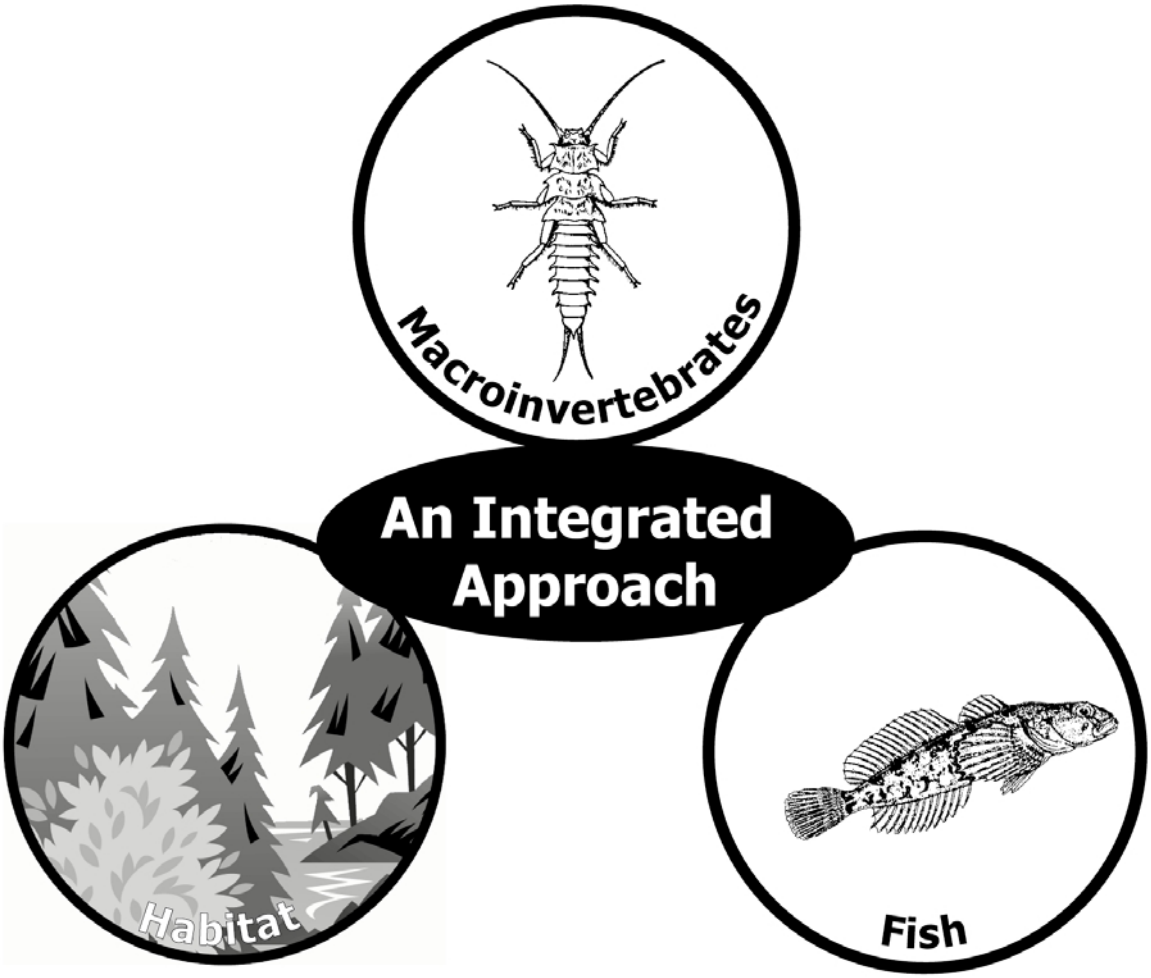
Idaho Small Stream Ecological Assessment Framework



Idaho Department of Environmental Quality

Final – June 2002

Idaho Small Stream Ecological Assessment Framework:

An Integrated Approach

Final
June 2002

The information set forth in this document is intended solely as guidance for use by the staff of the Idaho Department of Environmental Quality. The contents of this document are not intended to, nor do they, constitute a rulemaking by the Idaho Department of Environmental Quality. Furthermore, the contents of this document do not create any rights or benefits, substantive or procedural, enforceable at law or in equity, by any person. Nothing in this document shall be construed to constitute a valid defense by regulated parties in violation of any state or federal environmental statute, regulation or permit.

IDAHO DEPARTMENT OF ENVIRONMENTAL QUALITY

Acknowledgements

The development of the *Stream Ecological Assessment Framework* could not have been achieved without the dedicated effort of and suggestions from the Stream Assessment Team members. These individuals include: Cindy Barrett, Bill Clark, Lynn Van Every, Cyndi Grafe, Gretchen Hayslip, Chris Mebane, Dave Mosier, Angie Petersen, Steve Robinson, Jack Skille, Bob Steed, Daniel Stewart, and Sean Woodhead.

Special thanks also to Mike Edmondson who managed the Tetra Tech contract for the Stream Macroinvertebrate Index development. He also provided much needed database support by providing data sets for the development of the Stream Macroinvertebrate Index and Stream Habitat Index. Additionally, Mike Edmondson, Henry Navorro, Darren Brandt, and Chris Mebane accomplished considerable data testing and database tool development to evaluate the performance of all the indexes.

We sincerely appreciate the technical peer review provided by Steve Bauer, Christopher Robinson, and EPA. EPA provided DEQ with comprehensive comments from technical and policy perspectives. The EPA reviewers possessed a wide range of expertise including fish biology, ecology, monitoring, program policy and legal. The review included EPA Region 10 Idaho Operations office (Boise, Idaho): Leigh Woodruff. Also, from EPA Region 10 office (Seattle, Washington): Kerianne Gardner, Gretchen Hayslip, Lilian Herger, Curry Jones, Marcia Lagerloef, Theresa Pimentel and Steve Ralph. Lastly, from EPA Headquarters (Washington, D.C.): Susmita Dubey (Office of General Council); Susan Holdsworth, Mike Haire, Chris Faulkner, Christine Ruf (Office of Wetlands, Oceans and Watersheds); Sue Gilbertson, Ed Hanlon, Jennifer Wigal (Office of Science and Technology).

Also, greatly appreciated are the editorial and production support provided by Amy Luft, Pat Jones, and Barbara Mallard.

APPROPRIATE CITATION

Grafe, C.S., ed. 2002. Idaho Small Stream Ecological Assessment Framework: An Integrated Approach. Idaho Department of Environmental Quality; Boise, Idaho.

This entire document can be downloaded from the Idaho Department of Environmental Quality's website at http://www2.state.id.us/deq.

Table of Contents

Acknowledgements ii
Appropriate Citation ii

Table of Contents iii

List of Figures vii

List of Tables ix

Acronyms and Symbols xii

Abstract xiii

Chapter 1. Overview 1–1
Introduction 1–1
Regulatory Background 1–1
Use of Ecological Indicators 1–2
Use of Multimetric Indexes 1–2
Stream Macroinvertebrate Index 1–3
Stream Fish Index 1–3
Stream Habitat Index 1–3
Data Integration and Reporting of Assemblages 1–4
References 1–5

Chapter 2. Water Body Size Criteria 2–1
Introduction 2–1
Methods 2–1
Criteria Consideration and Calculation 2–1
Criteria Determination 2–2
Criteria Rating and Assignment of Water Body Size 2–3
References 2–5

Chapter 3. Stream Macroinvertebrate Index 3–1
Introduction 3–1
Methods 3–5
Definition of Site Criteria for Least Impacted and Stressed Sites 3–5
Biological Survey of Idaho Streams 3–6

Determinating Naturally-occurring Site Classes (Bioregional Delineations)..... 3–7
Testing Metric Discriminatory Ability within Bioregions..... 3–8
Scoring Metrics and Combining Metric Scores into a Regionally-Calibrated Index 3–12
Testing the SMI with Independent Data 3–13
Results and Discussion 3–14
Database Characteristics 3–14
Site Classification 3–14
Index Metric Selection..... 3–22
Index Development..... 3–29
Index Tested with Independent Data and Compared to Other Indexes 3–32
Northern Mountains Recalibration and Index Finalization 3–36
Conclusions and Recommendations 3–38
Conclusions..... 3–38
Index Rating and Application 3–39
Recommendations..... 3–40
Acknowledgements..... 3–42
References..... 3–43

Chapter 4. Stream Fish Indexes..... 4–1
Introduction..... 4–1
Methods 4–2
Data 4–3
Classification of Stream Types 4–3
Evaluation and Selection of Candidate Metrics..... 4–7
Results..... 4–18
Classification of Stream Types 4–18
Forest Streams..... 4–22
Rangeland Streams..... 4–36
Classification of Stream Types – Revisited..... 4–42
Native Amphibians: A Supplemental, Qualitative Metric..... 4–49
Discussion..... 4–50
Considerations for Setting Impairment Thresholds 4–50
Classification of Stream Types – Possible Refinements 4–52
Conclusions..... 4–55
Recommendations..... 4–55
Acknowledgments..... 4–57
References..... 4–58

Chapter 5. Evaluation of Idaho's Habitat Index for Wadeable Streams 5-1
Introduction 5-1
Methods 5-2
Data Sets 5-2
Habitat Data 5-5
Land Use Data 5-7
Biological Data 5-8
Data Analysis 5-8
Results 5-13
Classification of Sites 5-13
Evaluating Human Disturbance 5-14
Habitat Measure Testing 5-16
Selecting Measures for the Revised Habitat Index 5-22
Evaluating the Revised Habitat Index 5-26
Discussion 5-30
Classification of Sites 5-31
Identification of New Habitat Measures 5-32
Habitat Measures and Human Disturbance 5-33
Habitat Measures and Biological Condition 5-34
Statistical Considerations 5-36
Improvement of the Habitat Index 5-38
Recommendations 5-38
Conclusions 5-39
Acknowledgements 5-41
References 5-42
Chapter 6. Data Assessment and Reporting 6-1
Introduction 6-1
Methods 6-1
Stream Index Scoring 6-1
Index Data Integration Approach and Use Support Determination for Rivers and Streams 6-3
References 6-9
Appendix A. Metric Discrimination A-1
Appendix B. Metric Scoring Formulas B-1
Appendix C. Least Impacted and Stressed Site *A Priori* Stream Condition and Index Score (Draft 2000 Data Set) C-1

Appendix D. Least Impacted and Stressed Site *A Priori* Stream Condition and Index Score (Refined Data Set for Northern Mountains and Corrections for Ambiguous Taxa)..... D–1

Appendix E. Cumulative Distribution of Candidate Metrics, All Rangeland Sites..... E–1

Appendix F. Cumulative Distribution of Selected Metrics, Small Forest Streams F–1

Appendix G. Cumulative Distribution of Selected Metrics, Large Forest Streams G–1

Appendix H. Data Summary H–1

Rangeland Index H–1

Forest Index H–15

Appendix I. Correlation of Habitat Measures with Disturbance Measures, Fish Metrics, and Macroinvertebrate Metrics in the Northern Basin and Range Ecoregion I–1

Appendix J. Correlation of Habitat Measures with Disturbance Measures, Fish Metrics, and Macroinvertebrate Metrics in the Snake River Basin Ecoregion.....J–1

Appendix K. Correlation of Habitat Measures with Disturbance Measures, Fish Metrics, and Macroinvertebrate Metrics in the Northern and Middle Rockies Ecoregion..... K–1

Appendix L. Distributio of Values of SHI Habitat Measures.....L–1

Appendix M. Cumulative Distribution Functions of SHI Habitat Measures.....M–1

Glossary Glossary–1

References..... Glossary–8

List of Figures

Figure 3-1. Ecoregions of Idaho (Omernik 1987). 3–4
Figure 3-2. Distributions of selected metrics for sites, by least impacted ecoregions of Idaho. 3–16
Figure 3-3. Geographic distribution of least impacted and stressed biomonitoring sites in the bioregions of Idaho 3–18
Figure 3-4. NMDS ordination of family level relative abundance for 150 least impacted samples. 3–19
Figure 3-5. PCA ordination of 150 reference sites designated by bioregion, showing the first two axes. 3–20
Figure 3-6. Physical characteristics of all sampled sites in the ecoregions of Idaho.....3–22
Figure 3-7. Comparison of total taxa and subsample size. The target substample size was 500 organisms.....3–23
Figure 3-8. Selected distributions of least impacted and stressed metrics in bioregions of Idaho; calibration samples only. 3–26
Figure 3-9. Index score distributions in least impacted and stressed sites, calibration data. 3–31
Figure 3-10. Index score distributions in least impacted and stressed sites, test data. 3–32
Figure 3-11. SMI score distributions in least impacted and stressed sites, calibration and test sites combined. 3–37

Figure 4-1. Ecoregions of Idaho, combined ecoregion groups, with fish assemblage sample sites.. 4–6
Figure 4-2. Temperatures at which selected fish species were captured by electrofishing in Idaho from 1994-1998.. 4–14
Figure 4-3. Native distributions of Oncorhynchus mykiss (steelhead, redband, and rainbow trout) in Idaho.. 4–16
Figure 4-4. Discriminant analysis of reference site species occurrence and abundance grouped by ecoregions, and elevation-adjusted ecoregion aggregates 4–19
Figure 4-5. Elevations at which salmonid species occurred in wadeable streams (1st to 4th order). 4–22
Figure 4-6. Relative abundance of salmonids and sculpin. 4–24
Figure 4-7. Salmonid - sculpin composition with gradient in forest reference streams. 4–25
Figure 4-8. Relationships between stream size and salmonid age classes encountered. 4–26
Figure 4-9. Elevation, stream size, and catch per unit effort (CPUE). 4–28
Figure 4-10. Relative densities of cold water fish correlated with catch per unit effort (CPUE).....4–29
Figure 4-11. Small mountain streams: metric values for reference streams and apparently impacted test streams 4–31
Figure 4-12. Intermediate sized mountain streams: metric values for reference streams and apparently impacted test streams 4–32
Figure 4-13. Scoring curves for metrics used in the mountain streams IBI. 4–33
Figure 4-14. Ranges of forest SFI scores for reference (R) and test (T) sites. 4–35
Figure 4-15. Rangeland candidate metrics ranges minimally and apparently impacted sites sites. 4–37

Figure 4-16. Scoring curves used in the rangeland stream fish index. 4–40
Figure 4-17. Ranges of rangeland fish IBI scores for reference (R) and test (T) sites. 4–41
Figure 4-18. Canonical correlations of all fish metrics from both indexes grouped by reference and test classifications and by forest and rangeland ecoregion groups. 4–42
Figure 4-19. Habitat and fish index relationships for forest streams. 4–46
Figure 4-20. Percentages of channel widths covered by fine-grained (<6mm) sediment occurring at sites with SFI scores <67> (forest streams). 4–48
Figure 4-21. Flowchart of Stream Fish Index structure. 4–53

Figure 5-1. Distribution of sample sites 5–3
Figure 5-2. Comparison of land cover by for different ecoregions (n=228). 5–15
Figure 5-3. Variability of SHI for repeat visit to the same sites. 5–28
Figure 5-4. Variability of SHI's component measures. 5–29

Figure 6-1. Stream cold water aquatic life use support determination. 6–4
Figure 6-2. Big Cottonwood Creek located in Goose Creek HUC #17040211 6–6
Figure 6-3. Big Cottonwood Creek in 6th Field HUC #170402111901. BURP site at upper portion of watershed 6–7

Figure E-1. Cumulative distribution of candidate metrics, all rangeland sites. E–1

Figure F-1. Cumulative distribution of selected metrics, small forest streams. F–1

Figure G-1. Cumulative distribution of selected metrics, larger forest streams. G–1

List of Tables

Table 2-1. Water Body Size Categories Used to Rate Each Criterion 2–3
Table 2-2. Water Body Size Average Score Rating Categories. 2–4
Table 2-3. Example of data used to rate criteria.....2–4
Table 2-4. Example of rating each criterion. 2–4

Table 3-1. Non-biotic variables and criteria used for selecting least impacted sites *a priori*. 3–5
Table 3-2. Definitions of candidate macroinvertebrate metrics and predicted direction of metric response to increasing perturbation (modified after Barbour et al. 1999). 3–9
Table 3-3. Sample sizes in the ecoregions of Idaho by *a priori* stream condition (least impacted or stressed) and data set assignment (calibration or test). ..3–14
Table 3-4. Final site classification; three bioregions and the ecoregions they include. 3–17
Table 3-5. Eigenvectors of metrics in the PCA. 3–21
Table 3-6. Sample sizes in the bioregions of Idaho by *a priori* stream condition (least impacted or stressed) and data set assignment (calibration or test). ..3–21
Table 3-7. Median scores of assessed habitat features in the ecoregions of Idaho (scores from least impacted sites only). 3–23
Table 3-8. Discrimination efficiencies (DE) of candidate metrics in three bioregions, statewide DE, and metric trend with increasing impairment (▼ – decreasing, △ – increasing). Calibration data only. 3–25
Table 3-9. Correlation coefficients for metrics that show good discrimination efficiency.....3–30
Table 3-10. Discrimination efficiencies for the SMI using independent test data. 3–32
Table 3-11. SMI configuration (Index A) and other indexes used in Idaho. 3–34
Table 3-12. SMI configuration (Index A) and other indexes calibrated for the Northern Rockies, Snake River Plain, and Northern Basin and Range of Idaho (Robinson and Minshall 1998). 3–35
Table 3-13. Statistics of SMI. Least impacted distributions and DE's based on various percentiles. 3–37
Table 3-14. Samples with outlying index scores.....3–37
Table 3-15. Example rating categories based on 25th percentiles of least impacted SMI scores. 3–40

Table 4-1. Metrics from original IBI and suggested for cold water streams.....4–8
Table 4-2. Ecological concepts and reasoning of selected candidate metrics. 4–9
Table 4-3. Factors considered for classifying reference sites. 4–17
Table 4-4. Most frequently occurring species and genera in reference sites in forest and rangeland stream types. 4–21
Table 4-5. Pearson correlations for fish metrics, watershed disturbance, and Habitat Index ($p<0.1$ = +, $p<0.05$= ++); and numbers of significant associations between the metrics and with discrete habitat measures 4–45
Table 4-6. Comparison of percentile distributions of fish index scores at forest reference and test streams. 4–51

Table 4-7. Comparison of percentile distributions of fish index scores at rangeland reference and test streams. 4-51

Table 5-1. Selected variables and the number of sites for which data were available from the larger BURP data set. 5-4
Table 5-2. Habitat measures that were evaluated, their predicted response to human disturbance, whether the measure was included in the original habitat index for high (H) or low (L) gradient streams, whether the measure was new, and whether the measure was scored by eye in the field or based on measurements made in the field. 5-6
Table 5-3. Percentage of Idaho sites correctly classified by discriminant function analysis (DFA) for different grouping variables and different sets of predictor variables. 5-13
Table 5-4. Number of significant associations for habitat measures and human disturbance, fish metrics, and invertebrate metrics. 5-16
Table 5-5. Scoring criteria for the SHI. 5-23
Table 5-6. Correlation values (Spearman's r) for the original habitat index and the SHI. 5-25

Table 6-1. SMI bioregion scoring criteria* 6-2
Table 6-2. SFI bioregion scoring criteria 6-2
Table 6-3. SHI scoring criteria. 6-3
Table 6-4. Summary of water body size criteria results 6-7
Table 6-5. Stream index scores and corresponding condition ratings for Big Cottonwood Creek 6-8

Table B-1. Metric scoring formulas for SMI metrics B–1

Table C-1. Least impacted and stressed streams with index scores and biological condition ratings. C–1

Table D-1. Least impacted and stressed streams with SMI scores D–1

Table H-1. Rangeland Index H–1
Table H-2. Forest Index H–15

Table I-1. Basin and Range human disturbance correlations. I–1
Table I-2. Basin and Range fish correlations. I–4
Table I-3. Basin and Range bug correlations. I–7

Table J-1. Snake River human disturbance correlations J–1
Table J-2. Snake River fish correlations J–4
Table J-3. Snake River bug correlations J–7

Table K-1. Northern human disturbance correlations K–1
Table K-2. Northern fish correlations K–4
Table K-3. Northern bug correlations K–7

Acronyms and Symbols

ALUS	Aquatic Life Use Support
ANOVA	Analysis of Variance
BC	Bray-Curtis
BLM	Bureau of Land Management
BM	Blue Mountains
BURP	Beneficial Use Reconnaissance Program
cfs	cubic feet per second
CP	Columbia Plateau
CPUE	Catch per unit effort
C.V.	coefficient of variation
CWA	Clean Water Act
DE	discrimination efficiency
DELT	Deformities, eroded fins, lesions, or tumors
DEQ	Idaho Department of Environmental Quality
DFA	discriminant function analysis
EPA	Environmental Protection Agency
EPT	Ephemeroptera, Plectoptera, Trichoptera
GIS	Geographic Information System
HBI	Hilsenhoff's Biotic Index
HI	habitat index
IBI	Index of Biotic Integrity
IDFG	Idaho Department of Fish and Game
ISU	Idaho State University
m	meter
m^2	square meter
MR	Middle Rockies
NAWQA	National Water Quality Assessment Program
NBR	Northern Basin and Range
NMDS	non-metric multidimensional scaling
NNR	Northern Northern Rockies
NR	Northern Rockies
PCA	principle components analysis
s.d.	standard deviation
SFI	Stream Fish Index
SHI	Stream Habitat Index
SMI	Stream Macroinvertebrate Index
SNR	Southern Northern Rockies
SRP	Snake River Plain
TMDL	Total Maximum Daily Load
USFS	United States Forest Service
USGS	United States Geological Survey
WB	Wyoming Basin
WBAG	Water Body Assessment Guidance
WUM	Wasatch/Uinta Mountains

Abstract

This document describes the Idaho Department of Environmental Quality's (DEQ) ecological assessment approach to determine aquatic life use support in Idaho's small streams. DEQ uses biological indicators, habitat data and numeric water quality criteria to assess aquatic life use support for small streams. The intent of this document is to provide detailed technical information concerning the development and integration of the Stream Macroinvertebrate Index (SMI), Stream Fish Index (SFI), and Stream Habitat Index (SHI) used in the aquatic life use support determination.

DEQ applies the stream ecological assessment approach based on results from three water body size criteria: stream order, width, and depth. In general, the small stream method is applied to water bodies that have an average water body size criteria rating of less than 1.7.

DEQ uses several bioassessment tools or multimetric indexes to limit reliance on just one tool and still ensure direct measurements of aquatic life. DEQ contracted Jessup and Gerritsen with Tetra Tech, Inc. to develop the SMI. Jessup and Gerritsen used sites identified as least impacted and stressed to develop the SMI. The macroinvertebrate data is evaluated within the context of three bioregions: Northern Mountains, Central and Southern Mountains, and Basins. Based on this classification system, Jessup and Gerritsen identified nine significant macroinvertebrate metrics to characterize water quality condition. These SMI metrics include: total taxa, Ephemeroptera taxa, Plecoptera taxa, Trichoptera taxa, percent Plecoptera, Hilsenhoff Biotic Index, percent five dominant taxa, scraper taxa, and clinger taxa.

The Stream Fish Index is a bioassessment tool that directly measures the achievement of the Clean Water Act "fishable" goal. Mebane identified two different sets of metrics to characterize water quality condition for montane-forested and desert basin-rangeland classifications. The rangeland metrics include: percent cold water individuals, Jaccard's community similarity coefficient, percent omnivores and herbivores, percent cyprinids as longnose dace, percent of fish with certain abnormalities (deformities, eroded fins, lesions, and tumors), and catch per unit effort. The metrics in the forested classification comprise: number of cold water native species, percent cold water individuals, percent sensitive native individuals, number of sculpin age classes (unless sample is comprised solely of salmonids), number of salmonid age classes, and catch per unit effort.

DEQ contracted Fore and Bollman with Statistical Design and Rhithron Biological Associates, respectively, to develop the Stream Habitat Index (SHI). They determined that ecoregion groupings provided the most useful classification approach for the SHI. Fore and Bollman tested habitat measures with land use and biological data. They identified ten habitat measures that signaled water quality conditions. The SHI measures include: instream cover, large organic debris, percent fines less than 2mm in wetted width, embeddedness, number of Wolman size classes, channel shape (undercut), percent bank cover, percent canopy cover, disruptive pressures, and zone of influence.

DEQ integrates multiple data types using a rating and averaging approach. Index scores are adjusted to a common scale using a 1, 2, 3 scoring system. The converted scores are then averaged to provide a single score. Average scores greater than or equal to 2 are fully supporting of aquatic life, while scores less than to 2 are not fully supporting.

Chapter 1. Overview

Cynthia S. Grafe[1]

INTRODUCTION

This document describes the Idaho Department of Environmental Quality's (DEQ) ecological assessment approach to determine aquatic life use support (ALUS) in Idaho's small streams. Associated policies and other beneficial use approaches (e.g., recreation, domestic water supply, etc.) are addressed as part of the DEQ *Water Body Assessment Guidance* (Grafe et al. 2002). The intent of this document is to provide detailed technical information concerning the development of the Stream Macroinvertebrate Index (SMI), Stream Fish Index (SFI), and Stream Habitat Index (SHI) used in the ALUS determination for small streams.

The ALUS for small streams is addressed in this document, while the river ALUS is addressed in the *Idaho River Ecological Assessment Framework: An Integrated Approach* (Grafe 2002). It is important to make this distinction, since DEQ uses different monitoring and assessment protocols depending on water body size. Chapter 2 describes the criteria rating and averaging method DEQ uses to differentiate between small streams and rivers.

REGULATORY BACKGROUND

In 1972, Congress passed public law 92-500, Federal Water Pollution Control Act, commonly known as the Clean Water Act (CWA). The goal of this act was to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (Water Pollution Control Federation 1987). The act and the programs it generated have changed over the years as experience and perceptions of water quality have changed. It has been amended 15 times, most significantly in 1977, 1981, and 1987. One of the goals of the 1977 amendment was protecting and managing waters to insure "swimmable and fishable" conditions. This goal, along with the 1972 goal to restore and maintain chemical, physical, and biological integrity, relates water quality with more than just chemistry.

The federal government, through the U.S. Environmental Protection Agency (EPA), assumed the dominant role in defining and directing water pollution control programs across the country. DEQ implements the CWA in Idaho while the EPA provides oversight of Idaho's fulfillment of CWA requirements and responsibilities.

[1] Idaho Department of Environmental Quality, 1410 N. Hilton, Boise, ID 83706.

DEQ is charged with providing a consistent water body assessment method using data collected under the Beneficial Use Reconnaissance Project (BURP) and other similar sources. The assessment methods must determine if a water body is supporting or not supporting beneficial uses such as aquatic life. The *Water Quality Standards and Wastewater Treatment Requirements* are the Idaho legally established rules concerning beneficial uses and associated criteria (Rules of the Department of Health and Welfare, IDAPA 58.01.02).[2]

USE OF ECOLOGICAL INDICATORS

The strength of this ALUS assessment framework is the use of ecological indicators. Water quality is evaluated and compared to levels needed for the protection and maintenance of viable communities of aquatic species. Measurements of aquatic assemblages reflect long-term stream conditions more than instantaneous chemical measurements and provide a direct measure of the aquatic life beneficial use. DEQ uses both biological indicators and numeric water quality criteria to assess ALUS. Levels of aquatic life protection and maintenance are evaluated within the context of the Idaho water quality standards goals.

USE OF MULTIMETRIC INDEXES

To evaluate ALUS, DEQ applies multimetric indexes based on rapid bioassessment concepts developed by EPA (Barbour et al. 1999). Measurements of biological or physical habitat conditions known as metrics comprise the indexes. The indexes include several characteristics to gauge overall ecosystem health. The multimetric index value for a sample site is the sum of individual metric scores. Multimetric index scores are unitless, and therefore easily comparable. The index scores from the identified least impacted or reference sites are then used to develop a range of conditions that can be divided into any number of categories indicating different levels of impairment (Barbour et al. 1999). The group of least impacted or reference sites is known as the reference condition and is the benchmark used in the assessment process. DEQ compares the multimetric index scores of sites to this reference condition to determine use support.

The strength of such an approach is the integration of biological, physical, and chemical characteristics of the water body at different scales — individual, population, community, and ecosystem scales (Karr et al. 1986). This integration allows DEQ to detect water quality impairment cost-effectively and furnish this information in an understandable format.

Data used to calculate certain indexes, such as the SFI, may be limited due to sampling resource requirements, endangered or threatened species sampling restrictions, and sampling protocols incompatible with BURP methods. Therefore, DEQ has developed

[2] Henceforth, subsection 3 of regulation within IDAPA 58.01.02 are abbreviated as "WQS.XXX" where XXX is the subsection. For example, "IDAPA 58.01.02.100" is abbreviated as "WQS 100."

several bioassessment tools to limit reliance on just one tool and still ensure direct measurements of aquatic life. The stream ecological assessment framework integrates potentially three multimetric indexes in the ALUS determination: SMI, SFI, and SHI.

Stream Macroinvertebrate Index

DEQ contracted Tetra Tech, Inc. to develop the SMI. Benthic macroinvertebrates are aquatic insects found in the bottom substrate of streams. Jessup and Gerritsen (2002) used sites identified as least impacted and as stressed to develop the SMI. The macroinvertebrate data is evaluated within the context of three classes or bioregions: Northern Mountains, Central and Southern Mountains, and Basins. Jessup and Gerritsen (2002) identified nine significant macroinvertebrate metrics to characterize water quality condition. These SMI metrics include assemblage attributes such as richness, composition, pollution tolerance, diversity, feeding group, and habit. Jessup and Gerritsen also performed a reanalysis of the SMI in the Northern Mountains using a refined data set as well as evaluated ambiguous taxa for all bioregions. Chapter 3 details the data set and methods used to develop the SMI.

