->poor 5	3	1
Species richness and composition	Number of native species	10+	5-9	0-4
	Number of cottid species	3+	2	0-1
	Number of native cyprinid species	6+	3-5	0-2
	Number of sucker species	2	1	0
	Number of intolerant spp.	3+	1-2	0
	Percent common carp	0	1-9	10+
Trophic composition	Percent omnivores	0-24	25-49	50+
	Percent insectivores	40+	20-39	0-19
	Percent catchable salmonids	10+	1-9	0
Fish abundance and condition	Number of individuals	100+	50-99	0-50
	Percent introduced individuals	0-1	2-9	10+
	Percent anomalies	0-1	2-5	6+
	Total fish biomass (kg/km)	31+	16-30	0-15

Appendix I. Numbers of macroinvertebrate individuals by taxa collected from 49 northern Idaho headwater streams.

	STATION																								
TAXA	1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19	21	22	23	24	25	26	27
Ephemeroptera																									
Baetidae																									
Baetis s.l.							1																		
B. alexandri		1	2	6	7			20	13				4	13	15	3		12						1	
B. bicaudatus	42	2		5	42			9	27		3				11	2			3		16		3	3	13
B. hageni	25	3				11			17		2	3	1	10			9	8							
B. intermedius	12		3	16	4			4		1		1		47	35	11	11	2	45	3	10	4	1	10	
B. propinqus	9														4										
B. tricaudatus	2	3		62		13		3			1	23	1	27		4		5	47	1		4	2		2
Centroptilum						219				57		1													
Ephemerellidae																									
Attenuatella marginata																									
Caudatella																									
Drunella coloradensis	20	2	3	43	7	8	1	19	18		4		1	9		1	2		2		3	10	3		
D. doddsi			2	1	1			1						2	2	3		1	2	1	2			1	1
D. spinifera					1	1		6	1							1			2		1		3		
Serratella tibialis	114	2	7	12	40	3	4	8		2	14	4	3	22	38	6	4	2	7	7	18	6	6	21	3
Timpanoga hecuba																									
Heptageniidae																									
Cinygma																									
Cinygmula	4	5	28	8	86	11	2	17	67	1	6	8	50	6	19	11	3	13			10	13	8	5	13
Epeorus albertae			27											1					1		1				
E. deceptivus					30			1	3		21		12	5	6	28		1			46	3	2	9	15
E. grandis																									
E. longimanus	3		3	2	21									5	5	2	1	1							
Heptagenia criddlei		10																							
Ironodes																									
Rhithrogena			31		15				2		8				2	21	2		25	2	7	2		24	9
Leptophlebiidae																									
Paraleptophlebia s.l.												1						2					1		
P. bicornuta																									
P. debilis						2				5															
P. heteronea										11										1					
P. vaciva																	7				3			1	
Siphlonuridae																									
Ameletus s.l.																							1		

Appendix I. (Continued)

TAXA	STATION 1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19	21	22	23	24	25	26	27
A. cooki		2					1		4				13								3			1	
A. similor									3															1	
A. sparsatus			3			1						2	4	8	1		16	6	2	3		5		2	
A. validus						9						2													
Plecoptera																									
Capniidae					2								8	1			1						7		4
Chloroperlidae																									
Kathroperla																									
Suwallia	8	17	1	1	6						1					12			4	1	1		1		
Sweltsa	1		22	15	50	10	10	10	26	1	10	34	32	33	106	32	26	16	2	8	27	17	79	46	20
Leuctridae																									
Despaxia	4		1	1	7			8						8	2	2	6				5		1		
Nemouridae																									
Amphinemoura						10				25		13							1						
Visoka	1							3				2	3			1	1	2			4		6		3
Zapada			33	7	14			3	2		19		2	21	2	10					8	4			4
Peltoperlidae																									
Yoraperla	1				1	8		21	2	13	14	6			4	5					3	5			
Perlidae																									
Calineuria																									
Doroneuria	6			29		2	1	6	5			5	3					3			4	2			1
Hesperoperla										1	12							1	1			1			
Perlesta																									
Perlodidae																									
Isoperla	1	1	1		7									7	2								1		
Megarcys	9	1		5		11		5			11	1	5	14	5	5		4	1	1	7	5	6	1	1
Setvena					22				4																
Skwala			10										3	6	10	1	7		6	2	2	2	7	15	1
Pteronarcyidae																									
Pteronarcys																									
Megaloptera																									
Sialidae																									
Sialis						3				2															
Trichoptera																									
Brachycentridae																									