Stream Fish Index

The SFI is a bioassessment tool which directly measures the achievement of the Clean Water Act "fishable" goal. Mebane (2002) used sites identified as least impacted and stressed to develop the SFI. He developed two site classes: Montane-Forested and Desert Basin-Rangeland. Mebane (2002) identified two different sets of metrics to characterize water quality condition for forested and rangeland classes. For rangeland sites, six metrics were identified comprising assemblage attributes such as richness, composition, indicator, abundance, and condition. The forest metrics also included richness, composition, indicator, and abundance characteristics as well as reproductive function attributes. Also both classifications incorporate amphibian indicators as a secondary metric. Mebane's discussion of index development is found in Chapter 4.

Stream Habitat Index

DEQ contracted Statistical Design and Rhithron Biological Associates to develop the SHI. Fore and Bollman (2002) determined that ecoregion groupings provided the most useful classification approach for the SHI. Fore and Bollman (2002) used land use data to evaluate human disturbance gradients in the Snake River Basin and Northern Basin and Range ecoregions. In the Northern/Middle Rockies it was more difficult to develop a disturbance gradient using available land use data, so DEQ professional biologists identified least impacted sites and stressed sites based on observations of human disturbance at the site and in the watershed. Fore and Bollman (2002) also tested habitat measures with fish and macroinvertebrates. Ultimately, they identified ten habitat measures that signaled water quality conditions. Five of these metrics are quantitatively measured, while the other five are field rated using eye estimates. Chapter 5 describes the Fore and Bollman approach to developing the SHI.

DATA INTEGRATION AND REPORTING OF ASSEMBLAGES

To be meaningful to managers and the public, biological data need to be translated into coherent information that conveys the assessment results. The challenge is to interpret and report all the results from different assemblages, particularly when the results are varied or contradictory. DEQ integrates multiple data types by classifying results from the indexes using a 1, 2, 3 scoring system. The converted scores are then averaged to provide a single score that is interpreted for the ALUS determination. Chapter 6 describes the data integration approach and provides an example using actual data to more clearly explain the method.

REFERENCES

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and rivers: periphyton, benthic macroinvertebrates, and fish. Second edition. Environmental Protection Agency, Office of Water, Washington, DC.

Clean Water Act (PL 92-500)

Fore, L. and W. Bollman. 2002. Stream habitat index. Chapter 5. *In* Grafe, C.S. (editor). Stream ecological assessment framework: an integrated approach. Idaho Department of Environmental Quality. Boise, Idaho. pp.302.

Grafe, C.S. (editor). 2002. Idaho river ecological assessment framework: an integrated approach. Idaho Department of Environmental Quality. Boise, Idaho. 210 pp.

Grafe, C.S., C.A. Mebane, M.J. McIntyre, D.A. Essig, D.H. Brandt, and D.T. Mosier. 2000. The Idaho Department of Environmental Quality Water Body Assessment Guidance, Second Edition. Idaho Department of Environmental Quality. Boise, Idaho.

Jessup, B. and J. Gerritsen. 2002. Stream macroinvertebrate index. Chapter 3. *In* Grafe, C.S. (editor). Stream ecological assessment framework: an integrated approach. Idaho Department of Environmental Quality. Boise, Idaho. pp.302.

Karr, J. R., K. D. Fausch, P. L. Angermeier, P. R. Yant, and I. J. Schlosser. 1986. Assessment of biological integrity in running water: a method and its rationale. Illinois Natural History Survey Special Publication Number 5, Champaign, IL.

Mebane, C.A. 2002. Stream fish index. Chapter 4 *In* Grafe, C.S. (editor). Stream ecological assessment framework: an integrated approach. Idaho Department of Environmental Quality. Boise, Idaho. pp. 302.

Chapter 2.
Water Body Size Criteria

Cynthia S. Grafe[3]

INTRODUCTION

DEQ applies different monitoring and assessment protocols depending on water body size. Since individual perceptions of water body size vary, DEQ developed a consistent method of selecting and applying criteria to distinguish between small streams and rivers.

DEQ examined several water body size criteria and determined that no one criteria could characterize the varying sizes of Idaho streams. Some of the criteria considered were stream order, width, depth, discharge, and drainage area. These criteria were suggested in the literature and by Idaho State University (ISU) (Hughes et al. 1986, Royer and Minshall 1999). This chapter describes the reasons for adopting certain criteria, the application of the criteria, and supporting analysis.

METHODS

Criteria Consideration and Calculation

DEQ considered several criteria to determine water body size. The following is a description of each criterion and the methods used to determine the criteria.

- Stream order – This criterion is often used to determine water body size (Allan 1995) since it is relatively constant. However, with larger water bodies it can be very difficult to calculate the stream order using 1:24,000 topographical maps. For this reason, DEQ followed ISU's protocol (Royer and Minshall 1997) which used the Strahler (1957) method with 1:100,000 Geographic Information System (GIS) hydrography coverage and/or topographical maps. According to ISU, the stream order may be one order less using a 1:100,000 scale (Schomberg, personal communication, 1998). In cases where the water body is extremely large, such as the Snake River, it was assumed that the stream order was seven or greater. ISU only used this *a priori* criterion to distinguish water body size during the development of the RMI.

- Average width at baseflow (m) – This criterion is a measure of water conditions during baseflow when BURP sampling occurs. This is the average wetted width of all measurements taken at the site (n=6). Average width does not discern the

[3] Idaho Department of Environmental Quality, 1410 N. Hilton, Boise, ID 83706.

difference in water body size due to diversions or other water flow regulations. However, ISU did recommend this criterion be used to distinguish water body size.

- Average depth at baseflow (m) – This is an average of all the depth measurements taken at a site (n=approximately 60). These measurements are taken at the transects where macroinvertebrates are sampled. Similar to average width, this criterion assesses conditions during baseflow, but does not necessarily consider water flow regulations. ISU also recommended this criterion be used to distinguish water body size.

- Average greatest depth (m) – This is an average of the three greatest depths in the reach. Originally, DEQ was more concerned about wadability when selecting monitoring protocols for different size water bodies. Specifically, if the water depth was too great to use a Hess sampler per the wadeable stream protocol, then the nonwadeable monitoring protocol would be used. However, DEQ decided that wadability should not be the key criterion for using river protocols. Nonetheless, the average width and depth does take wadability into account and considers if a Hess sampler is appropriate for monitoring.

- Site discharge (cfs) – This is the discharge measured, either by the crew or by a nearby gaging station, on the sampling day. The DEQ protocol is to measure the discharge if the system is fairly wadeable and there is no nearby gage. If DEQ did not take a discharge measurement, then an extrapolation technique was used to determine discharge. There was concern that this criterion would be affected by flow diversions during the sampling period.

- Mean annual site discharge (cfs) – Similar to the site discharge, the mean annual site discharge is determined using data from nearby USGS gaging stations and a similar extrapolation technique. Hughes et al. (1986) suggested using mean annual discharge as a better measure of water body size than stream order. Additionally, DEQ determined that this long-term criterion should generally not be as influenced by flow diversions occurring during baseflow conditions on a particular sampling date.

- Site drainage area (m^2) – This criterion, which measures the drainage area above the site, is calculated using GIS hydrography (1:100,000) and Hydrologic unit codes (HUC) (4th and 5th field) coverages. Site drainage area was also suggested by Hughes (1986) as representative of water body size. DEQ was concerned about using this criterion because flows from similar drainage areas may vary dramatically in southern and northern Idaho due to climate differences.

Criteria Determination

DEQ eliminated some of the considered criteria for several reasons. DEQ decided that discharge should not be used because of influences from flow diversions. Also, this criterion was not recommended by ISU during the development of the River Macroinvertebrate Index (see Grafe 2002). Further, DEQ believed it would be difficult and time consuming to obtain mean annual discharge figures for Idaho water bodies.

DEQ did not select the site drainage area criterion because of the difficulty in calculating this information for all the water bodies and climatic differences between northern and southern Idaho.

DEQ ultimately selected stream order, average width, and average depth. These criteria were recommended by ISU (Royer and Minshall 1999) during the development of the River Macroinvertebrate Index to distinguish among different size water bodies. As noted previously, the formulation of the water body size criteria policy occurred during the development of the river ecological assessment framework. Consequently, DEQ wanted to ensure consistent application of criteria used in the development of river bioassessment tools. Most importantly, DEQ found that the integration of these three criteria seemed to adequately interpret water body size. The addition of the other considered criteria did not seem to significantly change the assignment of water body size classes (Grafe 2002).

Criteria Rating and Assignment of Water Body Size

For bioassessment purposes, DEQ has condensed the ISU size distinctions into two categories: small and large. The criteria and corresponding size categories are located in Table 2-1.

Table 2-1. Water body size categories used to rate each criterion.

Water Body Size Category	Stream Order	Ave. Width at Base Flow (m)	Ave. Depth at Base Flow (m)	Rating
Large	≥5	≥15	≥0.4	3
Small	<5	<15	<0.4	1

DEQ rates each criterion and then averages the rating or score. Through additional analysis, DEQ found that only two size categories, streams and rivers, were necessary to represent small to large water body characteristics for bioassessment purposes. Consequently, DEQ designates water bodies with average scores of greater than or equal to 1.7 as “rivers” while those water bodies scoring less than 1.7 would be classified as “streams” (see Table 2-2).

DEQ chose 1.7 based on the different combinations of rating results. Specifically, if a water body rated twice (1+1) in the small water body size category and only once (3) in the large category, then the total of five would result in an average score rating of 1.67, just below 1.7. Water bodies that have inconsistent scores in the three categories should be further evaluated using additional measures of stream size. The ultimate goal of determining water body size should be to ensure that the proper aquatic life use assessment process (see Section 6) is used. If the water has physical and biological characteristics indicative of a river rather than a stream the assessor needs to use the river assessment process.

Table 2-2. Water body size average score rating categories.

Water Body Class	Average Score Rating
River	≥1.7
Stream	<1.7

EXAMPLE

Tables 2-3 and 2-4 provide an example of the Raft River to illustrate the rating and scoring method. Although the name "Raft River" might conjure up pictures of a large river, this water body is actually a small stream. Table 2-3 shows the stream order, average width, and average depth results. It is important to note that the width and depth measurements were taken during baseflow conditions. Referring to Table 2-1, all the criteria fall within the "small" category and therefore should be rated "1". Table 2-4 shows the rating for each criterion and the average water body size score, which is "1," calculated from the data in Table 2-3. Since the average water body size score 1.7 or less, the Raft River is classified as a small stream.

Table 2-3. Example of data used to rate criteria.

Stream	Site I.D.	Stream Order	Average Width (m)	Average Depth (m)
Raft River	1999STWFA041	3	4.3	0.16

Table 2-4. Example of rating each criterion.

Stream	Site I.D.	Stream Order	Average Width	Average Depth	Criteria Average and Score
Raft River	1999STWFA041	1	1	1	1

REFERENCES

Allan, J.D. 1995. Stream ecology: structure and function of running waters. Chapman and Hall, London.

Grafe, C.S. (editor). 2002. Idaho River Ecological Assessment Framework: An Integrated Approach.

Hughes, R.M., Larsen, D.P., and Omernik, J.M. 1986. Regional reference sites: a method for assessing stream potentials. Environmental Management. Vol. 10, 5: 629-635.

Royer, T.V. and G.W. Minshall. 1999. Bioassessment methods for Idaho Rivers: validation and summary. Final report to the Idaho Division of Environmental Quality. Department of Biological Sciences, Idaho State University, Pocatello, ID. 30 pp.

Strahler, A.N. 1957. Quantitative analysis of watershed geomorphology. American Geophysics Union Transactions. 38:913-920.

Chapter 3.
Stream Macroinvertebrate Index

Benjamin Jessup[4] and Jeroen Gerritsen[5]

INTRODUCTION

DEQ is developing biological assessment tools for measuring the quality of streams as part of the state's bioassessment program. Through the 303(d) and Total Maximum Daily Load (TMDL) framework outlined in the CWA of 1972 (and revisions of 1977 and 1987 [PL-92-500]), those waters considered to be impaired and threatened must be identified and improved to meet their designated uses. The definition of impairment by natural resource management or regulatory agencies is typically based on attainment or non attainment of numerical water quality standards associated with a water body's designated use (WQS). If those standards are not met (or attained), then the water body is considered to be impaired. Resident biota in a watershed function as continual natural monitors of environmental quality, responding to the effects of episodic as well as cumulative pollution and habitat alteration. Ambient biological surveys are one of the primary approaches to biomonitoring. These surveys, in turn, are used to measure the attainment of biological integrity. The assessment of ecosystem health cannot be done without measuring the attainment of biological integrity goals as directed by the EPA and characterized by the state of Idaho.

The CWA (PL-92-500) has as one of its primary goals the maintenance and restoration of biological integrity, which incorporates biological, physical, and chemical quality. Biological integrity is commonly defined 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 the natural habitat of the region" (Karr and Dudley 1981, Gibson et al. 1996). This concept refers to the natural assemblage of indigenous organisms that would inhabit a particular area if it had not been affected by human activities. This integrity or naturally-occurring structure and function of the aquatic community becomes the primary least impacted condition used to measure and assess water bodies in a particular region.

Careful measurement of the natural aquatic ecosystem and its constituent biological communities can reveal the condition of biological integrity. Several key attributes are measured to indicate the quality of the aquatic resources. Biological surveys establish the attributes or measures used to summarize several community characteristics, such as taxa richness, number of individuals, sensitive or insensitive species, observed pathologies, other biological and ecological elements, and the presence or absence of essential habitat features.

[4] Tetra Tech, Inc., 10045 Red Run Blvd., Suite 110, Owings Mills, MD 21117.
[5] Tetra Tech, Inc., 10045 Red Run Blvd., Suite 110, Owings Mills, MD 21117.

Multimetric, invertebrate indexes of biotic integrity, variously called Rapid Bioassessment Protocol (Plafkin et al. 1989, Barbour et al. 1999), Invertebrate Condition Index (Ohio EPA 1989), Benthic IBI (Kerans and Karr 1994) have been developed for many regions of North America and are generally accepted for biological assessment of aquatic resource quality (e.g., Gibson et al. 1996, Southerland and Stribling 1995, Karr 1991). The framework of bioassessment consists of characterizing least impacted conditions from least impacted sites by identifying appropriate biological attributes with which to measure the conditions. These biological conditions within the least impacted sites may be representative of sustainable ecosystem health. The biological condition of any site can be assessed by measuring the specified biological attributes and comparing them to conditions in the least impacted sites.

Biological measurements, called metrics, represent elements of the structure and function of the bottom-dwelling macroinvertebrate assemblage. Metrics change in some predictable way with increased human influence (Barbour et al. 1996). They include specific measures of diversity, composition, and functional feeding group representation and include ecological information on tolerance to pollution. Multimetric indexes, such as the Index of Biotic Integrity, incorporate multiple biological community characteristics and measure the overall response of the community to environmental stressors (Karr et al. 1986, Barbour et al. 1995). Such a measure of the structure and function of the biota (using a regionally-calibrated multimetric index) is an appropriate indicator of ecological quality. Indexes can reflect biological responses to changes in physical habitat quality and water quality, as well as changes at the landscape level (geology, soil, and land uses) to the degree that they affect the sampled habitat.

The objectives of this study were 1) to develop a regionallycalibrated multimetric biological index for Idaho streams using the benthic macroinvertebrate assemblage, 2) to evaluate the index using independent test data and other indexes, and 3) to recommend appropriate applications for the index. Statewide biological stream assessment data from 1994-1996 were used for developing an index. An independent subset of the data were reserved to evaluate (confirm) the index. Results of the analysis were used to make recommendations for improving the state's biological sampling program to achieve more reliable assessments of Idaho streams.

Benthic macroinvertebrate assemblages are the most widely used target organisms in biological assessment, due to several advantages (Barbour et al. 1999).

- Macroinvertebrate assemblages are good indicators of localized conditions because they are relatively sedentary.

- Macroinvertebrates integrate the effects of many short-term environmental variations because most species have a life cycle of several months to one year.

- Degraded conditions can often be detected by an experienced biologist with only a cursory examination of the benthic macroinvertebrate assemblage because macro-invertebrates are relatively easy to identify to family.

- Benthic macroinvertebrate assemblages are made up of species that constitute a broad range of trophic levels and pollution tolerances.

- Sampling is relatively easy, requires few people and inexpensive gear, and has minimal detrimental effects on the resident biota.

- Benthic macroinvertebrates serve as a primary food source for fish.

- Benthic macroinvertebrates are abundant and diverse in most streams.

Metrics fall into categories of taxa richness and diversity, pollution tolerance, feeding groups, habit (mode of locomotion), and reproductive frequency. Each metric can be tested for consistent response to stressors and the most responsive metrics can be cumulatively assessed. Such an index incorporates several metrics, to characterize several response signals at once without giving undue weight to any single metric, producing an average response as an index score. All of the metrics selected for an index have proven responsiveness to impairment and the responses can be explained by ecological mechanisms. This cumulative signal from the biotic community is a reliable and integrated indicator of ecological quality.

In biological assessment, conditions in suspected impaired sites are compared to conditions in least impacted sites. The conditions in least impacted sites are perceived as least impacted conditions, following the concept of the "control" in experimental studies. Increasingly, water management agencies in the United States and abroad are using a regional least impacted condition, consisting of a composite of multiple sites, rather than a single site-specific control (e.g., Barbour et al. 1999, Gibson et al. 1996, Hughes et al. 1986, Reynoldson et al. 1995, Wright 1995, Davis and Simon 1995). Regional least impacted conditions are preferred because (1) they allow extrapolation to sites and areas of similar characteristics to the least impacted sites, (2) regional samples allow more robust estimation of spatial variability among sites and prevent the trivial comparison of paired sites, and (3) a set of regional least impacted sites may be more cost-effective than a paired least impacted site for every assessment (Hughes et al. 1986, Barbour et al. 1999).

To ensure that the signal perceived from the benthos is more sensitive to anthropogenic stressors than it is to natural stressors, the biomonitoring sites are divided into groups of relative ecological homogeneity and comparisons are made within the groups. Across the state, the underlying geology, riparian vegetation, elevation, gradient, stream geomorphology and other natural parameters vary by stream and by region. Biological conditions are expected to vary with some of these natural parameters in the absence of stressors. The framework of ecoregions (Omernik 1987) was developed to delineate areas of relatively similar natural characteristics (Figure 3-1). The assumption that least impacted biological communities are similar within ecoregions was tested. According to the results, ecoregions were split or combined into bioregions - geographic regions with similar biological community structure.

The proposed index of biological condition allows streams in Idaho to be rated according to the similarity of the biological metrics to least impacted streams within bioregions. As such, the conditions to which all samples are compared are the best attainable within a bioregion,

not hypothesized "pristine" conditions. The numerical index values can be converted to narrative ratings based on appropriate thresholds. The narrative ratings, ranging from "very good" to "very poor," could become primary indicators of stream conditions for natural resource decision-makers as they consider actions and priorities for the streams. Recommended thresholds, based on index value distributions in the least impacted sites, could be applied as biocriteria in the state's stream assessment program after additional testing and development.

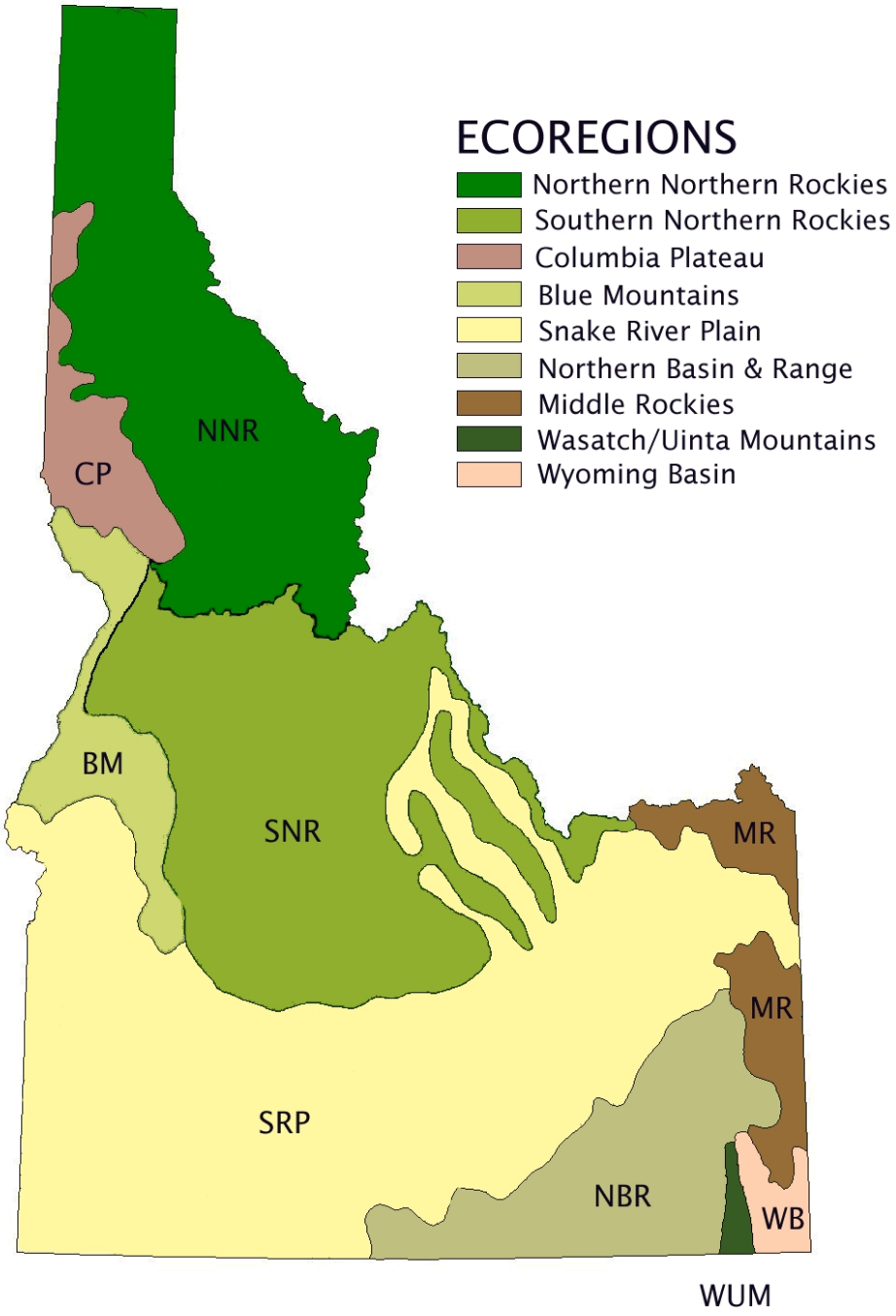


Figure 3-1. Ecoregions of Idaho (Omernik 1987).

METHODS

Biological index development, testing, and application require a stepwise procedure:
1) Definition of site criteria for least impacted and stressed sites,
2) Biological survey of streams,
3) Determination of naturally occurring site classes (bioregional delineations),
4) Testing metric discriminatory ability within bioregions,
5) Scoring candidate metrics and combining metric scores into a regionally calibrated index, and
6) Test index with independent data.

The steps are described below.

Definition of Site Criteria for Least Impacted and Stressed Sites

Professional DEQ biologists developed consensus definitions of least impacted and stressed (most impacted) conditions for Idaho streams (Table 3-1). These non-biotic criteria were intended to identify *a priori* the very best and very worst of sites. Sites must meet all criteria to be designated least impacted, but could be designated stressed by failing several criteria or by severely failing a single criterion (on the judgment of DEQ biologists). Sites not designated as least impacted or stressed were inconsequential to index development procedures.

Table 3-1. Non-biotic variables and criteria used for selecting least impacted sites *a priori*. All of the criteria must be met for a site to be rated "least impacted." "Stressed" sites fail several of the criteria or severely fail any single criterion.

Variable	"Least Impacted" Criteria
Chemical stressors	Likely sources of chemical stress are few (e.g., unbuffered croplands, irrigation returns, active or in-active mining areas, regulated discharges), or if potential sources are present, chemical data shows standards or guidelines are met, and thus effects are unlikely.
Flow modifications	Upstream impoundments absent. Irrigation withdrawal or other diversions absent, or if present, cause minimal disruption to the hydrologic cycle (almost all streams located in the semi-arid basin/lowland ecoregions will have some water withdrawals).
Sedimentation	Causes for anthropogenic sediment increases not apparent (e.g., crop or road gullies, livestock bank trampling, mass wasting). No field notes of highly turbid conditions. Channel substrate of less than 50% fine sediments (measured as bankfull). No "poor" qualitative cobble embeddedness estimates (75%). No "poor" habitat ratings for bank stability.

Variable	"Least Impacted" Criteria
Habitat structure complexity	Substrate is heterogeneous and site contains greater than 30% stable instream fish cover.
Channel complexity	Mixture of pool, glide, riffle, and run habitat types. Longitudinal habitat distribution rated sub-optimal or optimal. No "poor" habitat ratings for channel shape.
Shoreline/channel modifications	Evidence of artificial bank armoring, channel straightening, vegetation removal, or other disturbances absent or minimal.
Riparian vegetation	Riparian growth is extensive and old. It occurs all along the shoreline and is capable of shading the stream and buffering human influences. It overhangs the stream or deposits large woody debris. Bank vegetation protection >70% (sub-optimal or above) or canopy cover shading >25%. No "poor" habitat ratings for bank vegetative protection.
Riparian structure	The riparian vegetative structure has a canopy, understory, and ground cover (trees, shrubs, and ground cover).
Land use	Roads, logging, construction, farming, grazing, and other land uses that disturb the natural vegetation and soils are absent, infrequent, or do not impinge on the riparian zone. Evidence of unnatural bank failures, trampling, excess runoff, or irrigation returns absent or minimal. The habitat variables "disruptive pressures" and riparian "zone of influence" should be rated optimal (9-10) (see DEQ BURP field form).

Modified from Hughes (1995)

Biological Survey of Idaho Streams

In 1994, DEQ finalized its methodology for stream reconnaissance (DEQ 1996). Fifteen core parameters are measured at each site, including physical characteristics, habitat (Hayslip 1993), benthic macroinvertebrates (Clark and Maret 1993), and fish (Chandler et al. 1993). Benthic macroinvertebrates are collected with a Hess sampler (500 micrometers [µm] mesh) in three riffle habitat units. The three samples are composited in the laboratory, and the first 500 individuals are identified to the lowest practical level or to a prescribed level (e.g., Chironomidae were identified at the family level). Subsamples meet or exceed the 500 individual target depending on subsampling rules regarding minimum and maximum effort. A subsample with fewer than 500 individuals constitutes the entire sample. Since 1994, several thousand stream sites have been sampled using these protocols.

Data used for index development included benthic macroinvertebrate relative species abundances from riffle samples, location information, physical measurements, and habitat assessments over three summer sampling periods, from 1994 to 1996. The selection of streams for the biomonitoring program was not random, but targeted towards streams of interest to the state because of exceptionally high quality or suspected anthropogenic

impacts, among other reasons (DEQ 1996). Data were managed in a relational database for efficient storage and querying.

For certain steps of index development, sites were divided randomly into calibration and test sets. Site classification and final index evaluation used all the data (calibration and test). Approximately 65 percent of the samples were assigned to the calibration set and were used to determine metric discrimination and select metrics for the multimetric index. The remaining 35 percent of the data were used to test the index performance. Proportional representation of each ecoregion in Idaho was maintained in the calibration and test data sets as far as possible.

Determinating Naturally-occurring Site Classes (Bioregional Delineations)

Detecting changes in the biological assemblage due to human effects must take into account inherent differences due to natural factors. Natural variability in the macroinvertebrate assemblage may result from natural variability in the physical and chemical site characteristics across a geographic range. Much of the natural variability can be accounted for by dividing the area into ecological regions. Ecoregions (Omernik 1987) are delineations of areas with similar climate, geology, soils, vegetation, topography, and hydrology. Ecoregions have been accepted as a geographic framework for delineating regions of relatively homogeneous natural conditions (e.g., Barbour et al. 1996).

Two primary classification techniques, ordination and comparison of metric distributions, were used to justify separating or combining data from ecoregions into larger regions of relative biological homogeneity (bioregions). All of the least impacted sites were used in site classification. Stressed sites were not used because they are not truly representative of natural biological conditions. Ecoregions with few samples or that showed inconclusive groupings using the two techniques were combined with ecoregions of similar natural characteristics as determined by state biologists.

Alternative classification schemes were examined with multivariate ordination of the least impacted sites based on their species composition, following methods outlined in Jongman et al. (1987) and Ludwig and Reynolds (1988). Ordination is a category of methods for reducing the dimensionality of multivariate information (many species in many sites) by placing sites or species in an order. The first ordination method we used is non-metric multidimensional scaling (NMDS) using the Bray-Curtis (BC) dissimilarity coefficient. The BC coefficient contrasts relative taxa abundances between samples according to the formula:

$$BC = 1 - \left({2W}/{(A+B)} \right) \quad ,$$

where W is the sum of common taxa abundances and A and B are the sums of taxa abundances in individual sample units. A pair of samples with identical taxa abundances would have a BC coefficient of 0 and a pair of samples with no taxa in common would have a BC coefficient of 1. This ordination method has been shown to be robust for ordination of species composition (e.g., Kenkel and Orloci 1986, Ludwig and Reynolds 1988), and has been used successfully for classification of stream communities (e.g., Barbour et al.1996; Reynoldson et al.1995).

The site-by-site matrix of BC dissimilarity coefficients was used in the NMDS ordinations (McCune and Mefford 1997, Kruskal 1964). An acceptable ordination should have a stress coefficient (measuring the goodness-of-fit of the ordination to the original data) of less than 20 percent. Stress is lowered as additional dimensions are allowed in the ordination, and three axes are commonly required. The final NMDS configuration was plotted (as a scatterplot in two dimensions) to identify groupings of sites with similar taxa composition (low BC dissimilarity). When plotted points are labeled by site characteristics (e.g., ecoregions) the association between taxa composition and site characteristics can be visualized. Ecoregion groupings that overlap in the ordination plots could be combined into bioregions for subsequent analysis.

A second ordination using metric values in a principle components analysis (PCA) showed groupings of sites with similar metric values. Prior to analysis, all metrics were examined for normality using normal probability plots. Transformations were applied as needed (log or arcsin square-root functions) to normalize the metric distributions. All metrics are entered into the analysis as redundancy does not affect the ordination. NMDS and PCA ordinations proceeded using PC-ORD software (McCune and Mefford 1997).

The second technique used to discern bioregional delineations was a comparison of box and whisker diagrams of metric distributions from least impacted sites. Similar distributions of metrics (medians, inter-quartile ranges, and overall ranges) between ecoregions indicate similar biotic assemblages and justify aggregation of ecoregions into a single bioregion. Likewise, differences in distributions suggest distinct bioregions.

Testing Metric Discriminatory Ability within Bioregions

Metrics were included in the analysis based on successful performance in previous studies (Stribling et al. 1998, Gibson et al. 1996, Barbour et al. 1996), including an unpublished study in Wyoming (Stribling et al. 2000). The metrics fall into seven categories: taxonomic richness, composition, pollution tolerance, diversity, feeding group, habit, and voltinism. Metrics calculated from the Idaho data are given in Table 3-2. The general ecological meanings associated with each category are discussed below.

Table 3-2. Definitions of candidate macroinvertebrate metrics and predicted direction of metric response to increasing perturbation (modified after Barbour et al. 1999).

Metric	Definition	Predicted Response to Increasing Perturbation
Richness measures		
Total taxa	Number of distinct taxa in the macroinvertebrate assemblage	Decrease
EPT[1] taxa	Number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)	Decrease
Ephemeroptera Taxa	Number of mayfly taxa	Decrease
Plecoptera Taxa	Number of stonefly taxa	Decrease
Trichoptera Taxa	Number of caddisfly taxa	Decrease
Diptera taxa	Number of "true" fly taxa	Variable
Composition measures		
% EPT	Percent of the sample that is mayfly, stonefly, and caddisfly larvae	Decrease
% Ephemeroptera	Percent of sample that is mayfly nymphs	Decrease
% Plecoptera	Percent of sample that is stonefly nymphs	Decrease
% Trichoptera	Percent of sample that is caddisfly larvae	Decrease
% Elmidae	Percent of sample that is elmid beetle larvae or adults	Decrease
% Hydropsychidae	Percent of sample that is net spinning caddisfly larvae	Variable
% Diptera	Percent of sample that is "true" fly larvae	Increase
% Diptera (non-chironomid)	Percent of sample that is "true" fly larvae, but not of the midge family	Increase
% Chironomidae	Percent of sample of the midge family of flies	Increase
% non-insects	Percent of sample that is not insects	Increase
Pollution Tolerance Measures		
Intolerant taxa (0-1)	Taxa richness of those organisms considered to be most sensitive to perturbation (with a tolerance value of 0 or 1)	Decrease
Intolerant taxa (0-3)	Taxa richness of those organisms considered to be sensitive to perturbation (with a tolerance value of 0 to 3)	Decrease

Metric	Definition	Predicted Response to Increasing Perturbation
% Tolerant	Percent of sample considered to be tolerant of various types of perturbation (with tolerance values of 7 to 10)	Increase
Hilsenhoff Biotic Index	Abundance-weighted average tolerance of organisms to pollution. Originally designed to evaluate organic pollution (Hilsenhoff 1987).	Increase
Diversity Measures		
Shannon-Wiener Index	A measure of the heterogeneity of the community or of the diversity of dominant taxa (Shannon and Weaver 1949)	Decrease
Simpson's Index	The probability of randomly and independently selecting the same taxa from the sample twice (Simpson 1949)	Increase
% Dominant taxon	Percent of sample in the single most abundant taxon. Also calculated as dominant two, three, five, or 10 taxa.	Increase
Feeding Measures		
Scraper taxa	Number of taxa that scrape periphyton from substrates	Decrease
% Scrapers	Percent of sample that are scrapers	Decrease
% Collectors	Percent of individuals that scavenge organic matter	Variable
% Predators	Percent of the sample that are predators but not omnivores	Variable
Habit Measures		
Clinger taxa	Number of taxa that have fixed retreats or adaptations for attaching surfaces in flowing water	Decrease
% Cclingers	Percent of sample that are clingers	Decrease
% Cclingers of insects	Percent of insects in sample that are clingers	Decrease
Voltinism Measures		
Semi-voltine taxa	Number of taxa that have aquatic life cycles lasting more than one year	Decrease
% Semi-voltine	Percent of sample that are semi-voltine	Decrease

[1]EPT: Ephemeroptera, Plectoptera, Trichoptera

Taxa richness metrics. High taxa richness usually correlates with increased health of the assemblage and suggests that niche space, habitat, and food sources are adequate to support the survival and propagation of many species. "Total taxa" measures the overall variety of the macroinvertebrate assemblage. No identities of major taxonomic groups are derived

from the total taxa metric, but the elimination of taxa from a naturally diverse system can be readily detected. Subsets of "total" taxa richness are also used to accentuate key indicator groupings of organisms, such as mayflies, stoneflies, and caddisflies.

Composition measures can be characterized by two classes of information: identity and relative abundance. Identity is the knowledge of individual taxa and associated ecological patterns and environmental requirements (Barbour et al. 1995). Key taxa (i.e., those that are of special interest or ecological importance) and their abundance in the targeted assemblage provide information regarding suitability of stream conditions for growth and reproduction.

Pollution tolerance measures characterize the relative sensitivity of the assemblage to perturbation. They measure numbers or percent composition of pollution tolerant and intolerant taxa (Barbour et al. 1995). Tolerance is generally non-specific to the type of stressor. The Hilsenhoff Biotic Index (HBI) (Hilsenhoff 1987, 1988) was originally oriented toward detection of organic pollution using insects. Taxa tolerance values have since been adjusted to account for regional variation in taxa distributions and stressor types and to include the non-insect taxa. The HBI is an abundance-weighted average tolerance:

$$HBI = \sum \frac{n_i * tv_i}{N} \quad ,$$

where n_i is the number of individuals in the ith taxa, tv_i is the tolerance value assigned to the ith taxa, and N is the number of individuals in the sample with known tolerance values. The richness of intolerant taxa can be calculated at different tolerance levels: taxa with tolerance values less than 4, taxa with tolerance values less than 2, etc.

Diversity metrics are good indications of the ability of the ecosystem to support varied taxa evenly. Several diversity indexes, which are measures of information content and incorporate both richness and evenness in their formulas, may function as viable metrics in some cases, but are usually redundant with taxa richness and percent dominance (Barbour et al. 1996). The most common of these is the Shannon-Wiener index (Shannon and Weaver 1949):

$$H' = -\sum_{i=1}^{s} \left(\frac{n_i}{N} * \log_2 \left(\frac{n_i}{N} \right) \right) \quad ,$$

where n_i is the number of individuals in the ith taxa, and N is the total number of individuals in the sample. The base of the logarithm is most commonly 2, to reflect the binary basis of species presence/absence, but any other base could also be used. Percent dominance metrics evaluate the degree to which conditions favor a single taxon or few taxa.

Feeding measures encompass functional feeding groups and provide information on the balance of feeding strategies (food acquisition and morphology) in the benthic assemblage. Feeding groups include scrapers, collectors, and predators. Specialized feeders, such as scrapers, are more sensitive organisms and are thought to be well represented in healthy streams. Generalists, such as collectors, have a broader range of acceptable food materials

than specialists (Cummins and Klug 1979), and thus are more tolerant to pollution that might alter availability of certain food.

Habit (mode of locomotion) measures are those that denote the mode of existence and consist of morphological adaptations for maintaining position and moving about in the aquatic environment (Merritt and Cummins 1996). Habit categories include movement and positioning mechanisms such as skaters, divers, swimmers, clingers, sprawlers, climbers, and burrowers. The clingers are adapted to life in running waters and are sensitive to hydrologic perturbation, habitat disturbance, and other pollutants.

Voltinism measures. The percentage and richness of animals having aquatic life cycles longer than one year were calculated. A community where such semi-voltine organisms are well represented indicates that environmental conditions are relatively stabile, with perturbations that are either infrequent or mild relative to the organism's parameters for survival. A community in which no organisms require long residence times for maturation indicates that perturbations disrupt maturation or reproduction.

Using calibration data only, individual metrics were tested for separation of values between least impacted and stressed sites. The metrics exhibiting differing distributions were considered for inclusion in a multimetric index. The discrimination efficiency (DE) was used as the performance measure in this evaluation. It was calculated as the percentage of metric values in stressed sites that were worse than the worst quartile (25th or 75th percentile) of the least impacted metric values. The judgment of better and worse metric values required an understanding of the ecological mechanisms by which stressors influence biological metric values. Metrics were evaluated within bioregions. Consistency of response in all bioregions (relative degree of separation and trend of response) was a prerequisite for a metric's inclusion in the index.

Scoring Metrics and Combining Metric Scores into a Regionally-Calibrated Index

The purpose of an index is to provide a means of integrating information from the various measures of biological attributes (metrics). Metrics vary in their scale; they are integers, percentages, or dimensionless numbers. Prior to developing an integrated index for assessing biological condition, it is necessary to standardize candidate metrics via a transformation to unitless scores. The standardization assumes that each metric has the same importance in the index (i.e., they are weighted the same).

A continuous scoring strategy was used (Barbour et al. 1999), which rates the metric values on a percentage scale from the worst possible value to the optimal value. In this way, all metrics can score between 0 (worst) and 100 (optimal). To minimize the influence of potentially non-representative outliers, the 95th percentile of the data was considered optimal. Metrics that increase with increasing perturbation (such as percent dominant taxon) score best at the 5th percentile and worst at the maximum value recorded in the entire data set. Some of the metrics had skewed distributions; they contained many low values with few higher values (e. g., percent Elmidae, percent non-insects). Decreasing skewness equalizes a metric's contribution to the index compared to unskewed metrics. The transformation used

was the arc-sine square root function, which has greatest effect on percentage values less than 15 percent and greater than 85 percent.

The index was calculated as an average of the included metric scores. Alternative indexes were formulated from the metrics with strong and consistent discriminatory ability in all bioregions. The goal of alternative index formulation was to identify the index that: 1) included responsive metrics from all of the metric categories, 2) included metrics that were not redundant, and 3) gave the greatest separation between least impacted and stressed index scores. By including metrics from all categories, the index will incorporate diverse ecological information and may be responsive to a broad range of stressors. Redundant metrics in an index will bias the index towards the common response mechanisms (Barbour et al. 1992). To avoid redundant information in the index, correlation analysis (Pearson product-moment) was performed on metrics from all samples. Any metrics with a correlation coefficient greater than 0.9 or less than -0.9 were considered redundant and were not used together in any index formulations. Metrics with correlation coefficients greater than 0.8 were used together only when necessary to represent information from all metric categories. Each alternative index was tested for its ability to discriminate between least impacted and stressed sites using the index discrimination efficiency within each bioregion.

Because DEQ is interested in comparing the proposed macroinvertebrate index with indexes previously proposed or applied within the state, additional index formulations were tested. Metrics used in the River Macroinvertebrate Index (Royer et al. 2001), Macroinvertebrate Biotic index (described in Mebane 2000), Benthic Index of Biotic Integrity (Kerans and Karr 1994), and the analysis of Robinson and Minshall (1998) were scored and combined for side-by-side analysis with the SMI.

Testing the SMI with Independent Data

The data put aside for testing the SMI was not used in its development. Rather, the SMI was applied to this test data and the discriminatory ability was again evaluated. The same SMI thresholds established with calibration data (the 25th percentile of least impacted SMI scores) were used to calculate the percentage of "correct" site classifications of least impacted and stressed test sites. Some reduction in discriminatory ability may be expected using test data instead of the calibration data. Drastic reduction in discriminatory ability of the index in the test data would warrant reexamination of the index components.

In final steps of SMI development, the calibration and test data were re-combined and the SMI was recalibrated using the entire data set. Scoring formulas and index statistics are presented to aid natural resource managers in application of the SMI. SMI threshold values are suggested to allow narrative rating of sites into categories of biological integrity.

RESULTS AND DISCUSSION

Database Characteristics

DEQ personnel collected 1,758 valid samples from 1,440 biomonitoring sites during the summer index periods of 1994, 1995, and 1996. Using non-biological stream condition criteria (see Table 3-1), 150 least impacted and 145 stressed samples were identified. Samples that included benthic macroinvertebrate and habitat data were considered valid. The sites were located throughout the eight ecoregions of Idaho though the numbers or densities of sites per ecoregion were not equivalent. For development and confirmation of the multimetric index, the 295 samples were randomly divided into calibration and test sets. Sample sizes for the least impacted and stressed calibration and test data are presented in Table 3-3.

Table 3-3. Sample sizes in the ecoregions of Idaho by *a priori* stream condition (least impacted or stressed) and data set assignment (calibration or test).
The Northern Rockies ecoregion was divided into northern and southern portions.

Ecoregion	Least Impacted Calibration/Test	Stressed Calibration/Test
Northern Northern Rockies	17 / 9	13 / 7
Southern Northern Rockies	29 / 15	10 / 7
Middle Rockies	11 / 6	7 / 3
Blue Mountains	11 / 4	5 / 2
Wasatch and Uinta Mountains	3 / 1	0 / 0
Snake River Basin	16 / 8	35 / 21
Northern Basin and Range	9 / 5	16 / 8
Columbia Plateau	2 / 1	4 / 2
Wyoming Basin	2 / 1	3 / 2
Totals	100 / 50	93 / 52

Site Classification

Idaho streams lie within eight ecoregions (Figure 3-1): the Wyoming Basin, the Snake River Basin (SRB), the Northern Basin and Range (NBR), the Columbia Plateau (CP), the Middle Rockies (MR), the Northern Rockies (NR), the Blue Mountains (BM), and the Wasatch-Uinta Mountains (WUM). Preliminary indications that the Northern Rockies could have distinct biological characteristics between the northern and southern portions suggested division of the ecoregion at the watershed between the Clearwater River drainage to the north and the Salmon River drainage to the south. The WB, CP, and WUM had less than five least impacted sites. Because data from such small samples give unreliable signals, these ecoregions were grouped with similar ecoregions using the best professional judgment of the authors and DEQ staff.

The emphasis on ecoregions as the primary grouping variable comes from the understanding that the ecoregions incorporate many forms of ecological information. Climate, geology, soils, topography, vegetation, and hydrology are all considered in the ecoregion framework

(Omernik 1987). Examination of each physical habitat variable separately does not usually result in more clearly defined bioregional groupings. This assumption was investigated during ordination analysis.

Distributions of metric values in least impacted sites were plotted by ecoregion to detect similarities that would suggest a bioregional scheme (Figure 3-2). Few metrics had distributions that showed distinct differences between ecoregions. The northern Northern Rockies appeared unique in the average and maximum numbers of all taxa, Plecoptera taxa, and intolerant taxa. These and other metrics in the northern Northern Rockies were highly variable. Metric distributions among the other mountainous ecoregions were similar to each other, but they were different relative to non-mountainous ecoregions. This was especially evident in the pollution tolerance metrics HBI and intolerant taxa, which indicate that intolerant taxa are more diverse and abundant in the mountainous regions. The WUM distributions aligned with non-mountainous ecoregions, but this distribution represents only four samples and bioregional groupings based on this small sample would be insubstantial. The WUM was grouped with other mountainous regions based on similar physical habitat conditions (Omernik and Gallant 1986). Likewise, the WB metric distributions resembled some mountainous ecoregion distributions, but the small sample size (n = 3) and comparative physical habitat conditions warrant grouping the WB with other non-mountainous ecoregions. Thus, the bioregional scheme we suggest after reviewing these metric distributions includes three bioregions; 1) the Northern Mountains, 2) the Central and Southern Mountains, and 3) the Basins (Table 3-4, Figure 3-3).

NMDS ordination of relative taxa abundance (Figure 3-4) and PCA ordination of metrics (Figure 3-5) revealed that the Northern Mountains and the Basins are somewhat distinct from each other, whereas the other Southern and Central Mountain samples are dispersed throughout the ordination space. The NMDS ordination illustrates the similarity of relative abundances of taxa in the samples (Figure 3-4). The taxa groups (mostly families) that are most common show the strongest correlations to the ordination axes. These taxa include oligochaetes, chironomids, simuliids, baetids, heptageniids, rhyacophilids, and elmids. Stream gradient is correlated with the same axis as oligochaetes, heptageniids, and rhyacophilids. Latitude is correlated with the same axis as chironomids, with baetids at the other end of the axis. The Northern Mountains separate from the Basins on a diagonal axis, with greatest differences noted in the Plecoptera family abundances.

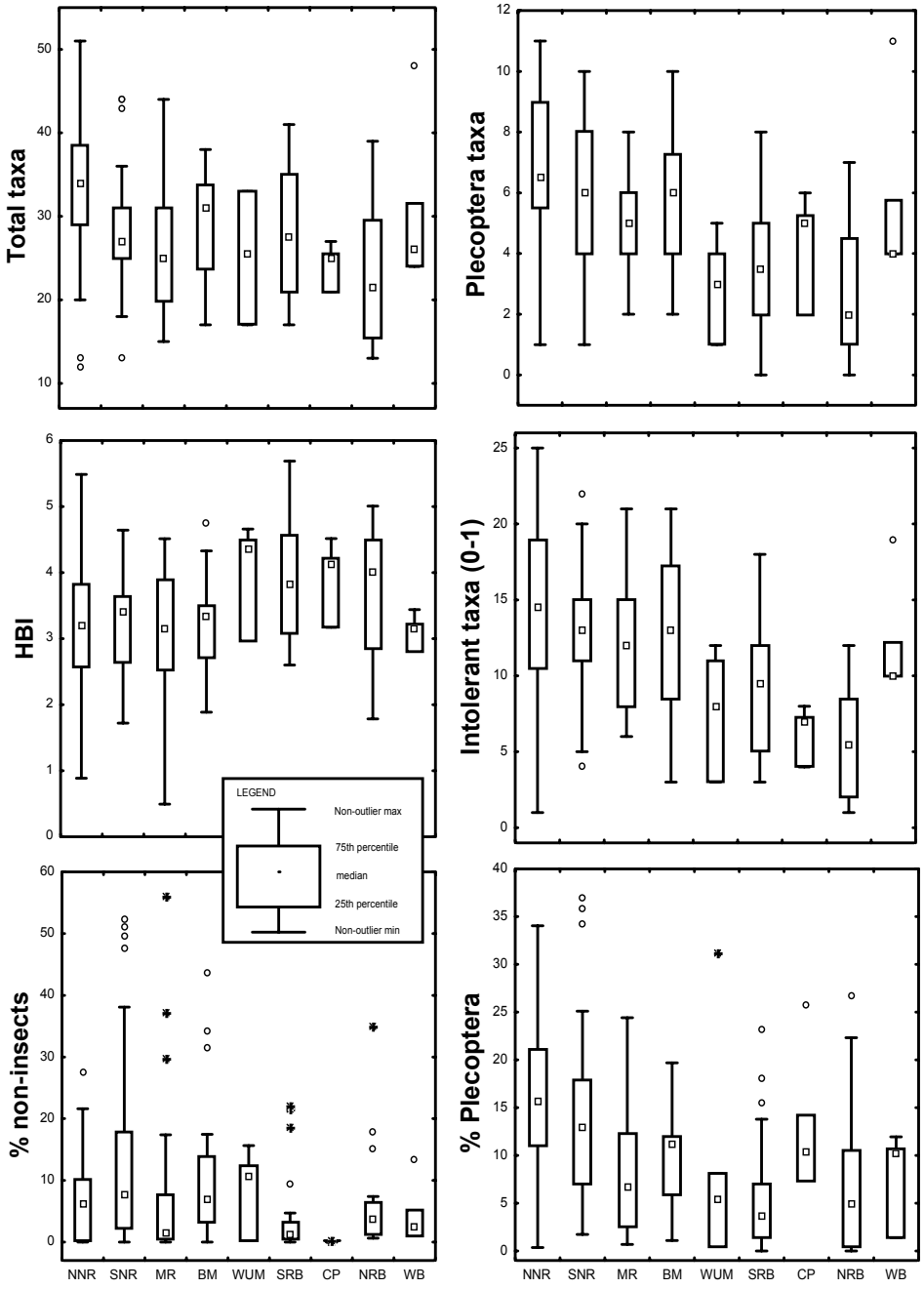


Figure 3-2. Distributions of selected metrics for sites, by least impacted ecoregions of Idaho.
The two divisions of the Northern Rockies are abbreviated NNR and SNR for the northern and southern portions. The WUM, CP, and WB ecoregions have fewer than five least impacted samples.

Table 3-4. Final site classification; three bioregions and the ecoregions they include.

Northern Mountains	Central and Southern Mountains	Basins
Northern Northern Rockies	Southern Northern Rockies	Snake River Basin
	Blue Mountains	Northern Basin and Range
	Middle Rockies	Columbia Plateau
	Wasatch and Uinta Mountains	Wyoming Basin

In the PCA ordination, the first two axes explained 47 percent of the variance (Figure 3-5). The first axis shows strong association with richness related metrics and the second axis is strongly associated with composition (percentage) metrics (Table 3-5). Samples with greater taxa richness in most taxa groups are on the left of the plot, where many of the Northern Mountain samples appear. The second axis generally separates samples with higher % EPT and intolerant individuals (bottom) from samples with higher % Diptera (top). The third axis explained another 10% of the variance and was associated with % Elmidae and % semi-voltine taxa.

These ordinations do not show conclusive evidence for bioregional groupings based on ecoregions. In general, the Northern Mountains have more taxa and more intolerant taxa than the Basins, though many of the taxa abundances are similar. The Central and Southern Mountains cover the ordination space, implying high variability in taxa abundances and metric values. Bioregions can only be defined in conjunction with metric distribution comparison and the expertise of local biologists. Sample sizes in the bioregions are displayed in Table 3-6.

Prevailing physical characteristics and habitat assessment scores in the ecoregions support grouping mountainous and non-mountainous regions, and separating out the northernmost Rockies. Land surface forms, potential natural vegetation, and land uses in the mountains are distinct from those in the plains (Omernick and Gallant 1986). The mountainous terrain supports coniferous forests with timber production and forest grazing as the primary land uses. The basins by contrast are mostly flatter with some tablelands, hills, and low mountains. They support prairie grasses and sagebrush that is grazed or irrigated and cultivated. The basins are generally drier than the mountains as well, receiving less than 25 inches of precipitation per year.

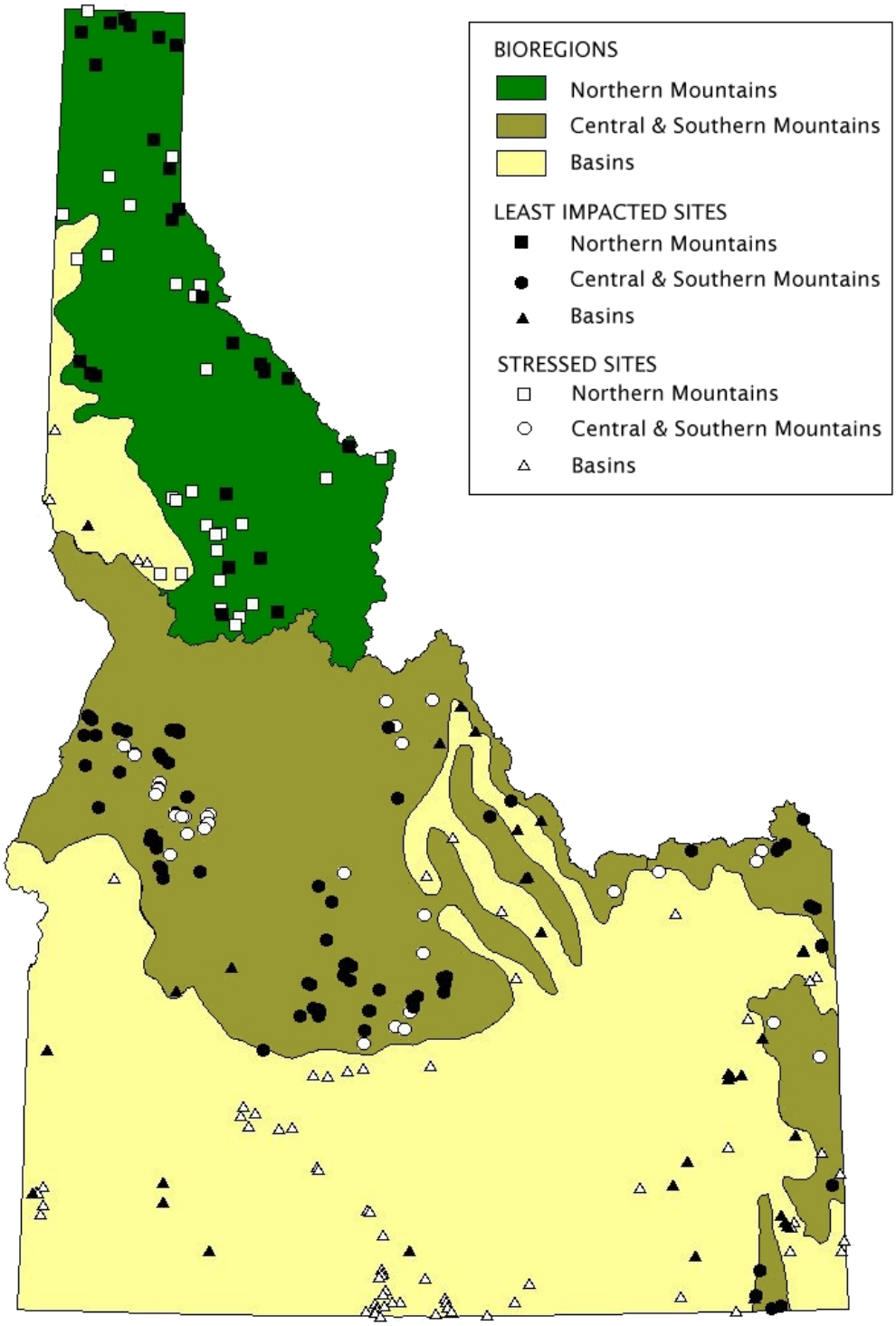


Figure 3-3. Geographic distribution of least impacted and stressed biomonitoring sites in the bioregions of Idaho.

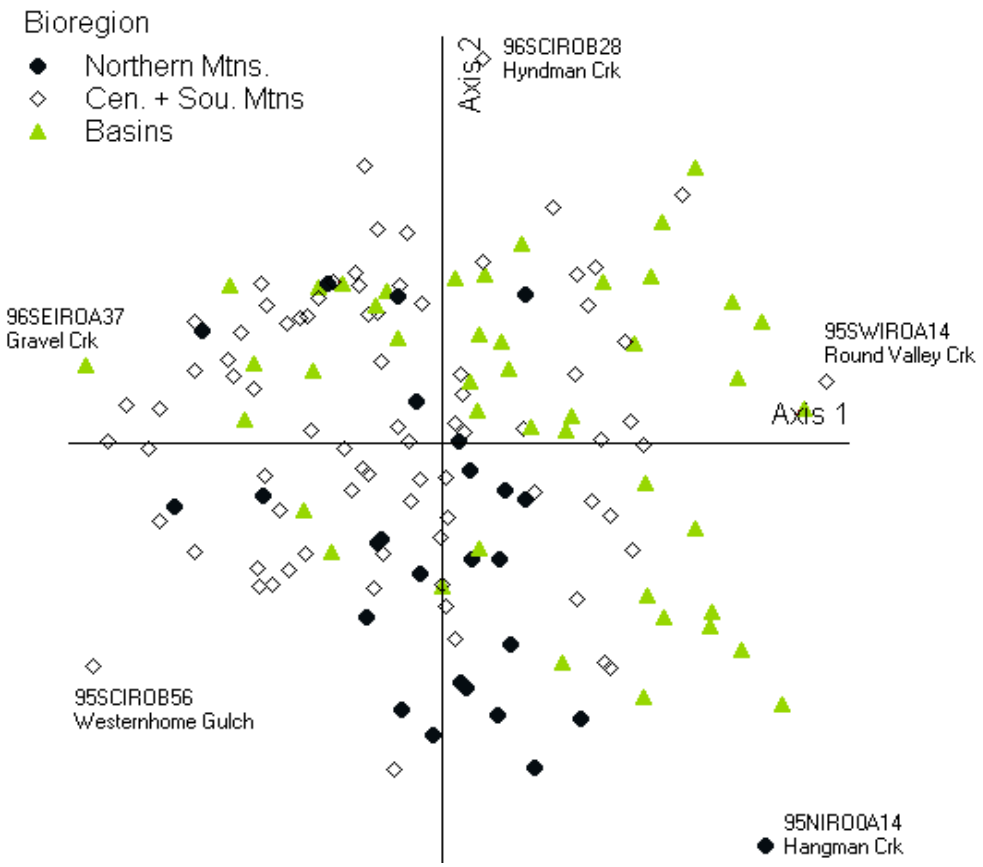


Figure 3-4. NMDS ordination of family level relative abundance for 150 least impacted samples.