Appendix I. (Continued)

TAXA	STATION 1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19	21	22	23	24	25	26	27
Amiocentrus							1																		
Brachycentrus	11	2	2	82	4		1	2						4		8	1	1	1					2	1
Micrasema	5	2				12	2			34		4	2	1						1					
Glossosomatidae																									
Agapteus																									
Glossosoma			1	4	1			1	5		1								3		1	4	1		1
Hydropsychidae																									
Arctopsyche	2	1		2	1				1		2			16		3	1		29	3	4	3	2	9	3
Hydroptilidae																									
Agraylea										1				3			3								
Lepidostomatidae																									
Lepidostoma										1			2												
Limnephilidae																									
Apatania					3								10		2			3						2	3
Dicosmoecus				1							1	3		1		1		1			1				
Ecclisiomyia									5				7	14	2			2			1		15		
Hesperophylax																									
Neophylax				3													1								
Neothremma											8														
Oligophlebodes																									
Onocosmoecus															1										
Pedomoecus																									
Psychoglypha		1								6					1	3	2	1					2		
Philopotamidae																									
Dolophilodes	7			30			3							30		1				3				1	1
Rhyacophilidae																									
Rhyacophila	21	2	15	22	25	3	2	13	5	20	9	12	4	19	25	8	5		2	1	20	8	3	3	2
Hemiptera																									
Corixidae																									
Coleoptera																									
Curculionidae																									
Dytiscidae																									
Hydroporous		1								3		1													
Elmidae																									
Heterlimnius	95	60	3	51	60	92	6	124	114	123	9	92	22	55	76	15	11	8	302	21	18	36	35	3	1

Appendix I. (Continued)

Taxa	STATION 1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19	21	22	23	24	25	26	27
Lara	1			3		1											1	1	1	1					
Narpus	3	1		1		1								4	1				1					1	
Optioservus	4	1																							
Haliplidae																									
Brychius																									
Hydrophilidae							1																		
Diptera																									
Athericidae																									
Atherix	3														2				5	1					
Blephariceridae																									
Agathon																									
Ceratopogonidae	1											1				2				1	1		3		
Chironomidae	132	26	33	52	132	18	8	70	35	59	44	47	77	180	187	44	70	47	17	34	61	40	75	43	12
Deuterophlebiidae					2																				
Dixidae																									
Dixa																									
Empididae																									
Chelifera																									
Oregoton			1		2	1					1		5		1			1			10	2	2		
Ephydridae																									
Pelecorhychidae																									
Glutops	3			32	2									9											
Psychodidae																									
Pericoma	1																								
Ptychopteridae																									
Ptychoptera						2				1		4													
Rhagionidae																									
Chrysopilus																									
Simuliidae																									
Simulium	1	1	4		6	4		3	1	20		54		3	1	3				1			3	2	1
Tabanidae										2															
Tipulidae																									
Antocha			2	1								1					2				1				
Dicranota	1		2						8	4			3	1			1	1							
Hexatoma		2	1		2	8	1	1	4		2	3	4	1	4										

Appendix I. (Continued)

Taxa	1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19	21	22	23	24	25	26	27
	STATION																								
Limnophila	1				1					1						2									
Tipula															1			1							
Hydracarina				1	1										1										
Oligochaeta				4	12				3	9		9		4	1										
Totals	554	149	241	502	617	464	45	358	375	402	192	348	281	590	575	252	194	152	512	98	299	175	280	207	115

Appendix I. (Continued)