Three bioregions are designated and outliers are labeled. In general, samples with greater percentages of oligochaetes, heptageniids, and rhyacophilids are on the left of the plot; chironomids are in the lower right; and baetids and elmids are in the upper right. Oligochaete-dominated samples separate from the others on the third axis (not shown), as do the elmids. Stream gradients are somewhat steeper in samples at the left of the plot.

The northern Northern Rockies and Blue Mountains are lower in elevation than the southern Northern Rockies, Middle Rockies, or Wasatch/Uinta Mountains (Figure 3-6). Compared to the non-mountainous regions, stream gradients are steeper and substrate particle sizes are larger in the mountains. The Middle Rockies ecoregion has more fine particles in its substrate composition than the other mountainous regions. The Snake River Basin has many large streams (by discharge), and the Columbia Plateau is dominated by small streams.

Habitat features in the least impacted sites of the ecoregions were assessed as scores (Table 3-7). The "channel shape" median scores were noticeably higher in the Central and Southern Mountains bioregions than either the Northern Mountains or the Basins bioregions. Other median scores were similar among ecoregions, though the Columbia Plateau and Northern Basin and Range scores were often lower. The highest total habitat scores (total of all habitat

feature scores) were in the southern Northern Rockies, Wasatch/Uinta Mountains, and Blue Mountains.

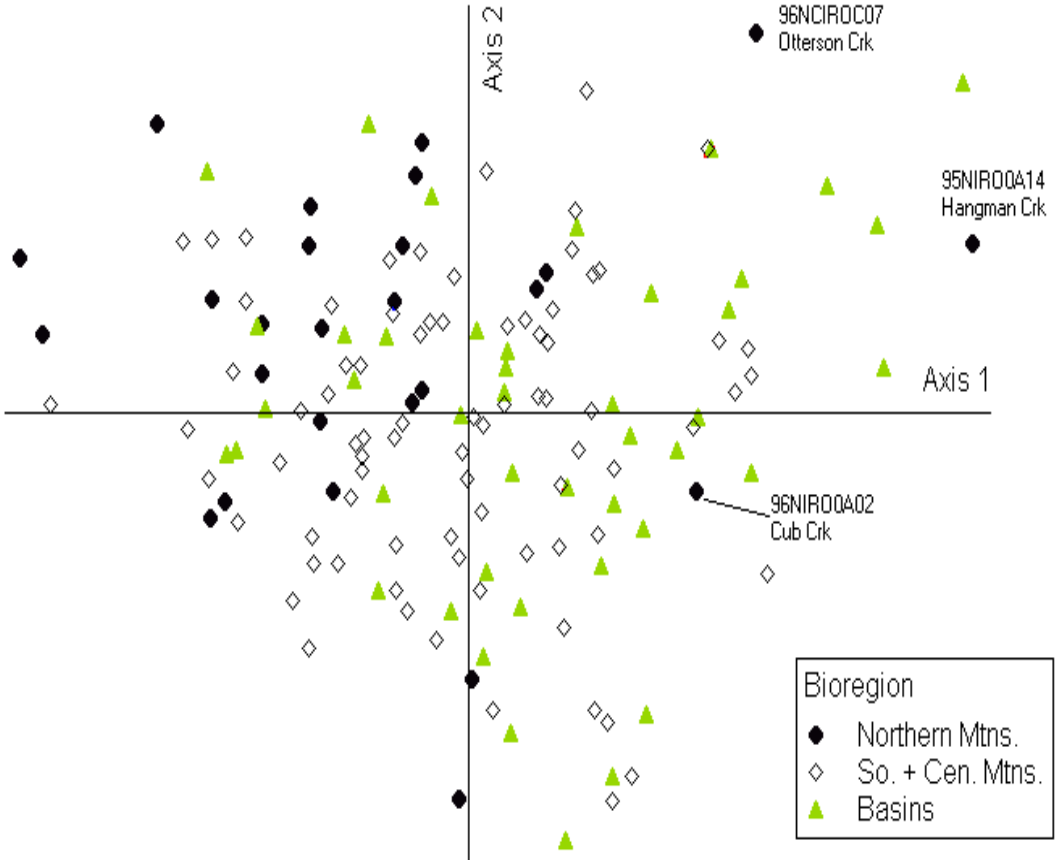


Figure 3-5. PCA ordination of 150 reference sites designated by bioregion, showing the first two axes. Thirty-six metrics with normal or normalized distributions went into the PCA. Samples with greater taxa richness in most taxa groups are on the left of the plot. The second axis generally separates samples with higher percent EPT and intolerant individuals (bottom) from samples with higher percent Diptera (top). Outlier samples from the Northern Mountains are labeled.

Table 3-5. Eigenvectors of metrics in the PCA.
Only metrics with eigenvectors greater than 0.2 on either of the first two axes are shown. Not shown are metrics that are redundant with those shown (percent dominant, percent 2 dominant, percent 3 dominant, etc.). The metric "% Diptera" was transformed by the arcsin square root function. Other transformed metrics were not retained in this table.

	Eigenvectors	
Metric	**1st axis**	**2nd axis**
Total taxa	**-0.24**	**0.21**
EPT taxa	**-0.25**	0.14
Plecoptera taxa	**-0.21**	0.10
Trichoptera taxa	**-0.21**	0.14
Diptera taxa	-0.11	**0.20**
% EPT	-0.10	**-0.30**
% Ephemeroptera	-0.03	**-0.26**
% Diptera	0.10	**0.31**
HBI	0.15	**0.28**
Intolerant taxa	**-0.25**	0.12
% 5 dominant	**0.27**	-0.01
Shannon-Wiener	**-0.27**	0.00
% Scrapers	-0.05	**-0.32**
% Collectors	0.09	**0.26**
Clinger taxa	**-0.23**	0.14
% Clingers	-0.05	**-0.23**

Table 3-6. Sample sizes in the bioregions of Idaho by *a priori* stream condition (least impacted or stressed) and data set assignment (calibration or test).

Ecoregion	**Least Impacted Calibration/Test**	**Stressed Calibration/Test**
Northern Mountains	17 / 9	13 / 7
Central and Southern Mountains	54 / 26	22 / 12
Basins	29 / 15	58 / 33
Totals	100 / 50	93 / 52

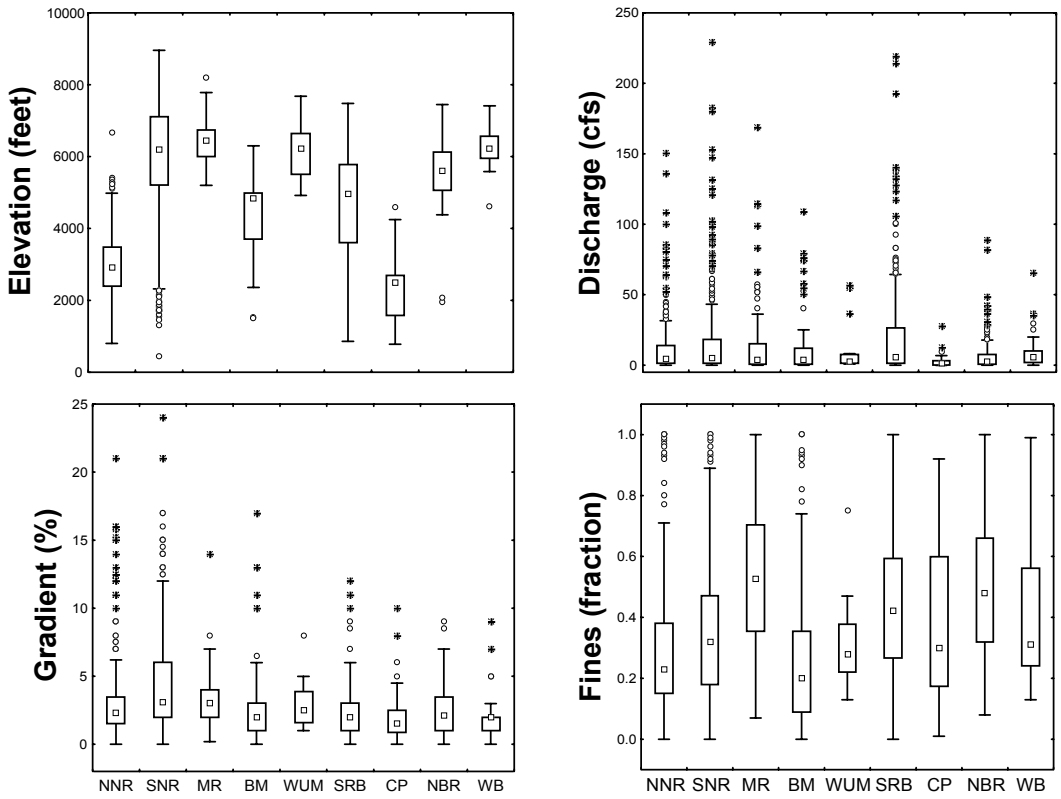


Figure 3-6. Physical characteristics of all sampled sites in the ecoregions of Idaho. The Northern Rockies are separated into northern (NNR) and southern (SNR) sub-ecoregions.

Index Metric Selection

Thirty-six biological metrics in six metric categories were calculated from the benthic macroinvertebrate taxa abundances (see Table 3-2). Taxa were identified to the lowest practical taxonomic level, usually genus or species. Laboratory protocol called for identification of 500 organisms from each composited sample; 37 percent of the samples were within 20 percent of this target. Three Hess sample grabs may fail to capture 500 or more organisms because of low densities caused by either oligotrophic or toxic conditions (natural or unnatural stressors). Very high densities may likewise be associated with conditions favorable to pollution intolerant or tolerant organisms. Taxa richness is expected to increase as more individuals are sampled, though composition metrics are independent of sample size. Total taxa richness was compared to subsample size in least impacted and stressed sites (Figure 3-7). At subsample sizes greater than 600, the least impacted taxa richness continued to increase with subsample size. Stressed taxa richness did not increase greatly with increasing subsample size. Though variability in subsample size was initially a concern, data were not re-sampled or eliminated from the analysis for three reasons. Richness in large subsamples increased only in least impacted sites, low densities may be a natural condition that should not be disregarded, and mathematical re-sampling (rarefaction; Hulbert 1971) would make routine application of the index more difficult.

Table 3-7. Median scores of assessed habitat features in the ecoregions of Idaho (scores from least impacted sites only).

	NNR	SNR	MR	BM	WUM	SRB	CP	NBR	WB
Substrate	12	10	6	12	9	10	13	8	10
Instream cover (fish)	15	17	16	17	17	15	14	15	17
Embeddedness	13	16	14	17	16	13	12	13	15
Velocity/Depth	15	15	15	10	15	15	13	15	9
Channel Shape	5	10	10	11	8	6	6	6	7
Pool/Riffle Ratio	4	2	3	1	1	4	4	2	0
Width/Depth Ratio	5	7	8	7	6	6	2	7	9
Bank Vegetation	7	8	7	10	10	8	4	9	10
Bank Stability	8	9	10	10	9	8	10	5	10
Disruptive Pressures	8	9	8	10	9	8	4	6	9
Zone of Influence	8	8	7	9	8	6	4	5	6
Total Score	93	112	104	110	112	103	89	89	107

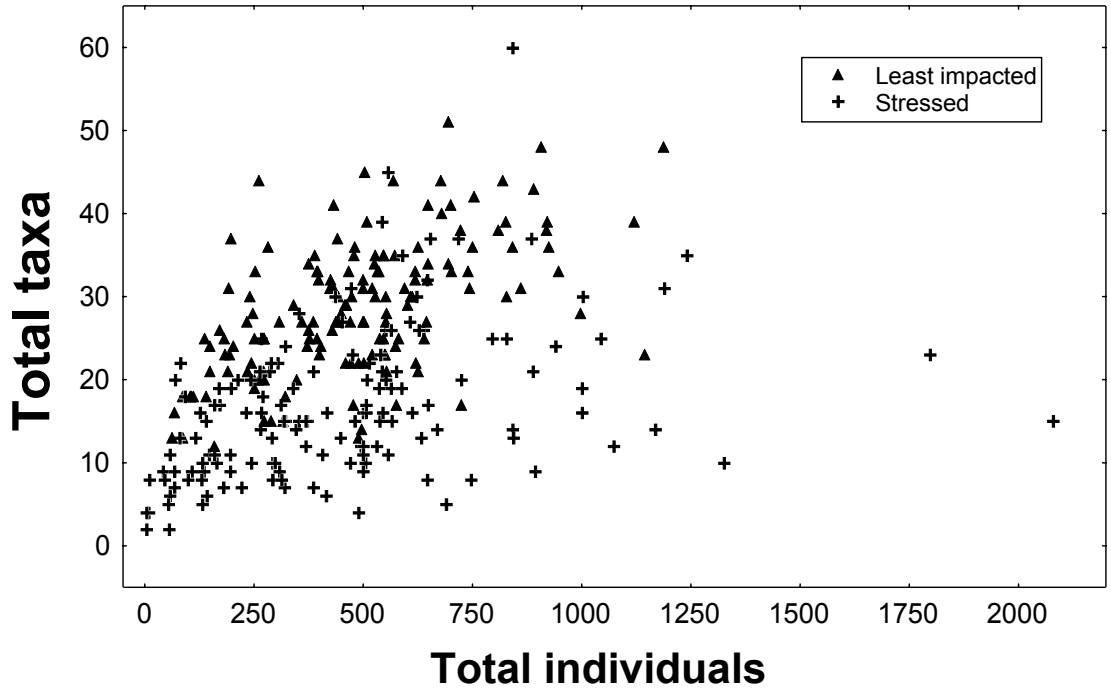


Figure 3-7. Comparison of total taxa and subsample size. The target substample size was 500 organisms.

During metric testing and initial index development, only calibration data was used. The discrimination efficiencies (DE) of the individual metrics were calculated as the percentage of stressed samples with metric values worse than the worst quartile of the least impacted metric values. Discrimination efficiencies of the 36 metrics are shown in Table 3-8. In all metric categories except voltinism, at least one metric had a DE of 75 percent or greater. Richness metrics performed well except for the Diptera taxa. Of the composition metrics, the percent Plecoptera metric had the best DE, while percent EPT also performed well. Intolerant taxa and HBI were better indicators of community pollution tolerance than was the percent tolerant metric. Of the diversity metrics, the two indexes and percent dominance using three or more taxa performed well. Scraper taxa richness and clinger taxa richness performed best in the feeding group and habit metric categories, respectively. The distributions of selected highly discriminating metrics are shown in Figure 3-8 and other metrics are included in Appendix A.

The lowest discrimination efficiencies were observed in the Northern Mountains. The most responsive metrics in this region were those related to overall taxa richness, total taxa, dominance, and diversity (Table 3-8). This suggests that the dominant stressor in the region may be predominantly those with moderate impact, such as logging operations. Because of their relative remoteness, the Northern Mountains may be less intensively used, resulting in stressed sites that are not as stressed compared to sites in accessible and populated regions.

Table 3-8. Discrimination efficiencies (DE) of candidate metrics in three bioregions, statewide DE, and metric trend with increasing impairment (▼ – decreasing, △ – increasing). Calibration data only.

	No. Mtns.	C&S Mtns	Basins	Idaho - ALL	Trend
Richness metrics					
Total taxa	64	71	78	74	▼
EPT[1] taxa	50	86	93	85	▼
Ephemeroptera taxa	50	81	91	83	▼
Plecoptera taxa	43	91	85	80	▼
Trichoptera taxa	29	71	86	74	▼
Diptera taxa	21	38	35	33	▼
Composition metrics					
Percent EPT	36	81	81	74	▼
Percent Ephemeroptera	36	71	66	62	▼
Percent Plecoptera	36	86	86	79	▼
Percent Trichoptera	50	67	71	67	▼
Percent Hydropsychidae					
Percent Elmidae	43	33	69	57	▼
Percent Diptera	14	62	47	45	△
Percent Diptera (non-chironomid)	7	48	31	31	△
Percent Chironomidae	14	57	55	50	△
Percent Non-insects	14	33	78	58	△
Pollution tolerance metrics					
Intolerant taxa (0-1)	36	91	97	86	▼
Intolerant taxa (0-3)	50	91	91	85	▼
Percent Tolerant	21	52	69	58	△
HBI	21	81	85	74	△
Diversity metrics					
Percent Dominant	50	52	74	66	△
Percent two dominant	64	71	83	77	△
Percent three dominant	71	91	90	87	△
Percent five dominant	71	91	90	87	△
Percent 10 dominant	79	95	88	88	△
Shannon-Wiener	57	81	88	82	▼
Simpson's	64	71	85	79	
Feeding group metrics					
Scraper taxa	29	81	85	75	▼
Percent Scraper	36	71	85	74	▼
Percent Predator	14	67	66	58	▼
Percent Collector	36	43	60	53	△
Habit metrics					
Clinger taxa	43	76	93	82	▼
Percent Clinger	29	52	81	67	▼
Percent Clingers of insects	29	48	74	61	▼
Voltinism metrics					
Semi-voltine taxa	14	24	53	41	
Percent Semi-voltine	36	29	64	52	

[1]EPT: Ephemeroptera, Plectoptera, Trichoptera
[2]HBI = Hilsenhoff Biotic Index

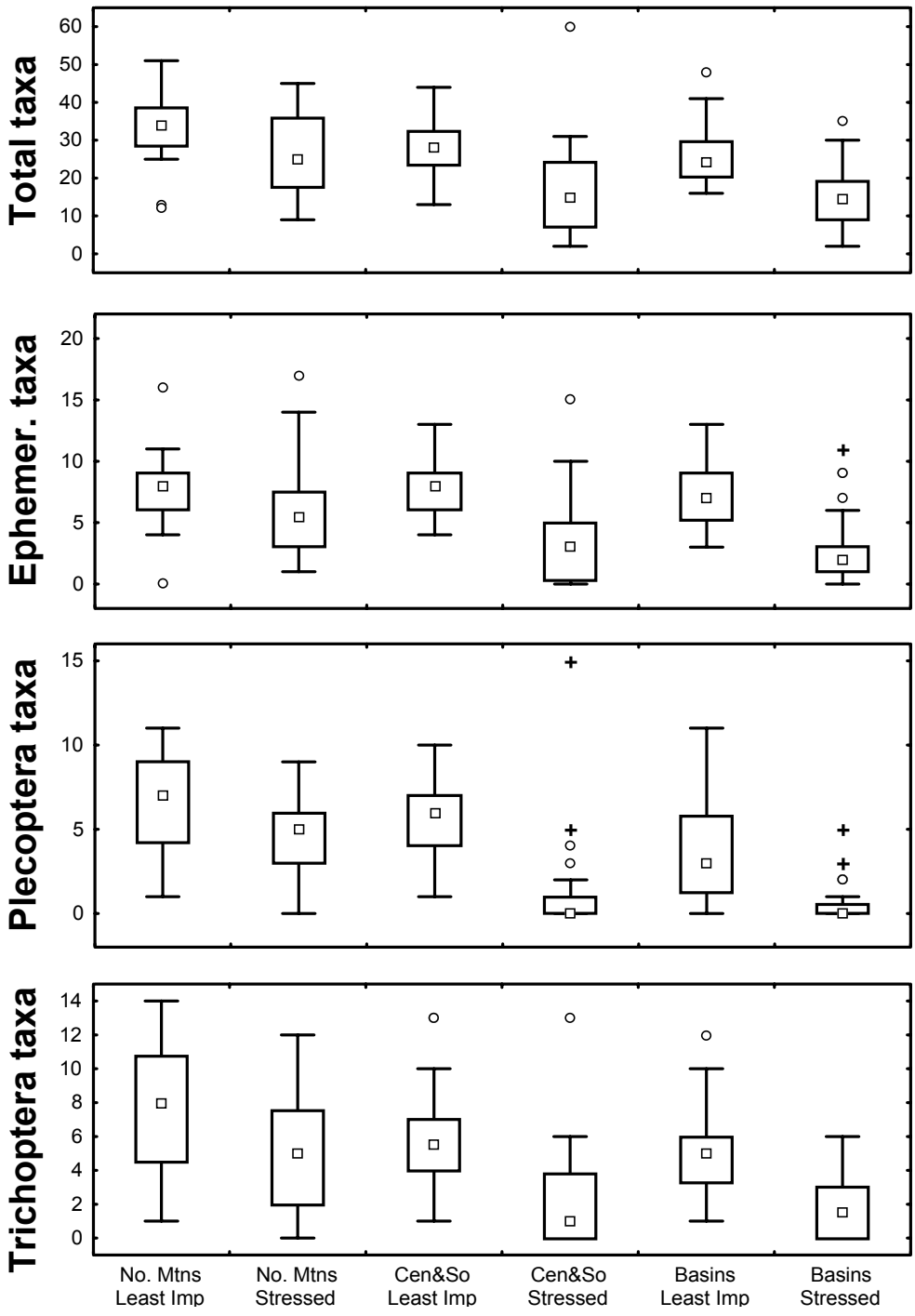


Figure 3-8. Selected distributions of least impacted and stressed metrics in bioregions of Idaho; calibration samples only.
Refer to legend in Figure 3-2.

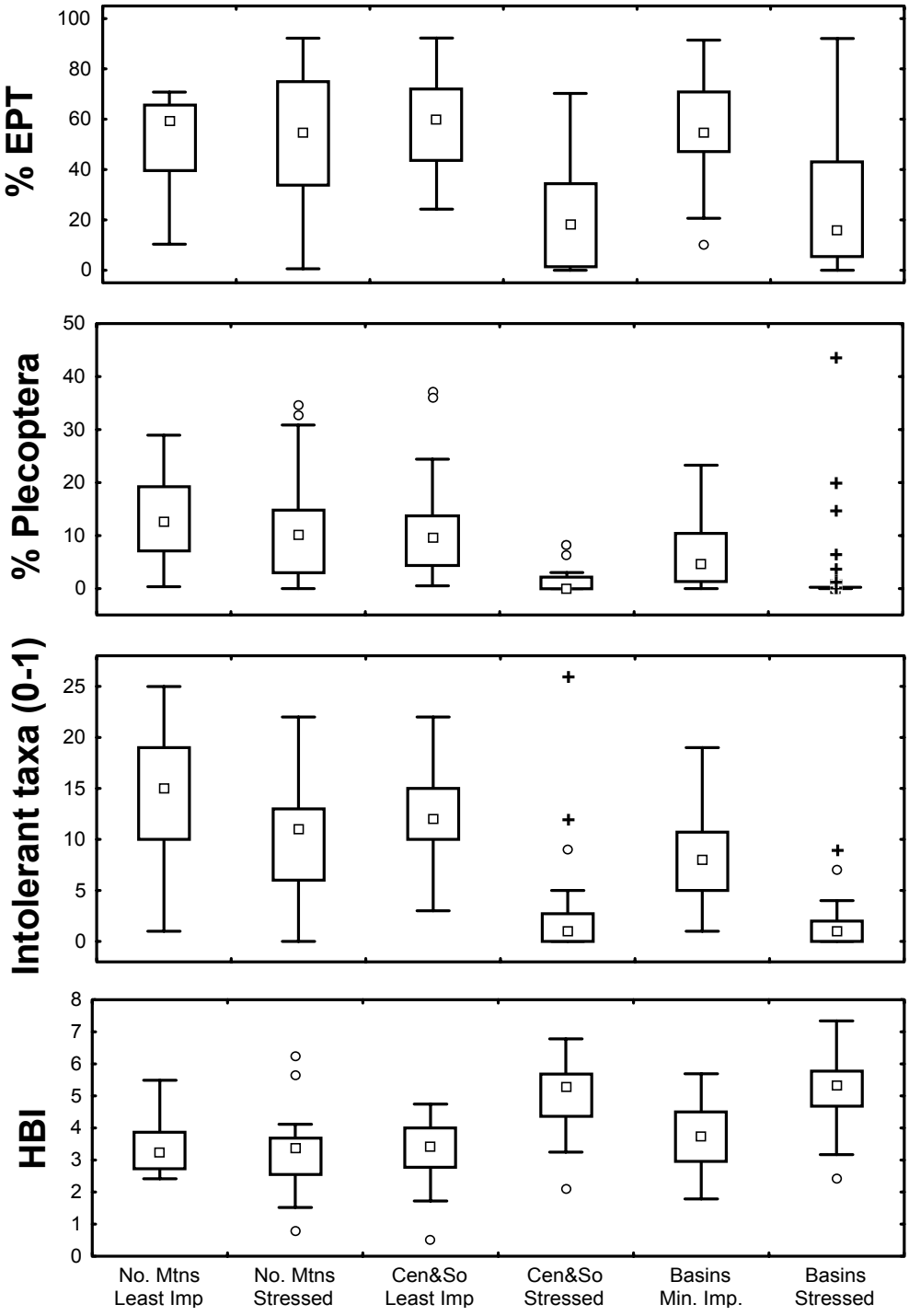


Figure 3-8. *(continued)*

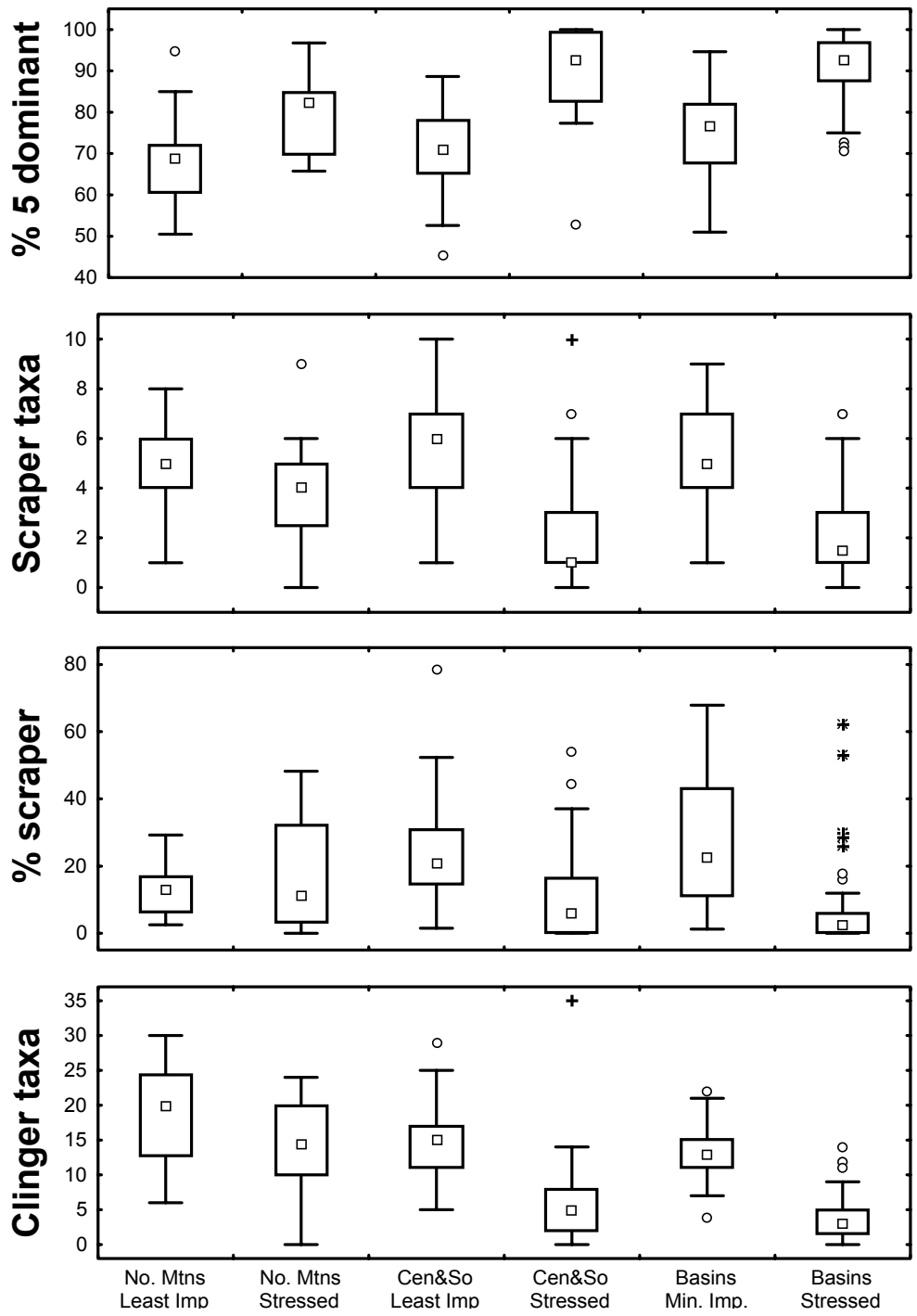


Figure 3-8. *(continued)*

Index Development

Alternative indexes were calculated as the average of metric scores. Metrics were included and interchanged in the index until the combination which best satisfied the index development goals (to include responsive metrics from all of the metric categories, to include metrics that are not redundant, and to show the greatest separation between least impacted and stressed index scores [expressed as the index DE]) was identified.

Fourteen metrics were selected as candidates for inclusion in the index based on robust discrimination between least impacted and stressed sites in the three bioregions. All metric categories were represented except voltinism. Redundancy between the metrics was checked using correlation analysis, with metrics considered excessively redundant if the correlation coefficient was greater than or equal to 0.90 (Table 3-9).

All multimetric index alternatives included four taxa richness metrics: total taxa, Ephemeroptera taxa, Plecoptera taxa, and Trichoptera taxa. The EPT taxa metric performed better than any of its components individually, but was redundant with total taxa and was eliminated in favor of the broader measure of all taxa. The inclusion of the three component metrics in the index allows the important insect orders to convey more distinct information into the assessment. The Plecoptera are represented as taxa counts and relative abundance in the index alternatives. The two metrics are not highly correlated and each conveys unique information about diversity and predominance of this sensitive taxa group. The HBI and intolerant taxa (0 to 1) were interchanged while testing alternatives. The intolerant taxa (0 to 3) metric was not included because of redundancy with total taxa and clinger taxa. Though the number of intolerant taxa outperformed the abundance weighted HBI in metric DE analysis, the index DE was higher when it included the HBI. Three dominance metrics, using three, five, and 10 taxa, were interchanged in some alternatives.

The index that best satisfied the three index development goals had a DE of 88.2 percent. The Stream Macroinvertebrate Index (SMI) includes the following nine metrics:

Total taxa	Trichoptera taxa	Percent 5 dominant taxa
Ephemeroptera taxa	Percent Plecoptera	Scraper taxa
Plecoptera taxa	HBI	Clinger taxa

Table 3-9. Correlation coefficients (Pearson product-moment r) for metrics that show good discrimination efficiency. Values greater than 0.85 or less than -0.85 are bold-typed.

	Total taxa	EPT taxa	Ephemeroptera taxa	Plecoptera taxa	Trichoptera taxa	% EPT	% Plecoptera	% Trichoptera	HBI	Intolerant taxa (0-1)	Intolerant taxa (0-3)	% 3 dominant	% 5 dominant	% 10 dominant	Shannon-Wiener	Scraper taxa	% Scrapers	Clinger taxa
Total taxa																		
EPT[1] taxa	**.92**																	
Ephemerop. taxa	.80	**.87**																
Plecoptera taxa	.77	**.86**	.63															
Trichoptera taxa	.82	**.86**	.60	.63														
% EPT	.26	.43	.40	.40	.31													
% Plecoptera	.26	.38	.23	.53	.24	.45												
% Trichoptera	.20	.23	.09	.13	.37	.31	.01											
HBI[2]	-.38	-.56	-.48	-.54	-.44	-.77	-.53	-.37										
Intolerant (0-1)	.84	**.94**	.81	.83	.82	.41	.37	.20	-.59									
Intolerant (0-3)	**.89**	**.97**	.82	**.88**	.83	.41	.40	.20	-.59	**.97**								
% 3 dominant	-.69	-.68	-.59	-.60	-.58	-.47	-.41	-.26	.59	-.64	-.67							
% 5 dominant	-.74	-.74	-.64	-.65	-.62	-.44	-.40	-.25	.57	-.69	-.72	**.95**						
% 10 dominant	-.82	-.80	-.70	-.70	-.69	-.35	-.36	-.23	.49	-.75	-.78	.83	**.91**					
Shannon-Wiener	.75	.74	.65	.64	.63	.48	.41	.25	-.60	.69	.72	**-.95**	**-.93**	-.84				
Scraper taxa	.72	.75	.73	.52	.69	.34	.12	.23	-.43	.71	.71	-.54	-.58	-.60	.58			
% Scrapers	.16	.26	.26	.18	.22	.41	.04	.20	-.49	.27	.24	-.29	-.26	-.19	.29	.44		
Clinger taxa	**.89**	**.93**	.79	.77	.84	.37	.28	.24	-.51	**.88**	**.91**	-.65	-.70	-.76	.71	.78	.27	

[1]EPT = Ephemeroptera, Plectoptera, Trichoptera

[2]HBI = Hilsenhoff Biotic Index

Table 3-9. Correlation coefficients for metrics that show good discrimination efficiency.

Of the proposed index metrics, the strongest correlation was between total taxa and clinger taxa (r = 0.89). Though the correlation coefficient was high, these metrics were both retained in the index because they represented important information from different metric categories. Correlations between other metrics were not as strong (r < 0.85). The seemingly redundant metrics Plecoptera taxa and percent Plecoptera had a correlation coefficient of only 0.53, demonstrating the difference in richness and composition measures of the assemblage. These two were not redundant because a single Plecopteran species could be abundant, resulting in a high percent Plecoptera. The degree of separation between least impacted and impaired site index values can be seen in box and whisker diagrams of index score distributions in the bioregions (Figure 3-9).

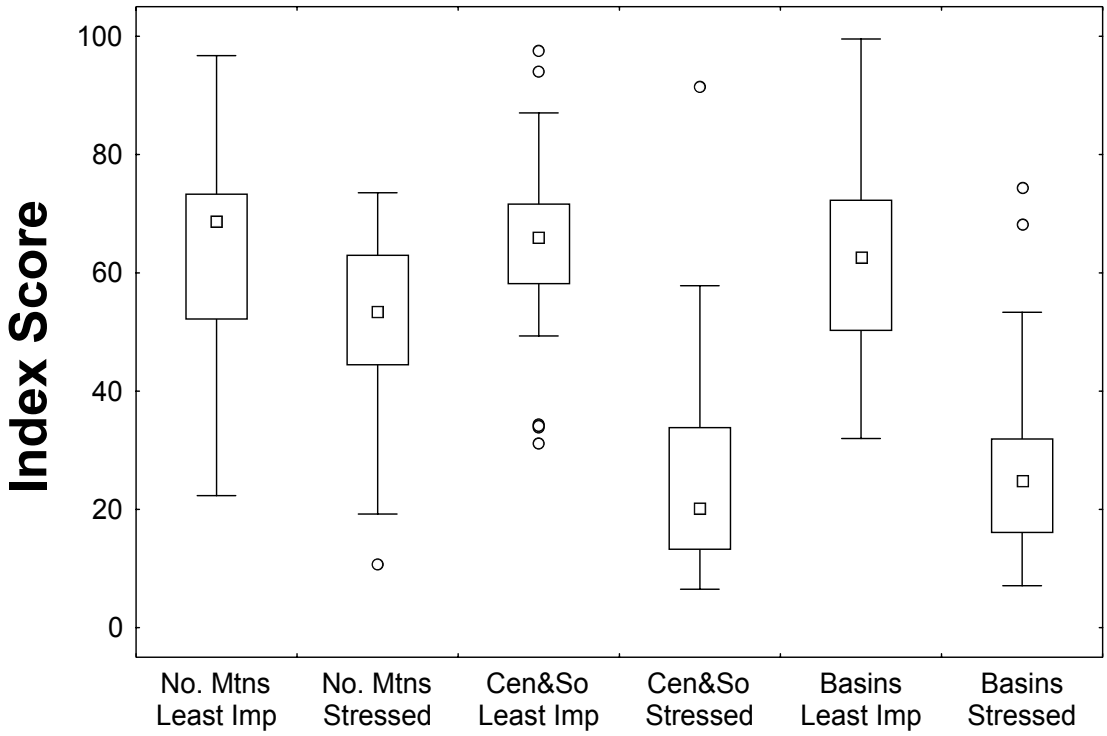


Figure 3-9. Index score distributions in least impacted and stressed sites, index development data.
The 25th percentiles of least impacted scores (the lower edge of the boxes) were used to judge discrimination efficiency.

The greatest degree of overlap between least impacted and stressed index scores is seen in the Northern Mountains. Though index alternatives that used the best performing metrics in the Northern Mountains were evaluated, none out-performed the proposed index. This may be attributed to relatively moderate stressors in this sparsely developed bioregion.

Index Tested with Independent Data and Compared to Other Indexes

The SMI was tested using the 25th percentile of least impacted calibration data as a threshold to which the randomly designated test data was compared. The index showed greater discriminating ability with test data than it did with calibration data (Table 3-10, Figure 3-10). The proposed index appears to be robust.

Table 3-10. Discrimination efficiencies for the SMI using independent test data.

	Northern Mountains	Central and Southern Mountains	Basins	Idaho - all
Least impacted	88.9	80.8	80	82.0
Stressed	71.4	100	93.9	92.3

The SMI was compared to several other indexes that have been applied in Idaho. For each index, discrimination abilities were calculated using all data (calibration and test). In comparison to the other indexes, the proposed index performed up to 10 percent better. The River Macroinvertebrate Index (Royer et al. 2001) was developed for use in larger rivers of Idaho and did not perform as well as the proposed index in any of the three bioregions (see Table 3-11). The data set under investigation is predominantly small wadeable streams, and the river index may be better suited to larger streams and rivers only.

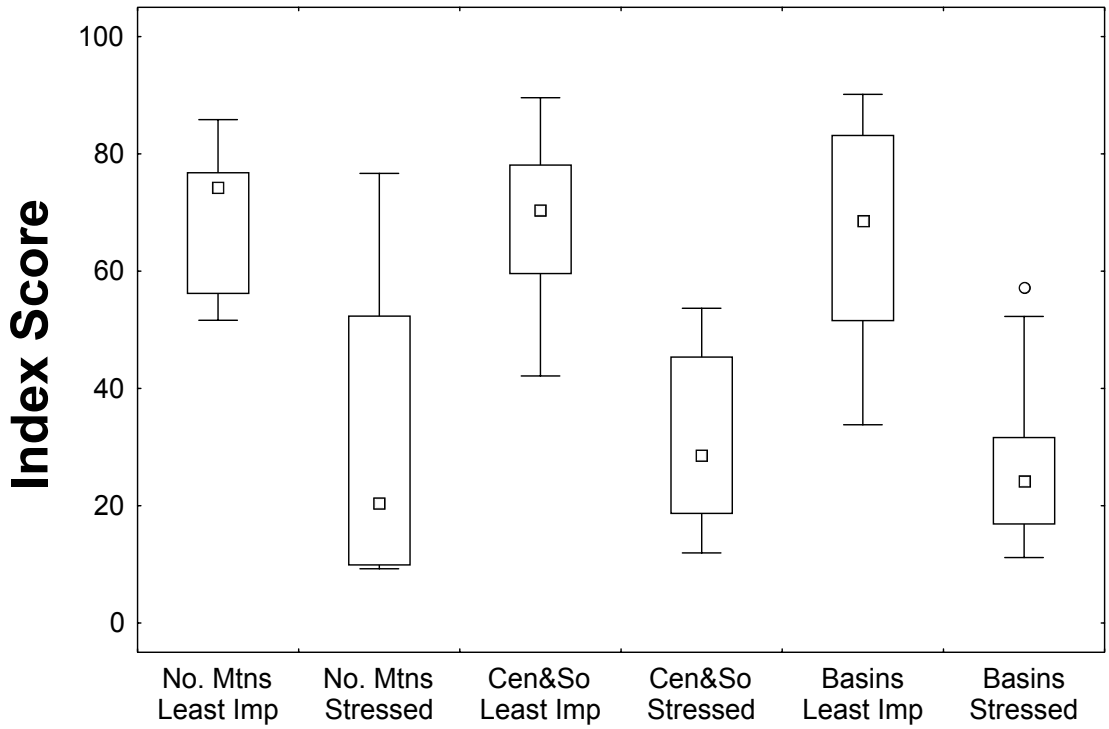


Figure 3-10. Index score distributions in least impacted and stressed sites, test data. The 25th percentiles of least impacted scores (calibration data, cf. Figure 3-9 were used to judge discrimination efficiency).

The Macroinvertebrate Biotic Index (described in Mebane 2000) developed by DEQ staff for statewide application performed equal to the SMI in the Basins bioregion (see Table 3-11), but identified 10 percent fewer impaired sites in the two mountain bioregions. It includes both total taxa and EPT taxa, that are redundant by our standards (Pearson product-moment correlation coefficient > 0.9).

The Benthic Index of Biotic Integrity (Kerans and Karr 1994) performed identically to the SMI in the Basins and the Northern Mountains but performed less efficiently (9 percent or 3 sites) in the Central and Southern Mountains (see Table 3-11). The two indexes have six metrics in common, but the Benthic Index of Biotic Integrity includes some metrics that did not show strong discrimination ability with the current data (percent predators and semi-voltine taxa).

The ecoregion-specific indexes developed by Robinson and Minshall (1998) were compared to the SMI within three ecoregions only (Northern Rockies, Snake River Plain, and Northern Basin and Range; Table 3-12). Roughly half of the metrics are composition metrics at the genus and family taxonomic levels. Discrimination efficiency of the Northern Basin and Range index was 100 percent, but the Snake River Plain and Northern Rockies were 84 percent and 68 percent, respectively (Table 3-12). Though the Robinson and Minshall indexes performed well, they are not applicable in all regions of the state.

Table 3-11. SMI configuration (Index A) and other indexes used in Idaho. Indexes are composed of the metrics opposite the index symbol. Discrimination efficiencies (DE, %) are based on the 25th percentile of least impacted index scores within the bioregions defined by this study.

	SMI	**RMI[1]**	**MBI[2]**	**B-IBI[3]**
Total taxa	A	RMI	MBI	B-IBI
EPT taxa		RMI	MBI	
Ephemerop. Taxa	A			B-IBI
Plecoptera taxa	A			B-IBI
Trichoptera taxa	A			B-IBI
Percent EPT			MBI	
Percent Plecoptera	A			
Percent Elmidae		RMI		
HBI	A		MBI	
Intolerant (0-1)				B-IBI
Percent Tolerant				B-IBI
Percent Dominant (# taxa)	A (5)	RMI (1)	MBI (1)	B-IBI (3)
Shannon-Wiener			MBI	
Scraper taxa	A			
Percent Scraper			MBI	
Percent Predators		RMI		B-IBI
Clinger taxa	A			B-IBI
Semi-voltine taxa				B-IBI
Northern Mountains (stressed n = 21)	57%	52%	48%	57%
Central and Southern (stressed n = 33)	97%	85%	85%	88%
Basins (stressed n = 91)	95%	91%	95%	95%
All Bioregions	89%	84%	85%	87%

[1]River Macroinvertebrate Index (Royer et al. 2001)
[2]Macroinvertebrate Biotic Index (described in Mebane 2001)
[3]Benthic Index of Biotic Integrity (Kerans and Karr 1994)

Table 3-12. SMI configuration (Index A) and other indexes calibrated for the Northern Rockies, Snake River Plain, and Northern Basin and Range of Idaho (Robinson and Minshall 1998).
Indexes are composed of the metrics opposite the index symbol. Discrimination efficiencies (DE, %) are based on the 25th percentile of least impacted index scores within the ecoregions. Metric calibration for SMI was based on bioregional statistics, but only sites within the three ecoregions were included for this comparison.

	SMI	**NR-I**	**SRP-I**	**NBR-I**
Total taxa	A			
EPT taxa		NR-I	SRP-I	NBR-I
Ephemeroptera taxa	A			
Plecoptera taxa	A			
Trichoptera taxa	A			
Percent EPT		NR-I	SRP-I	NBR-I
Percent Plecoptera	A			
Percent Chironomidae				NBR-I
EPT/Chironomidae		NR-I		
EPT/Chiron. + Oligochaeta			SRP-I	
HBI	A	NR-I	SRP-I	
Percent dominant (# taxa)	A (5)	NR-I (1)	SRP-I (1)	
Simpson's Index		NR-I		
Scraper taxa	A			
Percent scraper		NR-I		NBR-I
Percent filterers			SRP-I	NBR-I
Percent shredders		NR-I		
Clinger taxa	A			
Percent Baetis		NR-I		
Percent Heptageniidae				NBR-I
Percent Zapada		NR-I		NBR-I
Percent Hydropsychidae		NR-I		NBR-I
Percent Rhyacophilidae			SRP-I	
Percent Brachycentrus		NR-I	SRP-I	
Percent Ephemerellidae				NBR-I
Percent Drunella		NR-I		
Percent Capniidae			SRP-I	
Percent Elmidae		NR-I	SRP-I	NBR-I
Percent Simulidae		NR-I	SRP-I	
Percent Turbellaria			SRP-I	
Northern Rockies (stressed n = 37)	76%	68%		
Snake River Plain (stressed n = 56)	93%		84%	
No. Basin & Range (stressed n = 24)	96%			100.0%
Three Ecoregions	88%		82%	

Northern Mountains Recalibration and Index Finalization

After the initial development of the SMI and before establishing the final metric scoring criteria, the data set and metric calculations were refined in two ways. First, least impacted and stressed sites were redefined in the Northern Mountains. The data collected between 1994 and 1996 was augmented with data collected through 1999. The new data set included 31 least impacted sites and 38 stressed sites that better representated the best and worst conditions compared to the earlier data set (see Appendix D). The second refinement was a reexamination of the calculation of richness metrics. Most taxa groups were identified at a consistent taxonomic level (e.g., genus). However, some individuals of a sample were identified at family level or higher because the specimens lacked distintive characteristics (damaged or immature specimens). The uniqueness of these individuals identified at higher levels was ambiguous and counting them as unique may artificially increase measures of community diversity. Whereas preliminary calculations assumed they were unique, the final assumption was that they were not unique in samples where lower level specimens were also identified.

Refinement of the data set significantly improved the performance of the SMI in the Northern Mountains (Figure 3-11). Specifically, the index discrimination efficiency (DE) increased from 62 percent to 90 percent using the 25th percentile of least impacted sites as the criterion (Table 3-13). The DE in all bioregions was 94 percent also using the 25th percentile. Almost 75 percent of stressed site index scores were below the *minimum* least impacted scores. Scoring formulas for the final index metrics are presented in Appendix B. Five sites had index scores that appeared as outliers (Table 3-14). Outliers may signify natural variability, misclassification of stream conditions *a priori*, or an under-represented site class.

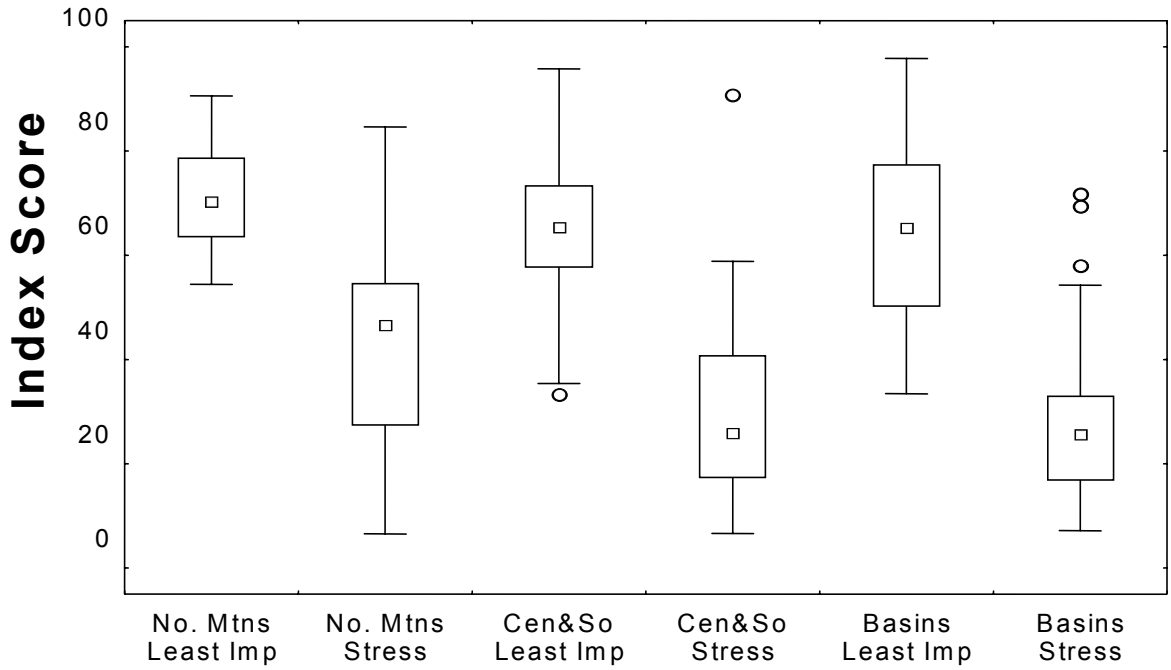


Figure 3-11. SMI score distributions in least impacted and stressed sites, calibration and test sites combined.
The SMI was recalibrated using updated least impacted and stressed sites in the Northern Mountains and eliminating ambiguous taxa in the other bioregions.

Table 3-13. Statistics of SMI. Least impacted distributions and DE's based on various percentiles.

	(n)	Min.	5th	10th	25th	median	75th	90th	Max.
Northern Mountains									
Scores (Least impacted)	(31)	39*	55	56	64	70	79	82	91
DE (% of stressed)	(38)	74%	79%	79%	90%	92%			
Central and Southern Mountains									
Scores (Least impacted)	(80)	33	36	50	58	65	73	81	96
DE (% of stressed)	(33)	70%	70%	91%	94%	97%			
Basins									
Scores (Least impacted)	(44)	33	34	42	50	64	77	88	98
DE (% of stressed)	(91)	75%	76%	89%	96%	98%			

* Minimum reference score of all Northern Mountains sites.

Table 3-14. Samples with outlying index scores.

Bioregion	Site ID	Stream name	Ecoregion	Condition	Index Score
C&S Mtns.	95EIRO0A92	Lower Yankee Fork	So. Northern Rockies	Stressed	90.6
C&S Mtns.	95SEIRO061	Beaver Creek	Wasatch & Uinta Mtns.	Least Imp.	33.2
Basins	96SCIROA07	Shoshone Creek	Snake River Basin	Stressed	69.4
Basins	96SCIROB68	Lower Chimney Creek	Snake River Basin	Stressed	71.7
Basins	96SCIROB18	Lower Big Creek	Snake River Basin	Stressed	57.9

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Of the three project objectives, two were accomplished through the above analysis and the third (to recommend appropriate applications of the index) is completed in the "Index Rating and Application" section below. A regionally-calibrated multimetric biological index for Idaho streams using the benthic macroinvertebrate assemblage was successfully developed and favorably evaluated. The Stream Macroinvertebrate Index (SMI) is robust and repeatable in the three bioregions of Idaho. The index incorporates nine benthic macroinvertebrate metrics from six metric categories, combining a range of ecological information on biological conditions in wadeable streams. The index "correctly" classifies 94 percent of the stressed sites below the 25th percentile of least impacted scores, showing excellent agreement with the stream condition assigned *a priori* by DEQ personnel.

The ecological significance of the nine metrics in the SMI can be described individually to illustrate the range of environmental influences on the index values. There are four richness metrics: total taxa, Ephemeroptera taxa, Plecoptera taxa, and Trichoptera taxa. Total taxa richness is a primary measure of biodiversity. Diversity of the benthic macroinvertebrate community indicates heterogeneity of habitat, complexity of trophic interactions and community dynamics, and a wide range of food resources. Diversity within each of the three insect orders confers similar information, but each of these orders is generally understood to have several species that are sensitive to pollution. High diversity within each of the orders therefore implies that favorable habitats, community dynamics, and food resources exist in the absence of pollution. The composition metric in the index, "Percent Plecoptera", confers information regarding the degree to which the stream can support larger populations of stoneflies. Stoneflies require clean, cold, and well oxygenated water for survival; conditions that are adversely impacted by a wide range of human activity. The HBI calculates the predominance of pollution tolerant individuals of all taxa groups, and thereby describes the likely existence of pollutants or perturbations at a site.

Predominance in the macroinvertebrate community by the top five taxa might indicate that conditions are only suitable for a limited type of organism. Such a condition may arise from limited food resource types, habitat degradation, or competitive displacement of native taxa by exotic species. High diversity in scraper taxa probably means conditions are suitable for a productive periphyton community—conditions including sufficient nutrients, non-toxic water, and stable substrate. A high diversity of clinger taxa likewise indicates stable substrate, as well as faster currents, as are expected in undisturbed stream channels of Idaho.

An understanding of the metric components of the index will aid in the appropriate application of the index. The index is a composite of the biological information, not necessarily a diagnostic tool, but a general status indicator. If a single metric value is suboptimal but all others in the index resemble least impacted values, it would be difficult to discern impairment from the index. However, if several metrics are suboptimal, that would

be reflected in the index value and further investigation might identify the source or sources of stress to the community. To apply the biological information for diagnostic purposes would require examination of individual metric responses to identify specific stressors and calibration of those stress-response relationships.

Index Rating and Application

With the response to stressors shown by the SMI in Figure 3-11, it is possible to propose a rating system for the index. The multimetric index value for a site is a summation of the scores of the metrics and has a finite range within each stream class and index period depending on the maximum possible scores of the metrics (Barbour et al. 1999). This range can be subdivided into any number of categories corresponding to various levels of impairment. Because the metrics are normalized to least impacted conditions and expectations for the stream classes, any decision on subdivision should reflect the distribution of the scores for the least impacted sites.

The number of rating categories that can be discerned is determined by the variability of the index in the least impacted sites. The interquartile ranges of the least impacted site scores are 15 to 27 points in the three bioregions (see Table 3-13). This suggests that five categories can be reliably discerned on the 100 point index scale (Fore et al. 1994, 1996).

In a suggested rating scheme, the ratings of "very good" or "good" are applied to sites with scores greater than the 25th percentile of the calibration least impacted index scores (Table 3-15). The threshold between "very good" and "good" is the mid-point between the 25th percentile and the maximum index score (100). Ratings of "fair," "poor," or "very poor" are assigned to sites with scores below the 25th percentile. The subdivisions below the 25th percentile are based on a trisection of the scale to the minimum index score (0). This or any alternative rating system allows rapid prioritization of sites by biological condition. Index discrimination efficiencies based on the minimum, 10th, 25th, and 50th percentiles are presented in Table 3-13. Adjustments to category thresholds or narrative labels based on the least impacted distributions will allow avoidance of Type I or Type II errors as needed. The recommended rating scheme consistently allows a Type I error of 25 percent, because the 25th percentile of least impacted sites is used as the threshold between "good" and "fair" ratings.

Using a percentile of the reference scores (e.g., the 25th) as a threshold results in that percentage of reference sites failing the criterion. Impairment, as measured by the index score, is a gradual continuum of condition. Yet, in a management context, a threshold value is required to trigger management action. The choice of the threshold reflects a tolerance for risk and uncertainty. Risks include the risk of declaring a good site impaired (false positive; statistical Type I error) and the risk of declaring an impaired site good (false negative; statistical Type II error). Assuming either risk is accepting error; there may be political consequences associated with not protecting or over-protecting Idaho's aquatic resources. An additional source of uncertainty comes from the selection of reference sites that truly represent least-stressed conditions.

A 25th percentile of least impacted conditions is commonly chosen because it is deemed sufficiently conservative to protect aquatic resources, and reflects some uncertainty in the reference site selection. Some states have selected a 10th percentile threshold if they have greater confidence that their reference sites are not stressed and their methods yield precise results (e.g., Maryland, West Virginia). Nevertheless, a lower percentile reduces the power to detect impairment. Furthermore, a decline in stream condition from the median to the 10th percentile (e.g., a decline of an index score from 64 to 42 in the Basins) would not trigger a management response, though this change in condition may be unacceptable in the context of antidegradation policy.

Table 3-15. Example rating categories based on 25th percentiles of least impacted SMI scores.

	Northern Mountains	**Central and Southern Mountains**	**Basins**
Rating	**Index score range**		
Very Good (midpoint between 25th percentile and maximum index score to maximum score)	84 - 100	80 - 100	76 - 100
Good (25th percentile to midpoint between 25th percentile and maximum score)	65 - 83	59 - 79	51 - 75
Fair (upper trisect of minimum score to 25th percentile)	44 - 64	40 - 58	34 - 50
Poor (middle trisect of minimum score to 25th percentile)	22 - 43	20 - 39	17 - 33
Very Poor (lower trisect of minimum score to 25th percentile)	0 - 21	0 - 19	0 - 16

Application of the biological SMI and rating system in Idaho could proceed as follows for any new biomonitoring sites:

(1) Collect biological sample and associated data.
(2) Identify organisms in a subsample to standard taxonomic level.
(3) Calculate the nine index metrics.
(4) Score index metrics using formulas (Appendix B).
(5) Calculate the biological SMI as an average of the nine metric scores.
(6) Rate the site's biological condition (Table 3-15 or alternative).
(7) Interpret rating in context of water resource management decisions.

Recommendations

- The multimetric macroinvertebrate index proposed in this study includes nine metrics: total taxa, Ephemeroptera taxa, Plecoptera taxa, Trichoptera taxa, percent Plecoptera, HBI, percent five dominant taxa, scraper taxa, and clinger taxa. The index should be applied in the bioregions of Idaho in its current initial form, with the understanding that improvements may be forthcoming as new data are incorporated into future analyses.