Taxa	Station 28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	TOTALS
Ephemeroptera																		
Baetidae																		
Baetis s.l.																		1
B. alexandri						13										2	5	117
B. bicaudatus		36	12		15				2		1	3	7	20			1	278
B. hageni									2									91
B. intermedius		35	40	23	39	26	26	7	4	6	15	16	10	28	17	32	25	569
B. propinqus	4																	17
B. tricaudatus			8	2	38	22	9	4	1	9	8	7	2	5	13	19	17	364
Centroptilum																		277
Ephemerellidae																		
Attenuatella marginata																		0
Caudatella																		0
Drunella coloradensis		25	7	1	4	6	8		12	2		4		1	3	3	7	239
D. doddsi		8	136	3	17	15	1		7	9		4	3	7		8	13	251
D. spinifera			1	1	3	1	5	4				11	4	3	16	15		80
Serratella tibialis		4	22	7	78	21	22	3	4	2	21	25	6	15	8	24	8	623
Timpanoga hecuba								2										2
Heptageniidae																		
Cinygma																		0
Cinygmula	1	59	6		3	8				21	2	1			1			496
Epeorus albertae			5															35
E. deceptivus	1	55	4		9	26	5		1	7		19	3	6	6	3		327
E. grandis		2			2					4		10						18
E. longimanus		1		1			12	1				4		1		1		64
Heptagenia criddlei				4				4	1								3	22
Ironodes																		0
Rhithrogena	1	23	49	32	50	21	6	1	16	9	17	27	6	51	5	108	31	603
Leptophlebiidae																		
Paraleptophlebia s.l.																		4
P. bicornuta								45										45
P. debilis								1										8
P. heteronea	1							7						3				23
P. vaciva	1		2	1		1	2		16		4		2			5	1	46
Siphlonuridae																		
Ameletus s.l.																		1
A. cooki																		24
A. similor		8								1								13
A. sparsatus			2	6					1		1			1	1			65
A. validus																		11
Plecoptera																		
Capniidae			1				3		5	2	6		2	3				45
Chloroperlidae																		
Kathroperla										1				1				2
Suwallia		2																55
Sweltsa	19	27	99	34	83	125	81	46	106	22	43	28	10	83	44	169	2	1654
Leuctridae																		
Despaxia			3			5	3	1										59

Appendix I. (Continued)

	Station																	
Taxa	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	Totals
Nemouridae																		
Amphinemoura																		49
Visoka							7							2				35
Zapada		20	1		1	19	12	1	1	28		9	4	34	3	1	1	269
Peltoperlidae																		
Yoraperla		53	4							6								146
Perlidae																		
Calineuria								9	2									11
Doroneuria				4	3					4		1						79
Hesperoperla			1	3		1			1		1							23
Perlesta			1															1
Perlodidae																		
Isoperla				1									1					22
Megarcys		23	2	4	13	37	19		2	3		12	2	11	3	3		232
Setvena																		26
Skwala	8		19	15	24	24	7	2	39		70	7	3	10	32	202	5	539
Pteronarcyidae																		
Pteronarcys				1														1
Megaloptera																		
Sialidae																		
Sialis								1										6
Trichoptera																		
Brachycentridae																		
Amiocentrus																		1
Brachycentrus		1	11	72	3	3	1	1				2		1			2	219
Micrasema						8			1	1	1			3				77
Glossosomatidae																		
Agapteus							1											11
Glossosoma				16	6	4	1	2				13		1				56
Hydropsychidae																		
Arctopsyche		2	25	9	31		10	2	9	36	8	22		9	3	1	13	262
Hydroptilidae																		
Agraylea	9				45			1			2	4					1	69
Lepidostomatidae																		
Lepidostoma							1				1						3	8
Limnephilidae																		
Apatania			13	5	7	1		2					1		13	12	6	83
Dicosmoecus					1		5		1		4		5			1		26
Ecclisiomyia	1		2			1	1			1	1		5		6			64
Hesperophylax																		0
Neophylax																		4
Neothremma												1						9
Oligophlebodes																		0
Onocosmoecus																		1
Pedomoecus																		0
Psychoglypha	15			1				27			4							63
Philopotamidae																		
Dolophilodes							4					1		3				84
Rhyacophilidae																		
Rhyacophila		17	4	6	8	35	41	5	8	6		17	1	17	37	4	7	462

Appendix I. (Continued)