- The index developed here is appropriate for biocriteria, and a rating system can be determined for application of biocriteria. The use of a 25th percentile threshold automatically results in 25 percent of least impacted sites scoring "fair" or worse. The acceptance levels for Type I and Type II errors in identifying biological condition should be defined and threshold index values assigned accordingly. The rating system suggested above (25th percentile) is only one alternative.

- Improvements to the index should be pursued. Such improvements may include reclassification, redevelopment, or recalibration depending on the availability of new data. Redevelopment would include re-testing all metrics and new metric combinations. Recalibration involves readjustment of scoring thresholds of the initial index metrics. Index redevelopment should accompany large changes in data availability, site classification, or *a priori* stream condition status. Index recalibration should accompany less extreme changes in database characteristics.

- Because site classification was largely dependent on professional judgement (especially in under-represented ecoregions), effort should be made to collect additional data where it is sparse. The Columbia Plateau, Wyoming Basin and Wasatch-Uinta Mountains jointly constitute less than 10 percent of the land area in the state, but it is important to group these ecoregions into bioregions with greater confidence. Minimally impacted and stressed sites would complement future analyes.

- Subsampling procedures should be reviewed to identify possible ways to avoid extremely large subsample sizes.

- Some least impacted sites had low scores, rating in the "fair" or "poor" range using the suggested rating scheme. Extremely low scores and outliers among the least impacted sites may indicate misidentification of stream condition *a priori*. These outliers may not be representative of their bioregions (e.g., unique anomalous geology or water source). The outliers should be excluded from the least impacted set if there are clearly anomalous conditions at the sites that would make them non-representative, or if there is previously undetected anthropogenic stress or pollution. They should not be excluded from the least impacted set simply because of a low score.

- We did not examine precision of individual site scores in this study. Precision of scores can be estimated from repeated (replicate) observations at sites. Interannual variability can be estimated from repeat visits in different years. These components of variability can be used to develop expectations of the overall natural variability of least impacted sites and precision of the methods, to sharpen and improve the ability to detect impairment.

ACKNOWLEDGEMENTS

This biological index development and report grew out of earlier data analysis supported by EPA, Office of Water, Office of Science and Technology. Susan Jackson, EPA/ Office of Science and Technology , and Gretchen Hayslip, EPA Region 9, initiated the data analysis project and provided critical discussions and reviews. The Project Manager for the final analysis presented here was Michael Edmondson of DEQ. Bill Clark, Michael Edmondson, Cynthia Grafe, Mike McIntyre, Chris Mebane, and David Moser of DEQ reviewed results and earlier drafts, and provided critical ideas and discussion on classification of Idaho streams. The report was produced by Brenda Fowler and Jackie Bowersox.

REFERENCES

Barbour, M.T., J. Gerritsen, G.E. Griffith, R. Frydenborg, E. McCarron, J.S. White, and M.L. Bastian. 1996. A framework for biological criteria for Florida streams using benthic macroinvertebrates. Journal of the North American Benthological Society. 15(2):185-211.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish. Second Edition. EPA/841-B-99-002. U.S. EPA, Office of Water. Washington, D.C.

Barbour, M.T., J.L. Plafkin, B.P. Bradley, C.G. Graves, and R.W. Wisseman. 1992. Evaluation of EPA's rapid bioassessment benthic metrics: metric redundancy and variability among reference stream sites. Environmental Toxicology and Chemistry. 11(4):437-449.

Barbour, M.T., J.B. Stribling, and J.R. Karr. 1995. Multimetric approach for establishing biocriteria and measuring biological condition. Pages 63-77 in W.S. Davis and T.P. Simon (editors). Biological assessment and criteria. Tools for water resource planning and decision making. Lewis Publishers. Boca Raton, Florida.

Chandler, G.L., T.R. Maret, and D.W. Zaroban. 1993. Protocols for assessment of biotic integrity (fish) in Idaho streams. Water Quality Monitoring Protocol Number 6. Idaho Division of Environmental Quality. Boise, Idaho. 40 p.

Clark, W.H. and T.R. Maret. 1993. Protocols for assessment of biotic integrity (macroinvertebrates) for wadable Idaho Streams. Water Quality Monitoring Protocols Report 5, Idaho Division of Environmental Quality. Boise, Idaho.

Cummins, K.W. and M.J. Klug. 1979. Feeding ecology of stream invertebrates. Annual Review of Ecology and Systematics. 10: 147-172.

Davis, W.S. and T.P. Simon (editors). 1995. Biological assessment and criteria. Tools for water resource planning and decision making. Lewis Publishers. Boca Raton, Florida.

Fore, L.S., J.R. Karr, and L.L. Conquest. 1994. Statistical properties of an index of biological integrity used to evaluate water resources. Canadian Journal Fisheries and Aquatic Sciences. 51: 1077-1087.

Fore, L.S., J.R. Karr, and R.W. Wisseman. 1996. Assessing invertebrate responses to human activities: evaluating alternative approaches. Journal of North American Benthological Society. 15: 212-231.

Gibson, G.R., M.T. Barbour, J.B. Stribling, J. Gerritsen, and J.R. Karr. 1996. Biological criteria: technical guidance for streams and small rivers. EPA 822-B-96-001. U.S. EPA, Office of Water. Washington, D.C.

Hayslip, G.A. (editor) 1993. Region 10 in-stream biological monitoring handbook for wadeable streams in the Pacific Northwest. EPA 910/9-92-013. U.S. EPA. Seattle, WA.

Hilsenhoff, W.L. 1987. An improved biotic index of organic stream pollution. Great Lakes Entomologist. 20: 31-39.

Hilsenhoff, W.L. 1988. Rapid field assessment of organic pollution with a family level biotic index. Journal of the North American Benthological Society. 7(1):65-68.

Hughes, R.M., D.P. Larsen, and J.M. Omernik. 1986. Regional reference sites: a method for assessing stream potentials. Environmental Management. 10:629-635.

Division of Environmental Quality (DEQ). 1996. 1996 beneficial use reconnaissance project workplan. Idaho Division of Environmental Quality. Boise, Idaho.

Idaho Water Quality Standards and Wastewater Treatment Requirements. IDAPA 58.01.02. Office of Administrative Rules. Boise Idaho.

Jongman, R.H., C.J.F. terBraak, and O.F.R. vanTongeren. 1987. Data analysis in community and landscape ecology. Pudoc Wageningen Publishing. Netherlands.

Karr, J.R. 1991. Biological integrity: a long-neglected aspect of water resource management. Ecological Applications. 1:66-84.

Karr, J.R. and D.R. Dudley. 1981. Ecological perspectives on water quality goals. Environmental Management. 5:55-68.

Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant, and L.J. Schlosser. 1986. Assessing biological integrity in running waters: a method and its rationale. Special publication 5. Illinois Natural History Survey.

Kenkel, N.C. and L. Orloci. 1986. Applying metric and nonmetric multidimensional scaling to ecological studies: some new results. Ecology. 67(4): 919-928.

Kerans, B.L. and J.R. Karr. 1994. A benthic index of biotic integrity (B-IBI) for rivers of the Tennessee Valley. Ecological Applications. 4:768-785.

Kruskal, J.B. 1964. Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis. Psychometrika. 29:1-27.

Ludwig, J.A. and J.F. Reynolds. 1988. Statistical ecology: a primer on methods and computing. John Wiley and Sons, Inc. New York, New York.

McCune, B. and M.J. Mefford. 1997. PC-ORD. Multivariate analysis of ecological data, Version 3.0. MjM Software Design. Gleneden Beach, Oregon.

Mebane, C.A. 2001. Testing bioassessment metrics: macroinvertebrate, sculpin, and salmonid responses to stream habitat, sediment and metals. Environmental Monitoring and Assessment. 67:292-322.

Merritt, R.W. and K.W. Cummins. 1996. An introduction to the aquatic insects of North America. Third edition. Kendall/Hunt Publishing Co. Dubuque, Iowa.

Ohio Environmental Protection Agency. 1989. Addendum to biological criteria for the protection of aquatic life, volume II: user's manual for biological field assessment of Ohio surface waters. Ohio EPA, Division of Water Quality Planning and Assessment, Ecological Assessment Section. Columbus, OH.

Omernik, J.M. and A.L. Gallant. 1986. Ecoregions of the Pacific Northwest. EPA/600/3-86/033. U.S. EPA, Environmental Research Laboratory. Corvalis, Oregon.

Omernik, J. M. 1987. Ecoregions of the conterminous United States. Annals of the Association of American Geographers. 77(1): 118-125.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish. EPA 440-4-89-001. U.S. EPA, Office of Water Regulations and Standards. Washington, D.C.

Reynoldson, T.B., R.C. Bailey, K.E. Day, and R.H. Norris. 1995. Biological guidelines for freshwater sediment based on **BE**nthic **A**ssessment of **S**edimen**T** (the BEAST) using a multivariate approach for predicting biological state. Australian Journal of Ecology. (1995) 20:198-219.

Robinson, C.T. and G.W. Minshall. 1998. Regional assessment of wadeable streams in Idaho, USA. Great Basin Naturalist. 58(1):54-65.

Royer, T.V., C.T. Robinson, and G.W. Minshall. 2001. Development of macroinvertebrate-based index for bioassessment of Idaho rivers: Environmental Management, v. 27, no. 4, p. 627-636.

Shannon, C.E. and W. Weaver. 1949. The mathematical theory of communication. The University of Illinois Press. Urbana, Illinois.

Simpson, E. H. 1949. Measurement of diversity. Nature 163(4148):688

Southerland, M.T. and J.B. Stribling. 1995. Status of biological criteria development and implementation. Pages 81-96 in W.S. Davis and T.P. Simon (editors). Biological assessment and criteria: tools for water resource planning and decision making. Lewis Publishers. Boca Raton, Florida.

Stribling, J.B., B.K. Jessup, and J. Gerritsen. 2000. Developmental biological and physical habitat criteria for Wyoming streams and their use in the TMDL process. Prepared for U.S. EPA Region 8. Denver, Colorado.

Stribling, J.B., B.K. Jessup, J.S. White, D. Boward, and M. Hurd. 1998. Development of a benthic index of biotic integrity for Maryland streams. Maryland Department of Natural Resources, Report no. CBWP-EA-98-2 for the Maryland Biological Stream Survey. Annapolis, Maryland.

Wright, J.F. 1995. Development and use of a system for predicting the macroinvertebrate fauna in flowing waters. Aust. J. Ecol. 20:181-197.

Chapter 4.
Stream Fish Indexes

Christopher A. Mebane[6]

INTRODUCTION

The approach of measuring the biological integrity of rivers and streams using a quantitative index of biological integrity (IBI) based on fish assemblages[7] was first described by Karr (1981). Since then the IBI approach has been widely applied to warm water streams and rivers in North America and elsewhere in the world. However, the application of the IBI to the cold water rivers and streams of the western USA has been limited (Simon 1999). The purpose of this paper is to describe the adaptation and testing of the IBI approach to cold water streams in Idaho's forested and rangeland ecoregions. The approach draws heavily from similar work to develop an IBI for cold water rivers in Idaho (Mebane 2000).

Waters that have biological integrity, as used here, are those that have "… a species composition, diversity, and functional organization comparable to that of natural habitats of the region" (Frey 1977). In the development of quantitative indices, these components of biological integrity (composition, diversity, and functional organization) are measured, and are intended to relate fish assemblages to other biotic and abiotic components of the ecosystem (Karr et al. 1986, Simon 1999). Comparisons to natural habitats of the region require classifying streams into relatively homogenous categories of fish assemblages. The natural fish assemblages are assumed to be shaped by broadscale factors such as selective extinctions during the late Pleistocene; recolonization patterns; long-term zoogeographic barriers such as waterfalls; broad climatic conditions (e.g. Benke 1992, Moyle 1994); intermediate, or stream scale climatic and geomorphological factors such as stream gradients (e.g. Kruse et al. 1996); and site scale features such as adequate resting refugia from canopy cover or pools in desert or forest trout streams (Li et la 1994, Herger et al. 1996). Only at the finest scale (stream or site scale), are human-caused disturbances assumed to affect the natural fish assemblage. The intermediate and broadscale factors are assumed to be important for classifying stream habitats in order to be able to detect human-caused effects to habitat or water quality.

Karr et al. (1986) developed the IBI for warm water Midwestern streams (i.e. waters too warm to support salmonids). Their original IBI consisted of 12 metrics that reflected fundamental ecological components of stream fish assemblages, which included measures of: taxonomic richness, habitat and trophic guild composition, and individual health and composition. Following this lead, fish IBIs have been developed and published for many

[6] Idaho Department of Environmental Quality, 1410 N. Hilton, Boise, ID 83706.

[7] The terms "assemblage" and "community" have been used interchangeably in bioassessment literature (e.g. Matthews and Hein 1987, Simon 1999a). Here, the term "assemblage" is used to mean a subset of a biological community composed of a single phylogenetic group, e.g. fish, arthropods (i.e. benthic macroinvertebrates), or diatoms.

regions of temperate North America and in other parts of the world (Simon 1999). Because of the substantial differences in fish faunas in areas outside the midwestern United States where the original IBI was developed, other workers have substituted regional metrics for the original 12 metrics. Most have maintained the ecological structure of the original IBI. Due to all the iterations, the term "IBI" should be thought of as a family of related indices, rather than a single index (Simon and Lyons 1995).

Most IBI versions have been developed for warm water streams rather than for cold water systems. Three significant factors complicate IBI development in cold water systems. First, the cold water streams of western North America have much lower species richness than do the cool or warm water systems. Selective extinctions in the late Pleistocene are still a major factor shaping modern, western fish assemblages. In contrast, the vast Mississippi drainage served as a refuge for fishes, avoiding extinctions, and possibly increasing speciation. The least disturbed Western streams have a nearly universal cold water-adapted fish assemblage: salmonids (*Oncorhynchus/Salvelinus* sp.), sculpin (*Cottus* sp.), sucker (*Catostomus* sp.), and dace (*Rhinichthys* sp.). In contrast, streams in the Mississippi drainage may have 40 to 50 native species (Moyle 1994). A second complicating factor is that species richness in warm water streams declines as habitats or water quality are degraded. In contrast, as cold water systems are degraded, species richness often increases as native cold water fishes decline, making their habitats vulnerable to invasion by facultative cool water native species or non-indigenous species, most of which were introduced from the Mississippi drainage (Moyle 1994). A third complicating factor is the homogenization of fish assemblages by extensive stocking of salmonids, which further blurs the already depauperate cold water western fish assemblages (Maret et al. 1997;. Rahel 2000).

These factors have slowed the development of a generally applicable cold water IBI for western streams and rivers. Despite these limitations, river fish assemblages are socially and ecologically important and should be evaluated in their own right. Regional state water quality standards and the national Clean Water Act explicitly call for protection of fish and fisheries. Direct assessment of the fish assemblage is more relevant to its management than surrogate approaches based on other assemblages or chemical and physical criteria alone.

METHODS

Since this report is longer than most research papers and presents diverse results, some methodological details are split up and reported with the respective results.

The analysis included descriptive and statistical approaches to classifying generally like and unlike stream types, and evaluating candidate metrics (variables that respond to water quality or habitat degradation). The latter step included examining patterns of potential response variables across undisturbed or minimally disturbed stream types, and across a range of sites with apparent human disturbance. The response variables (metrics) were converted to unitless scores that were then added together to form composite indexes. The indexes were then tested to see if they could discriminate between reference and impaired sites. The index results were additionally compared to amounts of fine sediment in stream channels and a habitat index. Excessive amounts of fine sediment and habitat degradation are common

causes of stream degradation. Thus, there should be some relationship between index scores and sediment and habitat measurements.

Data

Data were compiled primarily from the following sources:

- Idaho Department of Environmental Quality (DEQ) Beneficial Use Reconnaissance Program (BURP)
- Idaho Department of Fish and Game (IDFG) Resident Species Research Program
- Idaho State University, Stream Ecology Center (Robinson and Minshall, 1995)
- U.S. Geological Survey National Water Quality Assessment (NAWQA) Upper Snake River, Northern Rockies, Columbia Plateau, and Salt Lake study units[8] (limited to sites located on small streams in the ecoregions of interest)

Criteria for use of data were that they include at least single pass electrofishing data, with all fish species captured, identified, and recorded. This requirement excluded many surveys that recorded salmonids only. Other needed information included a physical description of the site (location, size, elevation), lengths of salmonids and sculpins, and electrofishing effort (duration in seconds).

Classification of Stream Types

Like taxonomy of organisms, classification attempts to distinguish and group distinct environments, communities, or ecosystem types. The objective of stream type classification is to group places where living systems are similar at higher taxonomic and ecological levels in the absence of human disturbance, and where the biological responses are similar after human disturbance (Karr 1999). Classifications are based on natural history, biogeography, and data analysis. In particular, a stream classification based on river morphological characteristics is helpful in predicting stream behavior, extrapolating data from one stream to another of similar character, and providing a consistent and reproducible frame of reference (Maret et al. 1997).

Major factors in grouping stream types

Ecoregion – Stream types were initially classified into two broad groups, forest and rangeland streams. Burton et al (1991) concluded that on a regional scale in Idaho, there are two major streams types that are clearly differentiated on factors limiting fish populations: 1) Stream and riparian systems dominated by forest overstory, and 2) those dominated by grass and shrub riparian vegetation. Forest canopy dominated streams occur primarily in mountain settings in Idaho and occur generally on gradients of more than 1.5 percent. Grass

[8] http://montana.usgs.gov/nrok/nrokpage.htm; and http://wwwidaho.wr.usgs.gov.nawqa/usnk_home.html

and shrub streams occur in the intermontane valleys, mountain meadows, and plains, and generally have gradients of less than 1.5 percent.

In forested mountain streams, salmonid populations are limited primarily by habitat structure. Physical habitat diversity is apparently the key to population size because in steeper gradient streams, resting areas and refugia are physically limited (Bjornn and Reiser 1991, Herger et al. 1996). Canopy closure in forested mountain streams may often limit primary production and the availability of drifting prey to fish due to the lack of light energy penetration in these streams. In contrast, most rangeland streams are located in meadows and valleys mostly at lower elevations in Idaho. Stream gradients are predominantly less than two percent, and natural riparian vegetation is dominated by grasses and shrubs, with little or no woodland overstory. In rangeland streams, light energy inputs and resting and feeding are not generally limiting (Burton et al. 1991). Beyond these differences in natural stream ecosystems, forest and rangeland streams may have different responses to environmental degradation. In forested stream systems, removal of the stream canopy by logging may increase local primary production, macroinvertebrate abundance and diversity, and abundances of salmonids, sculpin, and amphibians (Hawkins et al. 1983, Murphy and Meehan, 1991, Meehan 1996). In contrast, in the high desert trout streams of the inland Northwest, trout biomass was negatively correlated with loss of canopy due to grazing, despite increases in invertebrate productivity (Li et al. 1994).

Ecoregions of the Pacific Northwest correspond well with this forest/rangeland stream distinction. These ecoregions are based on perceived patterns of integrative factors including land use, landform, potential natural vegetation, and soils (Omernik and Gallant 1986). The seven ecoregions Omernik and Gallant mapped in Idaho can be grouped into predominately montane-forested ecoregions (Northern Rockies, Middle Rockies, Blue Mountains, and Wasatch-Uinta Mountains) and predominately desert basin-rangeland ecoregions (Snake River Basin/High Desert, Northern Basin and Range, Columbia Basin and Wyoming Basin). Henceforth, the terms “mountain,” “forest,” “basin,” or “rangeland” ecoregions are used to mean these groups. Fish assemblages in the forested streams are usually dominated by or exclusively composed of stenothermic trout and sculpin species (Burton et al. 1991, Maret el. 1997). Rangeland assemblages of the arid ecoregions of the Northwest are usually reported to include a mix of mesothermic minnows and suckers, and the stenothermal trout and sculpin species (e.g. Whittier et al. 1988, Hillman 1991, Pearsons et al. 1992, Tait et al. 1994, Maret el. 1997).

Elevation – I used elevation as a secondary factor to group the streams. Maret et al (1997) found that patterns of fish species distributions and assemblages did not correspond well with the mapped ecoregion boundaries. They suggested the reason may have been because many of their least-disturbed sample sites in rangeland (Snake River Basin and Northern Basin and Range) ecoregions were located near transitional areas between ecoregions and may have expressed characteristics of adjacent ecoregions. Robinson and Minshall (1995) concluded that *within* both the mapped Snake River Basin and Northern Basin and Range ecoregions, reference streams could be distinguished into upland and lowland streams by gradient, elevation, and whether the watersheds were typically forested or sagebrush/grass. The upland streams shared features of the Northern Rockies streams, in that they had higher gradients and more forest cover than the lowland streams, which were more typical of the

rangeland ecoregions. Most of the stream sites they considered lowland sites were below about 1600m and 1750m for the Snake River Basin and Northern Basin and Range ecoregions respectively. For this study, streams sites that were located above these elevations in these two ecoregions were considered to be "forest" streams. An elevational threshold of about 1200m was selected for this distinction for the Columbia Basin ecoregion of northern Idaho. I am not aware of any ecoregional comparative studies similar to Robinson and Minshall (1995) for this area. Instead, I selected 1200m based upon review of vegetation patterns shown on topographical maps, discussion with regional biologists, and the general ecological rule of thumb that in temperate latitudes, 1° of latitude is approximately equal 200m of elevation change (e.g. Flebbe 1996)[9] Latitude differences between Columbia Basin and southern Idaho rangeland ecoregion sites range from about 1 to 5°. Ecoregions and these ecoregion combinations are illustrated in Figure 4-1.

Stream size – Stream order or stream size is a major determinant for species richness, abundance, and life history use by fish (Platts 1979, Li et al. 1987). In theory, stream size should be an important factor in determining the fish assemblage in both rangeland and forested streams. However, few perennial rangeland streams could be considered in a reference condition over a significant longitudinal gradient. This prevented evaluation of different stream sizes as a classification feature. Other than the original distinction that this study is focused on wadeable perennial streams (i.e. no large rivers), stream size and fish assemblage relationships were not investigated in rangeland streams. In the forest streams, stream size and elevation are considered in classifications and evaluation of candidate metrics.

[9] Before finding Flebbe's reference to this rule of thumb of 200m per degree of latitude, I estimated latitudinal-elevational changes in Idaho to be about 170m per degree of latitude, which suggests this is a pretty good rule of thumb. I made this estimate by comparing alpine timberline elevations on topographic maps across 7° of latitude ranging from the Selkirk Mountains (≈1830m at 49°N) to the Albion Range in the Northern Basin and Range ecoregion (≈2990m at 42°N), including several mountain ranges in between (the Bitteroots, Boulder Mountains, Salmon River Mountains, and the Tetons).

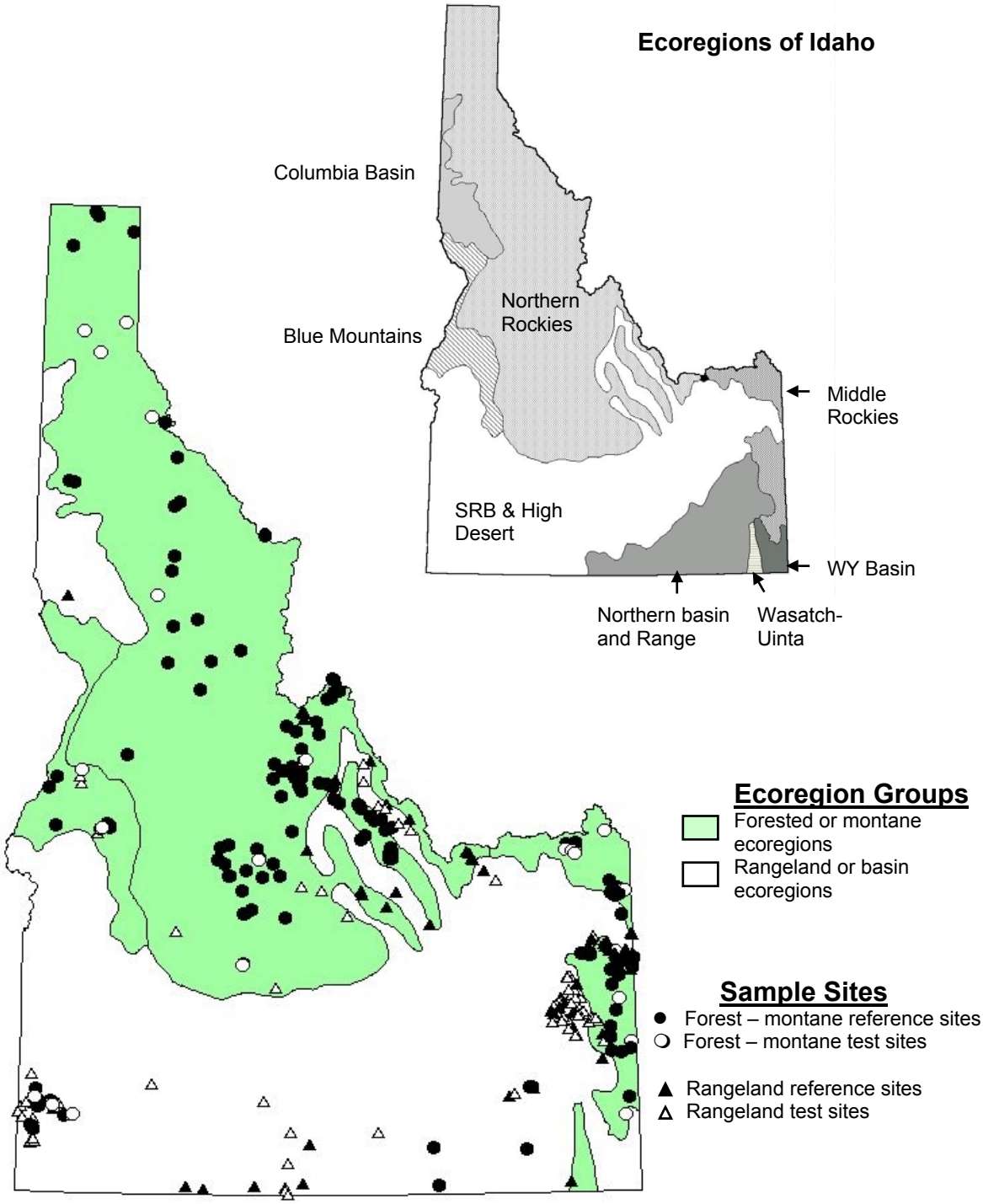


Figure 4-1. Ecoregions of Idaho (inset-top), combined ecoregion groups (bottom), with fish assemblage sample sites. Some sites not shown, due to missing coordinates.

Evaluation and Selection of Candidate Metrics

Selecting and testing candidate metrics involved three major steps:

- Compiling sampling data from a variety of sites with different types and intensities of human disturbance.
- Calculating attributes (metrics) that, according to literature reports, would be likely to show a relationship to human disturbances.
- Searching for empirical relationships, i.e. quantitative change across a range of conditions.

Candidate metrics

Many measures of composition, diversity, and functional organization of fish assemblages have been used or postulated for use to develop an IBI. Barbour et al. (1999) list 69 measures, and there are others beyond those. To focus the testing, I reviewed other efforts to modify the IBI approach to cold water or other species depauperate systems. Metrics used or proposed for indexes of biological integrity in several other cold water North American areas are listed in Table 4-1. Attempts to overcome the limited species richness include several common themes:

- Expanding the fish assemblage to a vertebrate assemblage by including amphibians
- Interpreting the ubiquitous salmonid populations through age class strength and abundance or biomass
- Interpreting sculpin populations, which are often sympatric with salmonids, but are not stocked or harvested
- Interpreting the composition of stenothermic and mesothermic fishes (i.e. obligate cold water and cool water tolerant fishes).

While these themes from previous investigations give insight into potentially useful metrics, in some cases the ecological interpretation of similar metrics have been contradictory or unexplained. For example, Fisher (1989) found significant correlations between increasing salmonid density, abundance and richness of amphibian species, and increasing timber harvest in their watersheds. Based on these correlations, he structured his index so that high species richness, abundance of amphibians, and high salmonid densities would indicate low biological integrity. In the Idaho qualitative index, dominance by benthic insectivores was assumed to be an indication of impairment (Table 4-1). However, a large portion of the natural fish assemblage in mountain streams can be considered benthic insectivores, since most juvenile salmonids occupy positions near the benthos and feed predominantly on benthic insects (Meehan and Murphy 1991), and the diet of all resident sculpin species are largely benthic insects (Bond 1963, Hendricks 1997, Zaroban et al. 1999). These examples caution us that metrics used in a multimetric index development should have both a theoretical basis and empirically tested performance. The ecological concepts and reasoning of each candidate metric are described in Table 4-2.

Table 4-1. Metrics from original IBI and suggested for cold water streams. The symbols (-) or (+) indicate a metric for which decreased or increased value (respectively) was supposed to indicate degraded water quality.

Original IBI (Karr et al. 1986)	**Cold water rivers in Idaho (Mebane 2000)**	**Northwest Coast Range cold water streams (Howlin et al. ms.)**
# fish species (-) # sucker species (-) # darter species (-) # sunfish species (-) # intolerant species (-) % green sunfish (+) % omnivores (+) % insectivorous cyprinids (-) % top carnivores (-) % hybrids (+) abundance or catch per effort (CPUE) (-) % with anomalies (+)	# cold water native species (-) # sculpin age classes (-) % sensitive native individuals (-) % cold water individuals (-) % tolerant individuals (+) # non-indigenous species (+) % carp (+) # age classes for selected salmonid species (-) # Cold water individuals/ electrofishing effort (-) % with deformities, eroded fins, lesions, or tumors (DELT anomalies) (+)	# native vertebrate species (-) % introduced species (+) % anadromous (-) % cool water (+) % tolerant individuals (+) # native cold water individuals (-) % native cold water individuals (-) # age classes for selected salmonid and sculpin species (-)
Idaho streams (Chandler et al. 1993)	**Cold water Vermont streams (Halliwell et al. 1999)**	**Northern and central Idaho erosive (e) or depositional (d) streams (Fisher 1989)**
# intolerant species (-) # non-indigenous species (+) # salmonid species (-) # benthic insectivore species (-) % insectivores (-) % total anomalies (+) % salmonids (-) Total fish biomass (-) Salmonid biomass (-) % young-of-year salmonids (-) Jaccard community similarity coefficient (-)	Resident lotic species Benthic insectivorous species Sensitive resident (lotic) species % omnivore and generalist feeders % individuals as benthic + water column insectivores % individuals as top carnivores + trout # individuals as lotic residents % individuals with disease or anomalies	# fish species (e -, d +) # salmonid species (e -) # non-salmonid species (e -, d +) # introduced species (e -) % salmonid individuals (e +) Average salmonid length (e -) Average salmonid weight (e -) Salmonid density (+, d -) Salmonid biomass (d -) Fish biomass (d -) # amphibian species (e +, d -) Amphibian biomass (d +) # intolerant species (d -) % hybrid species (d +) Macroinvertebrate density (d +)
Idaho qualitative IBI (IDEQ 1996)	**Cold water Wisconsin streams (Lyons et al. 1996)**	**Snake River Basin and Northern Basin and Range ecoregions (Robinson and Minshall 1992)**
Intolerant individuals (-) Tolerant species dominance (+) Benthic insectivores dominant (+) Hybridization with introduced species (+) Salmonid age class structure (shift or fewer classes) (-) Prevalence of anomalies (+)	# intolerant species (-) % cold water species (-) % tolerant species (+) % salmonids that are brook trout (i.e. natives) (-) % top carnivores (-)	# salmonid species (-) # tolerant species (+) % tolerant individuals (+) % salmonidae (-) Salmonid biomass (-) Salmonid condition factor (-)

Table 4-2. Ecological concepts and reasoning of selected candidate metrics.

Assemblage richness and composition metrics
Number of cold water native species *or* Percent cold water native individuals Species richness frequently changes in response to environmental stress. This metric is limited to native cold water species to exclude confounding introduced or tolerant native species. Reference cold water streams typically have one to three native cold water species. As habitats shift from cold to cool water, total species richness may increase as cool and warm water species expand their range. Most fish assemblages appear to be more unstable and fluctuate more in terms of species abundances than in terms of species presence or absence (Rahel 1990).
Number of native species In perennial streams in the rangeland ecoregions (Snake River Basin, Northern Basin and Range, and Columbia Basin), richness in reference streams may be four to six (or more) native species. As with other temperate areas for which IBIs have been developed, this metric assumes stressed streams will lose native species.
Percent cold water individuals This metric acknowledges widespread establishment of non-indigenous trout populations that have become part of the resident fishery in Idaho. Introduced trout often displace native trout but are still intolerant of degraded water quality conditions. Low representation of cold water species may indicate degraded conditions.
Jaccard community similarity coefficient (JC) Departures of faunal composition from that expected to occur at a site is an intuitive, interpretable, and ecologically meaningful way of describing biological impairment; taxa composition must change before structural or functional attributes of an ecosystem change (Hawkins 2000). Metric assumes taxa composition is relatively stable at reference sites, measures degree of similarity in taxa composition between mean of reference sites and a test site. Cool water rangeland streams have higher taxa richness than cold water streams, suggesting measures of community persistence, or comparison of observed taxa presence to expected taxa presence may be useful. Jaccard coefficients values increase as the degree of similarity with the reference station(s) increases, values range from 0 to 1.0 for stations with no taxa in common to stations with same taxa as reference sites. Coefficient was calculated as JC = $a/(a + b + c)$ where a is the number of taxa in common to both reference and comparison sites, and b and c are the number of taxa unique to the comparison and reference sites. Index calculated at genus level because genera are more widely distributed in Idaho than species. For example, *Catostomus ardens* only occurs upstream of Shoshone Falls and *Catostomus columbianus* only occurs downstream; genus *Catostomus* is ubiquitous but not species within the genus. The five most frequently occurring genera at reference streams were used to define the assemblage. and because including rare species makes c large, and when c is large all JC values are low and stable, which provides no useful information.
Percent sculpins (Cottids) Mottled, Paiute, shorthead, Shoshone, slimy, torrent, and Wood River sculpins require well-oxygenated rubble or rubble/gravel substrate, and are absent or rare from streams with fine-grained substrates, highly embedded cobble substrates, or elevated metals (McCormick et al. 1994, Mebane 2001). Larvae of these species and some adults burrow into the interstitial spaces of cobble substrate for refuge (Bond 1963, Finger 1982, Haro and Brusven 1994). Some freshwater sculpin species (e.g. reticulate, Pit) are tolerant of fine sediments and low dissolved oxygen, but do not occur in the study area (Zaroban et al. 1999). Sculpin have similar physiological needs as many salmonids, but relatively sessile habits make them excellent water-quality indicators (Carline et al 1994, Bond 1963). Sculpin species have wide but disjunct distributions. They may be absent from small, high elevation, or high gradient reference streams. Sculpin diets overlap with trout, and when abundant, may reduce food consumption and production of salmonids (Johnson 1985, Brocksen et al. 1968). Percent sculpin and sculpin age-class metrics may be functionally similar.
Percent salmonids Several IBI models for cold water or mixed cool and cold water assemblages have used the percentage of salmonids as an indication of environmental suitability for intolerant species (Table 1; Barbour et al. 1999). This metric is conceptually similar with the percentage of cold water species metric, since almost all cold water species in the sample sites were salmonids and sculpins.

Table 4-2. *(continued)*

Indicator species metrics
Percent sensitive native individuals Tolerances of many species to environmental stress have been listed for many species (Zaroban et al. 1999). River systems that are similar to natural reference conditions will include sensitive native individuals. Conversely, sensitive natives will be the first to decline in a system that is highly turbid, silty, or warmer than historic conditions
Percent tolerant individuals The proportion of fishes that thrive in or tolerate poor-quality water is likely to be high in rivers with poor water quality. This metric includes some native cyprinids (minnows) and catostomids (suckers), as well as many introduced, non-indigenous species (e.g. carp, tench, bullheads, centrarchids).
Percent non-indigenous individuals This metric reflects the severity of biological pollution by dominance of invading or introduced non-indigenous species. The number of nonindigenous species is measured by how many species have become established, rather than dominance by any one or more non-indigenous species. Presence of a non-indigenous species is usually permanent and less variable than the percent of non-indigenous individuals.
Percent of cyprinids as longnose dace Overall, native cyprinids may increase their dominance in Idaho streams in response to degradation (Royer and Minshall 1996). However, of the non-cold water fishes (i.e. other than salmonids and sculpins), longnose dace's environmental requirements may make it a useful indicator species. They require well oxygenated, flowing water, and access to riffle habitats, where they deposit their eggs in rock crevices, and principle food items are dipterans and mayflies. The longnose dace seeks the interstices between stones in gravel-rock substrates of riffle areas of streams to spawn (Scott and Crossman 1998). Sedimentation, loss of riffle habitats, and diminished stream flows adversely affect longnose dace populations (Probst 1982, New Mexico Natural Heritage Program, http://nmnhp.unm.edu). Longnose dace are widely distributed in Idaho streams, and were frequently captured in rangeland streams (Table 4; Simpson and Wallace 1982). Probst (1982) reported longnose dace were affected by siltation of spawning riffles but otherwise tolerated a wide range of environmental conditions. Poff and Allan (1995) also reported longnose dace were sensitive to siltation in Minnesota and Wisconsin streams.
Trophic composition
Percent omnivore plus herbivore individuals This metric is a measurement of omnivore species that take significant quantities of both plant and animal materials (including detritus). It assumes that the dominance of omnivores occurs as specific components of the food base become less reliable in response to degradation. The opportunistic foraging habits of omnivores make them more successful than specialized foragers (Karr et al. 1986). This metric was broadened to include herbivores. Herbivores are considered specialized feeders, however they thrive when sunlight and nutrient conditions are sufficient to support lush plant growth. These conditions may result from removal of riparian shading and nutrient inputs from agriculture (Cuffney et al. 1997).
Percent insectivore individuals This metric assumes that as habitats are degraded, insect food sources are reduced in diversity, and there is a shift from insectivorous to omnivorous species (Karr et al. 1986). Most salmonids, all sculpin, and some native cyprinids are included in this metric. In the wadeable streams of this study area, carnivores, (i.e. piscivores-fish that feed on other fish) were uncommon. These species include northern pikeminnow (formerly known as the northern squawfish), smallmouth bass, and adult fluvial bull trout; these species are more common in large rivers and reservoirs. Thus, this metric is the inverse of, and redundant with, the *% Omnivores and Herbivores* metric.

Table 4-2. *(continued)*

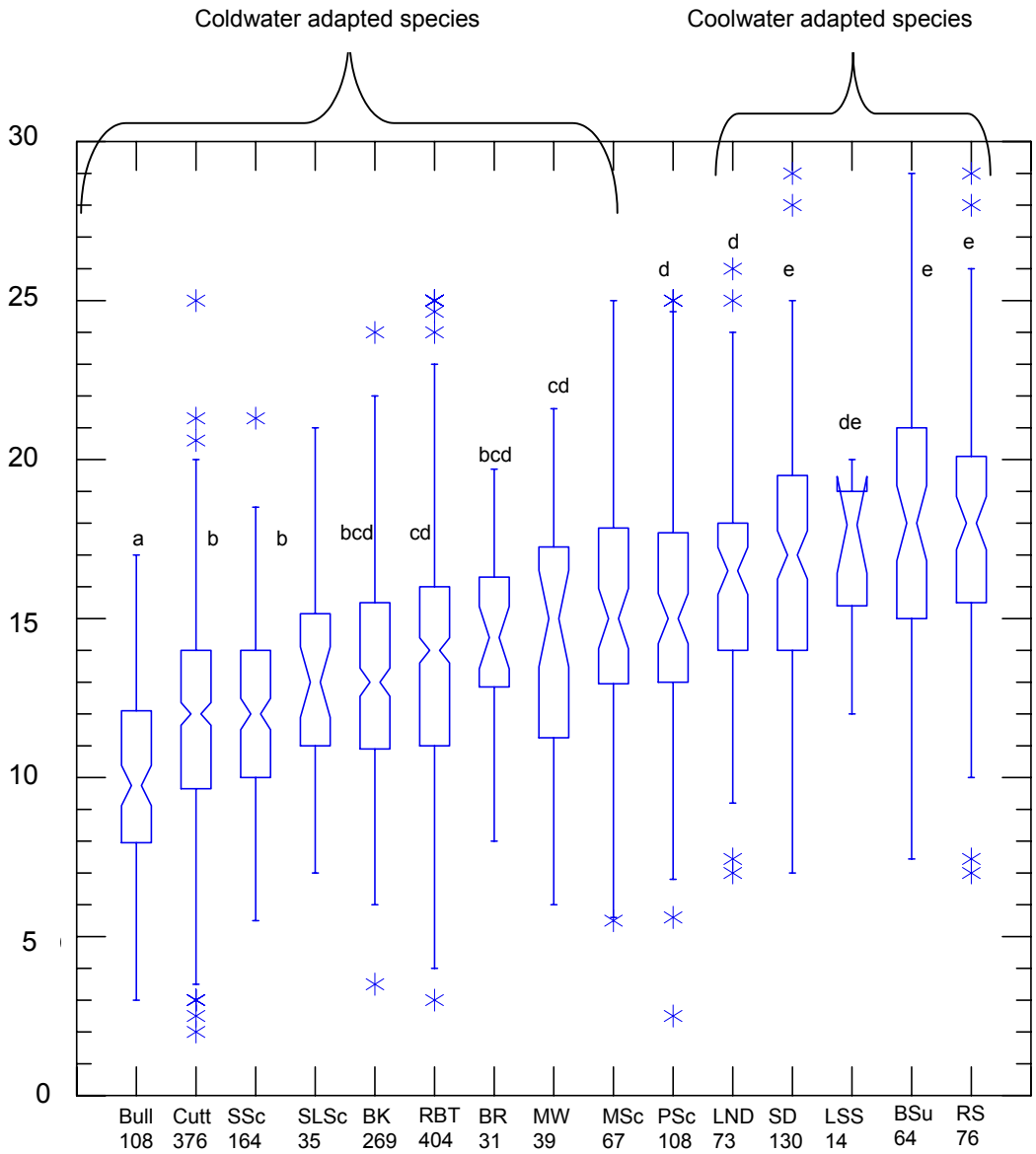
Reproductive function metrics
Number of salmonid age classes This metric reflects suitability and stability of conditions in a surveyed location for salmonid spawning, juvenile rearing, and adult salmonids. Age classes are inferred from measured size classes and typical length at age relationships (same for sculpin age class metrics). Shifts in age class distribution are frequently responses to different stressors, such as exploitation, recruitment failure, food limitation, or niche shifts (Munnkittrick and Dixon 1989).
Number of selected salmonid ("trout") age classes (Genus *Oncorhynchus*, *Salvelinus*, and *Salmo* [Trout, char, and salmon]; mountain whitefish are excluded.) This metric is similar in concept to salmonid age classes, but restricted to redd building gravel spawners. It excludes gravel or rock broadcast spawners with pelagic free embryos, which develop in river backwaters rather than in substrate interstices. It also excludes mountain whitefish due to their markedly different reproductive strategy from trout, salmon, and char. Mountain whitefish spawn by broadcasting eggs and milt over gravelly areas, and no redd is built (e.g. nonguarding open substratum, lithopelagophils, Simon (1998b)). Neither whitefish embyros or larvae appear to utilize intergravel spaces for either embyros or alevins; development occurs in quiescent river backwaters (Northcote and Ennis 1994). Trout bury their eggs in redds in gravelly areas (e.g. nonguarding brood hiding lithophils, (Simon 1999b)) The spawning success of trout may be more sensitive to siltation than whitefish because fines embedded in gravels reduces interstitial spaces between the gravel particles, in turn reducing intergravel dissolved oxygen necessary for egg and alevin survival. The surface layer of embedded gravels may still be suitable for broadcast spawners. The spawning success of trout and salmon are sensitive to excessive siltation because fines embedded in gravels reduces interstitial spaces between the gravel particles, in turn reducing intergravel dissolved oxygen necessary for egg and alevin survival (Chapman 1988, Maret et al. 1993). Trout age classes declined with increasing proportions of fine sediments in mountain streams in central Idaho (Mebane 2001). Mountain whitefish were abundant and multiple age classes were present at apparently degraded large river sites at which trout were absent or rare (Mebane 2000), and thus may be more resilient than other salmonids to temperature and low intergravel dissolved oxygen.
Number of sculpin age classes This number reflects the availability of un-embedded cobble substrate required for cavity nesters and juvenile refuge. Sedentary life histories result in adult home ranges of <50-150m (Hendricks 1997). Their low dispersal distances are advantageous for assessing site conditions over several years. Sculpin age classes declined with increasing proportions of fine sediments in mountain streams in central and eastern Idaho (Mebane 2001).

Table 4-2. *(continued)*

Abundance and condition metrics
Number of cold water individuals per minute of electrofishing (catch per unit effort, CPUE) Cold water fish should be more abundant at locations with favorable conditions for cold water biota. However a myriad of natural and anthropogenic factors that limit the abundance of fish complicates interpretation, particularly with trout that are subject to harvest. Erman (1986) reported that fish abundance was more variable than assemblage structure and was driven by climate changes. Defining this metric as cold water instead of salmonid abundance (Table 1) may lessen potential confounding harvest effects. Since abundances of all fish may increase in response to some types of degraded water quality (the paradox of enrichment), limiting the metric to cold water individuals may avoid that response. Estimates of density or biomass can be difficult to measure, for example sampling efficiency drops in larger waters and density estimates difficult in complex habitats (e.g. logjams). Abundance needs to be normalized to compare different-size habitats, different fishing efforts, etc. The DEQ sampling program typically uses single-pass electrofishing to sample the fish assemblage. Precise, unbiased abundance estimates may require a large number of removal passes or mark-recapture sampling. However, a single catch-per-effort pass will sample a consistent proportion of the fish species in small streams, in terms of both richness and abundance, when compared with removal sampling. Also, if the stream stations are about 35 times the mean stream width, the influence of fish entering and leaving the station may be negligible, making block nets unnecessary for CPUE sampling (Simonson and Lyons 1995). Kruse et al (1998) also compared single-pass sampling efficiency to intensive methods since intensive sampling to obtain unbiased population estimates limits the ability of field crews to assess large areas. Kruse et al. found that in trout streams with low densities (<0.4 fish/m2) and where most refuge habitat was in boulder pools, with limited amounts of instream vegetation, undercut banks, or woody debris, single pass electrofishing was sufficient for estimating fish abundance in small mountain streams. The stream features in Kruse et al.'s (1998) study area in the Middle Rockies ecoregion (Omernik and Gallant 1986) likely comparable to those in similar mountain ecoregions of Idaho.
Percent of fish with DELT anomalies Fish may develop external deformities, eroded fins, lesions, or tumors (DELT anomalies) in response to exposure to contaminated sediments or other exposure routes. This metric excludes protozoan or other parasitic infestations that are often unrelated to water quality. <u>Issues:</u> Numerous field and laboratory studies on fish have shown that the liver is the most frequent site of neoplasms in fish that were correlated with chemical contamination. Less common neoplasms of other epithelial tissues, including the skin, have been linked to environmental contamination. Etiology of other gross external pathological anomalies are inconsistent and have not been closely linked to chemical contamination (Harshbarger and Clark 1990, Horness et al. 1998). Yet, DELT anomalies may be more common in areas with significant urban agricultural development than at reference sites. In this study area, Munn and Gruber (1997) found more frequent detections of organochlorine compounds in fish tissue collected from agricultural streams than from streams without agriculture as a major upstream land use. Frequency of DELT anomalies was also higher at agricultural streams (Munn. unpub. data), but no correlations between concentrations, frequency of chemical detections, and frequency of DELT anomalies were found. Mebane (2000) found DELT anomalies were about twice as high at river sites which significant agricultural development upstream than at other sites, suggesting an association between pesticide use and anomalies. Sanders et al. (1999) qualitatively associated the occurrence of DELT anomalies to pollution sources in Ohio rivers. While DELT anomalies are a crude measure, with frequent false positive results (i.e. DELT anomalies without chemical stressors) , the possibility of identifying areas with elevated incidences of cancer or other abnormalities in wild fish for further study outweighs these limitations.
Percent of fish with any anomalies This metric is the same concept as with DELT anomalies, but not limited to deformities, eroded fins, lesions, or tumors in response to exposure to contaminated sediments or other exposure routes. It includes protozoan or other parasitic infestations, such as blackspot disease, which are often unrelated to water chemistry.

Cold water species evaluation

Accurate classification of fish species attributes is a fundamental requirement that must be met before an IBI can be developed. These attributes include thermal tolerance, tolerance of low dissolved oxygen and siltation, and trophic guild. Zaroban et al. (1999) recently published a comprehensive list of these attributes for 132 Pacific Northwest species. The authors cautioned that because of the breadth of their compilation, their classifications were necessarily subjective, and based primarily on previous reviews (e.g. the state "Fishes of..." books). Testing most of the classifications would be major studies unto themselves, and would certainly be beyond the scope of this analysis. However, the regional temperature classifications can be evaluated and potentially refined with more geographically specific (i.e. Idaho) matched temperature and species occurrence records. Temperature measurements were usually made at the beginning of each electrofishing pass. Therefore, each fish was captured within about 20 minutes and 100m of that single point temperature measurement. While stream temperatures are variable, even within 20 minutes and 100m, it is reasonable to assume that each fish captured could have experienced the instantaneous temperature measured at the beginning of each electrofishing pass. Singly, this means little; but when the distributions from many such records are plotted, patterns of temperature preference, overlap, and separation between species begin to take shape (Figure 4-2).



Code	Common Name	Scientific Name	Code	Common Name	Scientific Name
Bull	Bull trout	*Salvelinus confluentus*	MW	Mountain whitefish	*Prosopium williamsoni*
SSc	Shorthead sculpin	*Cottus confusus*	MSC	Mottled sculpin	*Cottus bairdi*
Cutt	Cutthroat trout	*Oncorhynchus clarki*	PSC	Paiute sculpin	*Cottus beldingi*
SLSC	Slimy sculpin	*Cottus cognatus*	LND	Longnose dace	*Rhinichthys cataractae*
BK	Brook trout	*Salvelinus fontinalis*	SD	Speckled dace	*Rhinichthys osculus*
RBT	Rainbow trout	*Oncorhynchus mykiss*	LSS	Largescale sucker	*Catostomus macrocheilus*
BR	Brown trout	*Salmo trutta*	BSU	Bridgelip sucker	*Catostomus columbianus*
			RS	Redside shiner	*Richardsonius balteatus*

Figure 4-2. Temperatures at which selected fish species were captured by electrofishing in Idaho from 1994-1998. Plots are in rank order by median temperatures. The boxes indicate the median and upper and lower quartiles (the central 50% of the values), the whiskers extend up to 1.5X the interquartile value, and asterisks show outlying values. Species with few matched temperature and capture records were excluded. Plots marked with the same letter indicates that their means are not significantly different at P <0.05 using Tukey's multiple comparison procedure.

The distribution of temperature at which selected fish species were captured supports the division of the fish species into broad categories of mesothermal (cool water adapted) cyprinid-catostomid species groups and stenothermal (cold water adapted) cottid-salmonid species groups. Within the stenothermal group, species can be grouped as moderately stenothermal (rainbow trout, mountain whitefish, mottled and Paiute sculpin) and strongly stenothermal groups (cutthroat and brook trout, shorthead and slimy sculpin).

The temperature distributions for bull trout support the viewpoint that bull trout are extraordinarily stenothermal. In our summertime surveys, bull trout were found in both the coldest waters (9.8°C median temperature), and among the most limited range of temperatures for the stenotherms. Most bull trout were found at temperatures below 12°C (75th percentile of temperatures) and were never captured above 17°C.

These field data support the qualitative thermal classifications listed in Zaroban et al. (1999). Median stream temperatures at which the stenothermal, cold water-classified fishes were collected were approximately less than 15°C. The sole difference suggested between these distributions and their list is that regionally mottled sculpin were listed as cool water. The data shown in Figure 4-2 suggest that the cool water-classified mottled sculpin, cold water-classified Paiute sculpin, and cold water-classified mountain whitefish have similar summertime temperature occurrences. Mottled sculpin are included in the cold water metrics used here (e.g. cold water native species, percent cold water species).

Native species evaluation

Several of the metrics are defined as native or cold water native species. For most species, determining whether a species captured at a given stream is or is not indigenous is a simple matter of consulting a reference list (e.g. Simpson and Wallace 1982, Zaroban et al. 1999). However, in the case of the *Oncorhynchus mykiss*, which may be considered either a rainbow, redband, or steelhead trout, it is not a simple matter to determine whether a population is native or introduced. Behnke (1992) states that only two forms of *O. mykiss* are native to Idaho, the interior redband trout and the anadromous steelhead trout. Either or both or both forms were historically widely distributed in the lower Snake River and its tributaries as far upstream as Shoshone Falls (Figure 3). Subsequently, the coastal rainbow trout form of *O. mykiss* has been extensively stocked within and beyond the historical range of *O. mykiss* in Idaho. Determining whether an individual *O. mykiss* was a wild fish, or resulted from natural reproduction by a previous introduction is very difficult. Thus, for this report, unless an *O. mykiss* individual could be identified as a hatchery fish by its appearance, any *O. mykiss* caught within their historical range (Figure 4-3) is presumed to represent a native species at that site. *O. mykiss* captured beyond their historical distribution are always scored as non-indigenous species in the "native species" metrics (e.g. upper Snake River basin, Spokane River basin).

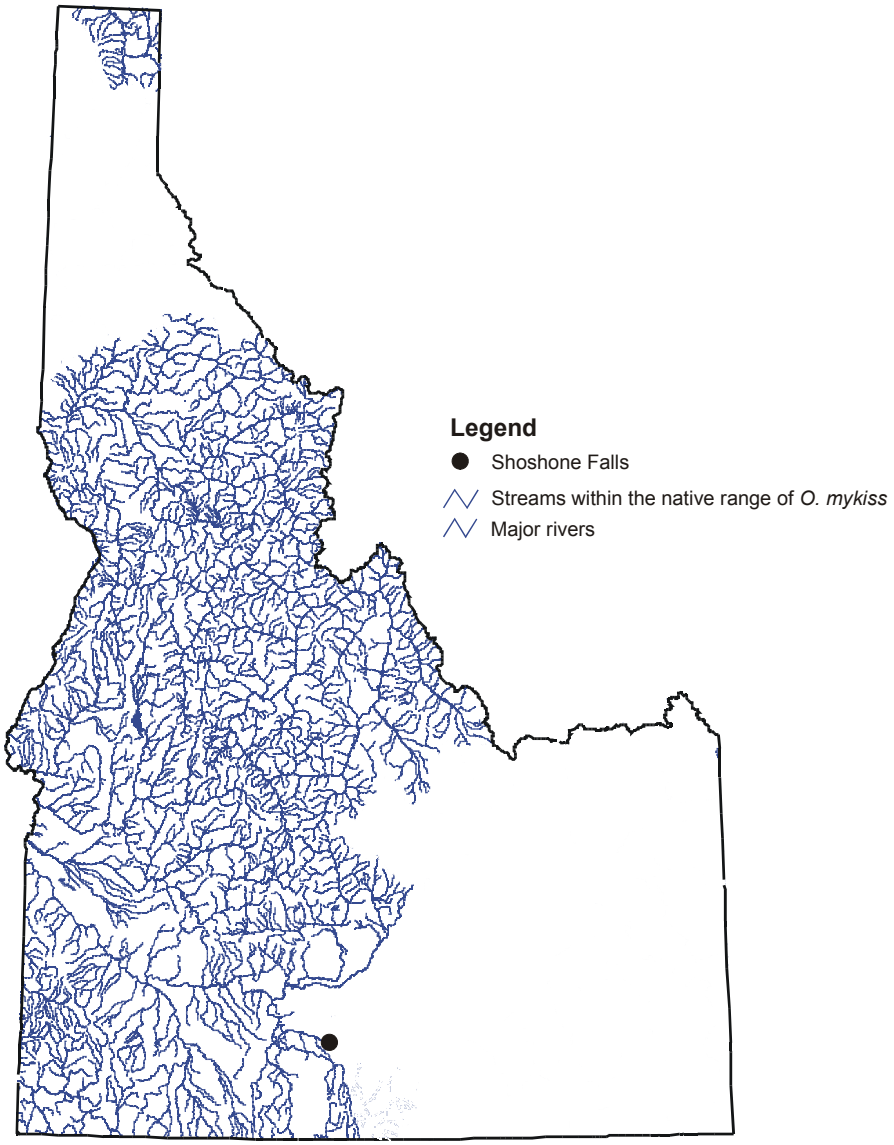


Figure 4-3. Native distributions of *Oncorhynchus mykiss* (steelhead, redband, and rainbow trout) in Idaho. Historically, *O. mykiss* occurred only in the Snake River basin downstream of Shoshone Falls and the Kootenai basin. *O. mykiss* found within their historical range are considered a native species, and non-native elsewhere. Historic distributions are from Behnke (1992).

Evaluation of anthropogenic disturbance

The utility of any bioassessment index depends on its ability to adequately respond to disturbance. Each candidate metric was a candidate because of assumptions that each measure of ecological structure or function would change in response to anthropogenic disturbance. This assumption needed to be tested for each metric, and for the combination of

the metrics into an index, for the approach to be valid. This required some evaluation of disturbance for each sample location. Because no single quantitative measure of disturbance was available for all sites, a qualitative ranking scheme was used to group sites into apparent reference sites (minimally disturbed) and apparent test sites (apparently anthropogenically disturbed). Indeterminant sites were considered "other" and were not used in index development. The BURP sites were grouped by interviewing regional biomonitoring team leaders using the criteria in Table 4-3. The IDFG surveys included a similar field rating of observed land use proximate to the survey site (e.g. no use; no use observed [but the sampling crew was not certain there was in fact no ongoing use]; light grazing; heavy grazing; agricultural activities next to streams; etc. [K. Meyer, IDFG, Resident Species Research Program, pers. comm.]) IDFG sites coded as no use, no use observed, or light grazing were considered reference; agricultural or heavy grazing sites were considered test sites (the IDFG sites used were from rangeland streams with grazing and the primary human land use). Robinson and Minshall (1995) were studying characteristics of least-disturbed streams, so all of their streams were specifically selected as reference streams. NAWQA sites were assigned to reference or test groups following discussions with the study team leaders.

Table 4-3. Factors considered for classifying reference sites.