Taxa	Station 28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	Totals
Hemiptera																		
Corixidae								8										8
Coleoptera																		
Curculionidae																		0
Dytiscidae																		
Hydroporous			1		1	1		9					1					18
Elmidae																		
Heterlimnius	3	30	19	15	14	89	24	6	48	3	2	15	3	9	4	81	26	1823
Lara															5			14
Narpus				3				1	1									18
Optioservus				1													5	11
Haliplidae																		
Brychius								3										3
Hydrophilidae													1					2
Diptera																		
Athericidae																		
Atherix																		11
Blephariceridae																		
Agathon				2														2
Ceratopogonidae							1											5
Chironomidae	50	9	125	29	192	271	255	459	26	39	43	30	40	162	204	219	54	3426
Deuterophlebiidae																		331
Dixidae																		
Dixa																		0
Empididae																		
Chelifera														1				1
Oregoton					3	1	2			1				1				19
Ephydridae								8										23
Pelecorhychidae																		
Glutops	4					2		2	1		2							57
Psychodidae																		
Pericoma																		1
Ptychopteridae																		
Ptychoptera																		7
Rhagionidae																		
Chrysopilus				1														1
Simuliidae																		
Simulium			2	5	5	2	5					3	2	24			2	151
Tabanidae								2										11
Tipulidae																		
Antocha	1			1	1	4	3	2	1				4	3	6	5	1	38
Dicranota		1	1			9	3	1			1							37
Hexatoma	2	2	6		4	4			6			2				4	3	67
Limnophila									1									6
Tipula								8										9
Hydracarina	2		5		5	2		1	1			2	1		2		1	26
Oligochaeta			3	6		4	30		6	9								100
Totals	123	443	642	315	708	812	616	689	333	232	258	300	129	519	432	922	243	15,693

Appendix J. Modified IBI Scores for 47 northern Idaho headwater streams.

Station	Stream	*A. truei* density metric	Intoler. species metric	Salmonid species metric	Invert. species metric	% intro. density metric	Fish individs. metric	Salmonid density metric	density metric	Modified IBI score
1	L MOOSE	1	5	5	5	1	5	5	5	32
2	TOBOGGAN	3	5	5	5	5	5	5	3	36
3	CAYUSE	1	5	5	5	5	5	5	5	36
4	OSIER	3	3	3	3	1	5	3	5	26
5	GOOSE	3	5	5	5	1	5	3	5	32
6	BREAKFAST	1	1	1	3	1	1	1	1	10
8	LARSON	3	3	1	3	5	5	5	5	30
9	FRENCH	3	3	5	5	3	5	5	5	34
10	HEM	5	5	3	5	3	5	5	3	34
11	SILVER	1	1	3	3	3	1	1	1	14
12	L N FK	5	5	5	5	5	5	3	3	36
13	FISHOOK	1	3	1	3	5	5	5	3	26
14	EAGLE	5	3	3	3	5	5	1	1	26
15	QUARTZ	3	3	3	3	1	5	3	1	22
16	GOLD	1	3	1	3	1	5	3	3	20
17	RED IVES	1	5	3	3	5	5	3	3	28
18	BIRD	5	3	3	3	5	5	1	1	26
19	PROSPECTO	5	3	3	3	5	5	1	1	26
21	ST MARIES	1	5	5	5	1	5	3	5	30
22	GOLD CENT	3	5	5	3	5	5	3	3	32
23	LLL	3	5	5	5	5	5	3	3	34
24	OUTLAW	3	3	1	3	5	5	3	5	28
25	SISTERS	3	3	3	3	5	5	1	3	26
26	LOOP	5	5	5	5	5	3	1	1	30
27	U LOOP	1	3	3	3	5	5	3	3	26
28	N FK ST J	1	3	5	5	5	3	1	1	24
29	FALLS	1	3	1	3	1	5	5	3	22
30	SHOSHONE	3	1	1	1	1	5	3	5	20
31	LOST	1	5	5	3	5	3	1	3	26
32	YELLOWDOG	1	5	5	5	1	3	1	3	24
33	FLAT	3	3	3	3	1	5	3	5	26
34	CINNAMON	1	3	1	3	1	5	3	3	20
36	U TEEPE	1	3	3	3	5	5	3	5	28
37	PRICHARD	3	3	3	5	5	1	5	3	28
38	W FK EAGL	1	1	3	5	5	3	1	1	20
39	SKOOKUM	1	3	5	5	5	3	1	5	28
40	CASCADE	1	1	1	3	5	5	3	5	24
41	B CABIN	1	1	1	3	1	5	5	5	22
42	IRON	1	1	1	3	3	5	5	1	20
43	B ELK	1	3	3	3	1	5	5	5	26
45	COPPER	1	3	5	5	1	3	5	5	28
46	KALISPELL	1	1	5	5	5	3	5	5	30
47	GRANITE	1	3	5	5	3	3	5	5	30
48	BEAVER	1	1	3	5	5	3	1	1	20
49	SOLDIER	1	1	1	5	5	1	5	3	22
50	HUNT	1	1	1	3	3	5	5	3	22
51	INDIAN	1	3	1	5	5	5	5	3	28