Variable	Criteria
Roads	Not constraining riparian zone, crossings are infrequent, no evidence of road associated failures from culverts or gullies to streams.
Riparian vegetation extensive and old	Riparian growth is considered extensive when it occurs all along the shoreline and is capable of shading the stream and buffering human influences. It is considered old when overhangs the stream or deposits large woody debris
Riparian structure complex	Complexity characterized by presence of a canopy, understory and groundcover (trees, shrubs, and groundcover
Channel complex	Mixture of pool, glide, riffle, and run habitat types
Habitat structure complex	Substrate heterogeneous
Chemical stressors likely minimal	Likely sources of chemical stress are few (e.g. unbuffered croplands, irrigation returns, active or in-active mining areas, regulated discharges), or if potential sources present, chemical data shows standards or guidelines met, and thus effects are unlikely.
Shoreline/channel modification minimal	Evidence of riprap, channel straightening, vegetation removal or other disturbances absent or minimal.
Flow modifications minimal	Upstream impoundments absent. Irrigation withdrawal or other diversions absent, or if present, likely cause minimal disruption to the hydrologic cycle (i.e. acknowledging that almost all streams located in the semi-arid basin/lowland ecoregions will have some water withdrawals)
Evidence of excessive sedimentation absent	Apparent anthropogenic sediment increases not noted (e.g. crop or road gullies, livestock bank trampling, mass wasting) No field notes of highly turbid conditions. No indications from habitat variables of excessive sedimentation (e.g. No "poor" qualitative cobble embeddedness estimates (≥75%), channel substrate <50% fine sediments (measured as bankfull).
Grazing in riparian zone minimal	Absence of laid back, trampled, or unstable banks.
Logging, construction, or other disturbances minimal	If present, buffered from riparian zone
Agricultural disturbances	Croplands not impinging riparian zone, runoff or irrigation returns minimal

Modified from Hughes (1995)

RESULTS

Classification of Stream Types

Discriminant analysis of species' abundances and presence-and-absence was used as a way to test for multivariate differences between the descriptive grouping of streams by ecoregion and elevation into the "rangeland" and "forest" stream types. The goal of discriminant analysis is to find a linear combination of variables that can be used to separate groups, or to assign new sites based on the model developed for known sites. Discriminant analysis is usually better at confirming group memberships for known samples than predicting group memberships of unknown samples (Matthews 1993). A limitation to the technique is that since it is constrained to linear combinations of variables, interpretation of nonlinear relationships is difficult (Engelman1996; James and McCulloch 1990). Here, the assumption was that ecoregions were natural aquatic ecosystem groupings, and that species' abundances, or presence-and-absence at reference sites would be separated by ecoregions.

Fish species' abundance was not differentiated by mapped ecoregions (Figure 4-4a). When plotted, confidence ellipses centered on the centroids of each groups' canonical scores overlapped almost completely. The differentiation was improved by grouping the ecoregions into elevation-adjusted aggregates of the predominantly "rangeland" and "forest" type ecoregion groups (Figure 4-4b). To see if reducing the noise in the abundance data improved the separation, the canonical scores were plotted after tranforming the fish species occurrence into simple presence-and-absence data, ignoring the abundances or abundance ranks of the species (Figure 4-4c). The presence-and-absence and species' abundance plots were similar; group differentiations were somewhat stronger based upon species abundance plots.

The pool of shared species between ecoregions is likely a factor in the large overlap in the rangeland and forest groups. Of the most frequently occurring species in both ecoregion groups, five are common to both. Only the rank of their abundance differs (Table 4-4). Rainbow trout were the most common species encountered in both groups. The results of these analyses suggest that for the purpose of grouping fish assemblages based upon species composition, these elevation-adjusted ecoregion groups improved upon ecoregions as a differentiator. However, their is much overlap between the species composition of these ecoregion groups, and therefore, while these "rangeland" and "forest" stream distinctions may be intuitive and useful, they are by no means hard and fast.

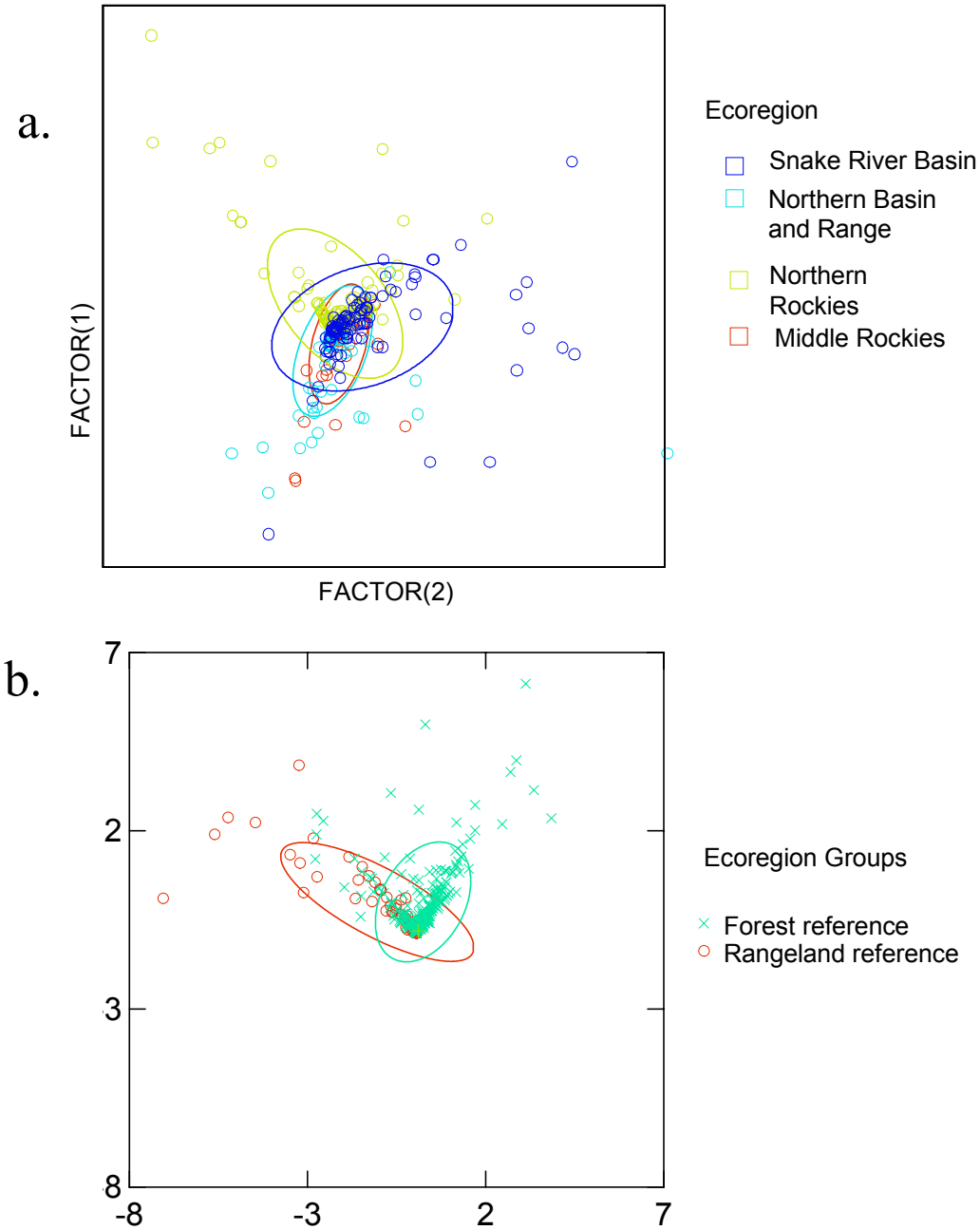


Figure 4-4. Discriminant analysis of reference site species occurrence and abundance grouped by ecoregions (a, top), and elevation-adjusted ecoregion aggregates (b, bottom). Groups clusters nearly completely overlap, indicating poor discrimination between ecoregions.

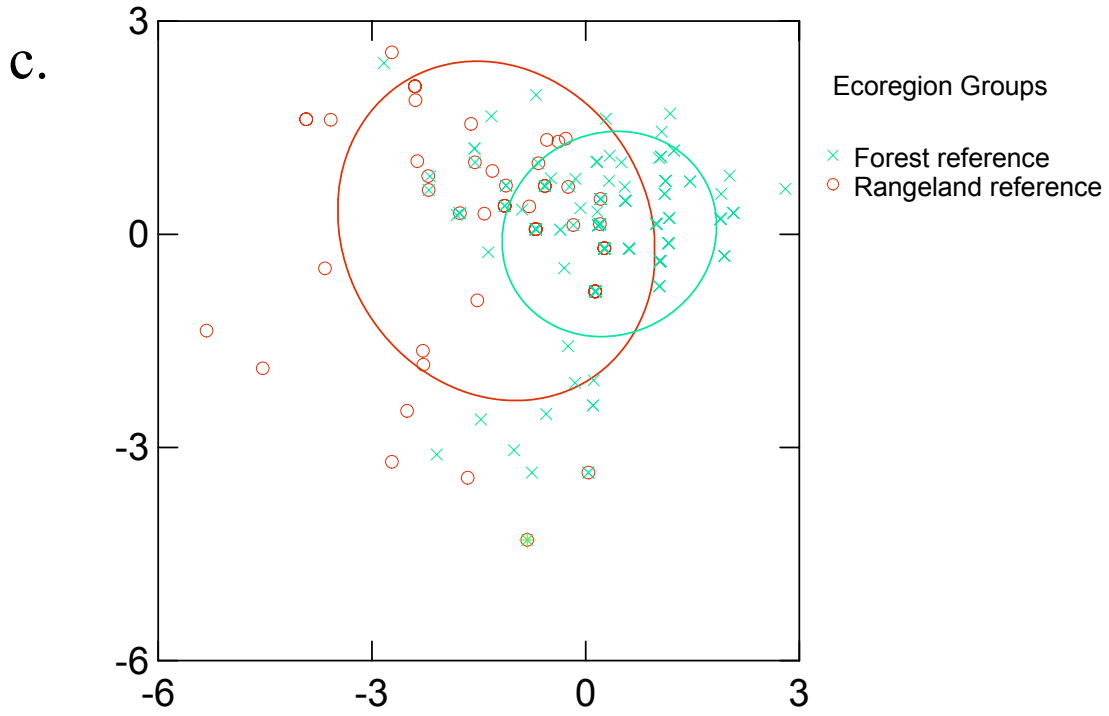


Figure 4-4. *(continued)* Discriminant analysis of reference site fish species presence-absence (12 most common species with a frequency of occurrence of at 0.1 in either group) grouped by elevation-adjusted ecoregion aggregates.

Table 4-4. Most frequently occurring species and genera in reference sites in forest and rangeland stream types.

Ranking by species and frequency of occurrence (%)									
Forest streams									
1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Rainbow trout	Cutthroat trout	Brook trout	Shorthead sculpin	Bull trout	Mottled sculpin	Paiute sculpin	Chinook salmon	Specked dace	Redside shiner
36%	30%	26%	26%	20%	11%	9%	7%	7%	6%
Rangeland streams									
Rainbow trout	Speckled dace	Redside shiner	Mottled sculpin	Cutthroat trout	Longnose dace	Mountain sucker	Paiute sculpin	Bridgelip sucker	Brook trout
69%	38%	31%	25%	18%	16%	15%	14%	11%	8%
Ranking by genus and frequency of occurrence (%)									
Forest streams									
1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Oncor.	*Cottus*	*Salve.*	*Rhini.*	*Richard.*	*Cato.*	*Prosop.*	*Salmo*	*Micro.*	*Ptycho.*
77%	53%	46%	12%	5.7%	5.7%	2.5%	1.6%	0.8%	0.4%
Rangeland streams									
Oncor.	*Rhini.*	*Cottus*	*Cato.*	*Richard.*	*Salve.*	*Prosopium*	*Ptycho.*	*Salmo*	*Micro.*
89%	58%	46%	34%	31%	9.2%	6.2%	6.2%	1.5%	1.5%

Genus abbreviations:
Oncor. – *Oncorhynchus* (Pacific trout and salmon)
Cottus – *Cottus* (sculpin)
Salve. – *Salvelinus* (char trout)
Richard – *Richardsonius* (shiners)
Rhini. – *Rhinichthys* (dace)
Cato. – *Catostomous* (suckers)
Prosop. – *Prosopium (*whitefishes*)*
Salmo . – *Salmo* (Atlantic trout and salmon)
Ptycho. – *Ptychocheilus* (pikeminnows)
Micro. – *Micropterus* (bass)

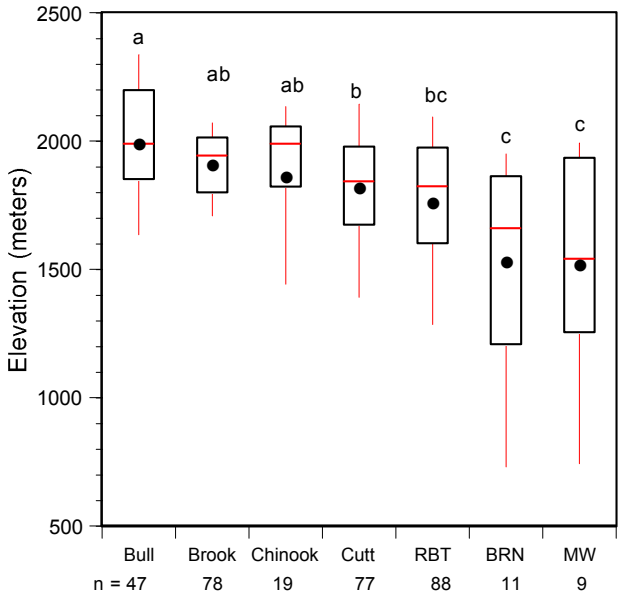
Forest Streams

Results in the "forest," or "mountain" ecoregion groups, were considered with the expectation that within this ecoregion group, elevation and stream size were additional factors influencing the natural stream assemblage of fishes (e.g. Platts 1979, Vannote et al 1980, Li et al. 1987). Further, an expression of anthropogenic disturbance to stream habitats may be that the natural elevational zonation of fish species in a stream can be shifted upstream (Rahel and Hubert 1991). Some comparisons of effects of elevation and stream size on fish assemblages from reference streams are discussed below, followed by metric testing and index construction.

Effects of elevation and stream size

Distribution of salmonid species by elevation – Seven salmonid species were captured frequently enough in the reference sites to make some observations about their occurrence at different elevations. In order of average occurrence by decreasing elevation, the salmonids were distributed as follows (Figure 4-5):

> Bull trout > brook trout > chinook salmon > cutthroat trout > rainbow trout > brown trout > mountain whitefish .



Data limited to stations located between latitude 43° 30' and 45° 30' to lessen the effects of altitude. Dot indicates the mean. For each species marked with the same leter, the means were not significantly different (P<0.05), using Tukey's multiple comparison procedure.

Figure 4-5. Elevations at which salmonid species occurred in wadeable streams (1st to 4th order).

These rankings are similar to, but not identical to, the rankings by cold water occurrence (Figure 4-2). The relative ranks of brook trout and cutthroat trout changes, for example. One difference between the comparisons is that the rankings by elevation were restricted to reference sites only, whereas the rankings by temperature were for all sites with matched temperature and capture data. The purpose of the comparison was to see if the distributions suggested an additional elevation stratification was needed. While there are elevational patterns, particularly with bull trout and rainbow trout, there was significant overlap in the elevations at which the common salmonid species were captured. This overlap suggests that additional stratification by elevation within the forest ecoregion groups may not be that helpful for bioassessment.

Distribution of salmonids and sculpins by elevation, stream size, and gradient – Salmonids and sculpin are ubiquitous in mountain streams, and were usually the only families of fish encountered in this analysis. Sculpins may be a useful indicator of chronic or episodic pollution and may decline or be extirpated from streams in which native salmonids remain present or even abundant (Carline et al 1994, McCormick et al. 1994, T.R. Maret personal communication). Some sculpin species appear to have similar physiological needs trout, but their relatively sessile habits may make sculpin slower to recolonize episodically unsuitable habitats than the more motile salmonids (Bond 1963, Carline et al. 1994). However, the relative distribution of sculpins and salmonids in mountain reference streams varies greatly, and is apparently unrelated to environmental impacts. In many streams, only salmonids occur, particularly in the smaller streams. Thus, the challenge is to distinguish when the scarcity of sculpin may indicate an episodic disturbance from natural conditions where only salmonids occur and sculpin are absent or sparse.

Trout and sculpin relative abundances were plotted to consider whether the "trout-sculpin" zone could be divided into a "trout" and a "trout-sculpin" zone (e.g. McPhee 1966, Rahel and Hubert 1991). To avoid confounding the effects of disturbance, latitude and elevation on temperature, data were limited to reference streams within two degrees of latitude (43° 30'N to 45° 30'N). In small streams, sculpin became less common above about 2000m and absent above 2300m. This is consistent with Maret et al.'s (1997) observations that sculpin were rarely encountered above 2000m in small streams in the upper Snake River Basin. However, in the larger 3rd and 4th order streams, there was no obvious relationship between salmonid-sculpin distributions and elevation; the highest large stream sampled at about 2400m had about even abundances of trout and sculpin (Figure 4-6). These results did not suggest that additional elevational stratification within the forest-mountain stream ecoregion groups would be useful, except perhaps for small streams only. As the bottom graph in Figure 4-6 shows, overall, the median percent composition of small reference streams was 100 percent salmonids, whereas for the 3rd and 4th order reference streams, 75 percent had less than 100 percent salmonids. Thus, stream size could be used as stratifier between trout streams and trout-sculpin streams.

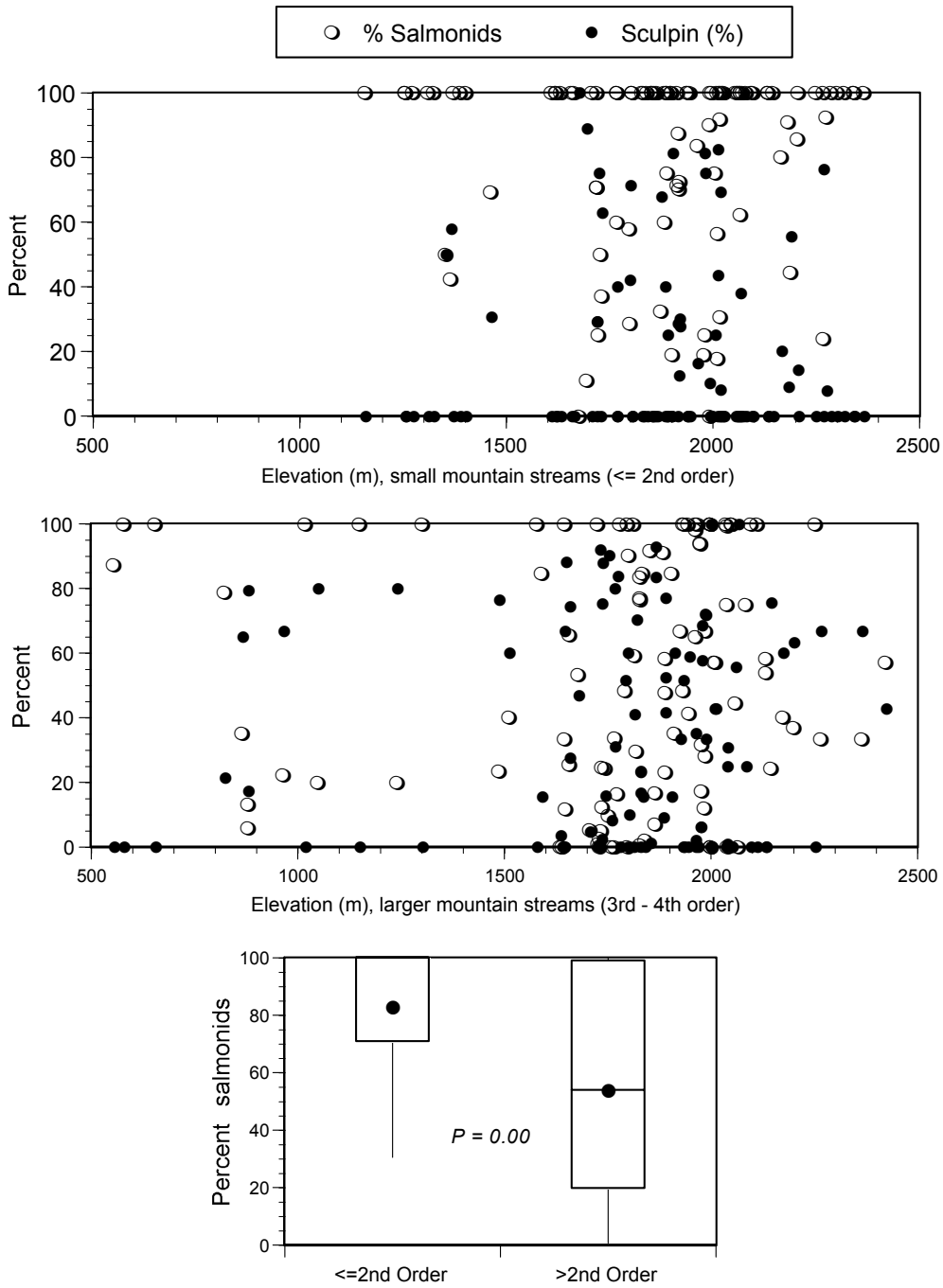


Figure 4-6. Relative abundance of salmonids and sculpin in mountain reference streams. Streams with salmonids comprising the entire fish assemblage are common, particularly in the small mountain streams.

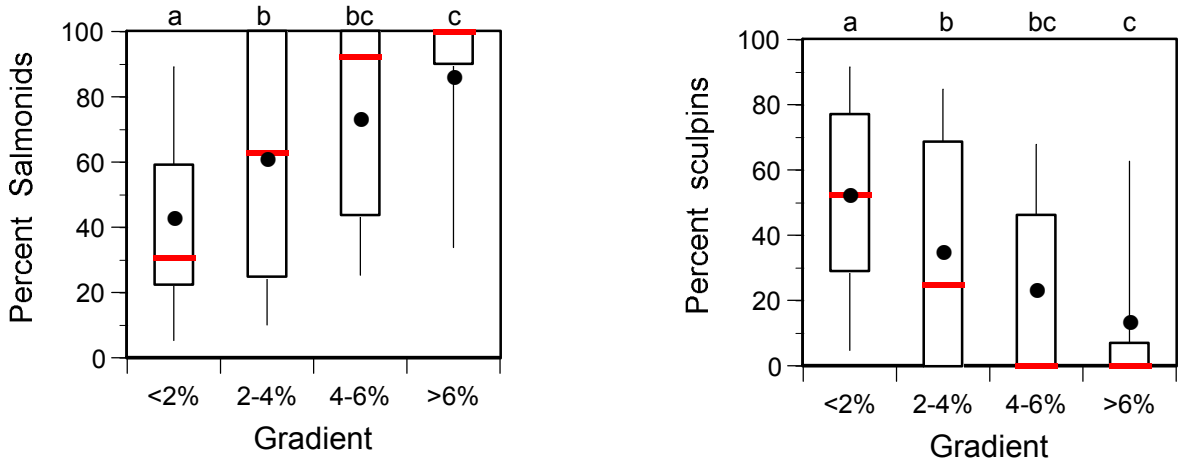
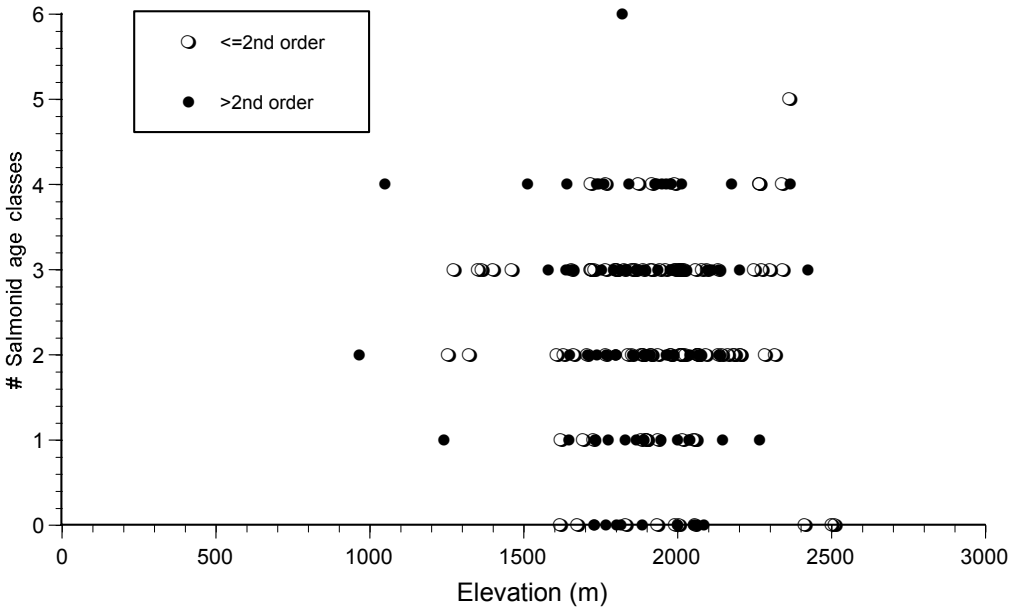


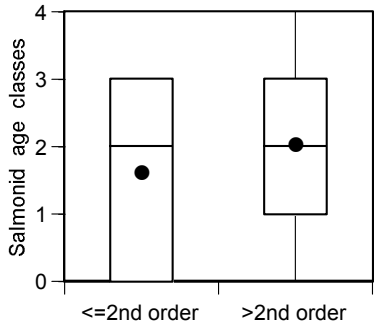
Figure 4-7. Salmonid - sculpin composition with gradient in forest reference streams. The means of groups marked with the same letter are not significantly different at P<0.05.

The relative composition of salmonids and sculpins in forest streams showed a clear graded change with stream gradient (Figure 4-7). At low gradient sites (less than 2 percent), sculpins were usually the most abundant fish captured, averaging over 50 percent of the assemblage. As stream gradient steepened, the proportions of salmonids increased and the proportions of sculpins decreased. At stream gradients greater than 4 percent , the median proportion of salmonids captured was greater than 90 percent, and the median proportion of sculpins was 0 percent .

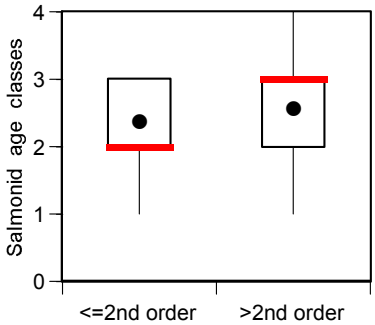
Gradient, stream size, and elevation are inter-related variables. Streams at high elevations are usually low stream order, small, and steeply cascading. Gradient appears to best explain natural distribution patterns among the salmonids and sculpins. Since the salmonids and sculpins together make up the vast majority of fishes in these mountain-forest stream types (Table 4-4, Figure 4-7), stream gradient needs to be factored into the stream classification in order to interpret biosurveys of these stream types.



Number of salmonid age classes captured at small and larger mountain reference streams (small stream ≤ 2nd order > larger stream) by elevation.



Salmonid age classes by reference stream sizes



Salmonid age classes, excluding fishless streams

Figure 4-8. Relationships between stream size and salmonid age classes encountered. In the box plots, age classes are shown for all mountain reference streams, including those with no fish, and limited to those reference streams with fish. Where medians overlap with other quartiles, medians are the thicker lines.

Salmonid age class presence – Whether age classes were more limited at upstream sites was tested. Summertime age classes of salmonids were segregated by stream size, and tested whether older and larger fishes occupying higher order, lower elevation streams, and juvenile fish in the headwater streams. The data did not give clear support to this idea (Figure 4-8). Except at the highest elevations sampled, where no fish occurred, no relationship between elevation and salmonid age class expression was apparent. Fish were rarely found above 2400m. There was an apparent relationship between stream size and salmonid age class strength (Figure 4-8, box plots). However, when excluding reference streams with no fish (presumably fishless because of flows, barriers, gradient or other non-anthropogenic effects), the median number of salmonid age classes captured at larger stream sites was higher than at small stream sites (3 vs. 2).

Abundance of cold water fishes – The relative abundance of cold water-adapted fishes was similarly compared by elevation and stream size (Figure 4-9). Relative abundance of cold water fish was measured through the number of cold water individuals captured per minute of electrofishing (catch-per-unit-effort, CPUE). At moderate elevations, between 1600m and 2200m in central Idaho, no relationship between elevation and cold water fish abundance was apparent. Statistical differences were tested for after grouping streams fish by size ($\leq 2^{nd}$ order and $\geq 3^{rd}$ order) and then into groups by 250m elevations (<1750m, 1751-2000m, etc. CPUE was not statistically significantly different within these elevations.

When limiting the evaluations of abundance versus stream size to only those streams with fish, the box plots suggest a slight pattern of higher abundances occurring in the larger streams. The differences were not statistically significant (P=0.3, Mann-Whitney).

Since some data sets did not list their electrofishing effort, but areal density was reported or could be calculated, I looked at the relationship between the two measures (Figure 4-12). The two measures were related well enough that either could be used in an index, or one roughly estimated from the other. The purpose of including abundance in an index of biological integrity is to draw an inference about the relative water and habitat quality, rather than make absolute population estimates for fisheries management purposes. Regression errors from predicting one value from the other were largest at the highest values; metric scores based upon mid-range values could use areal density to estimate CPUE as follows:

$$\text{CPUE} \approx 18^* \text{ (number cold water fish captured/square meter)} \qquad r^2 = 0.48$$

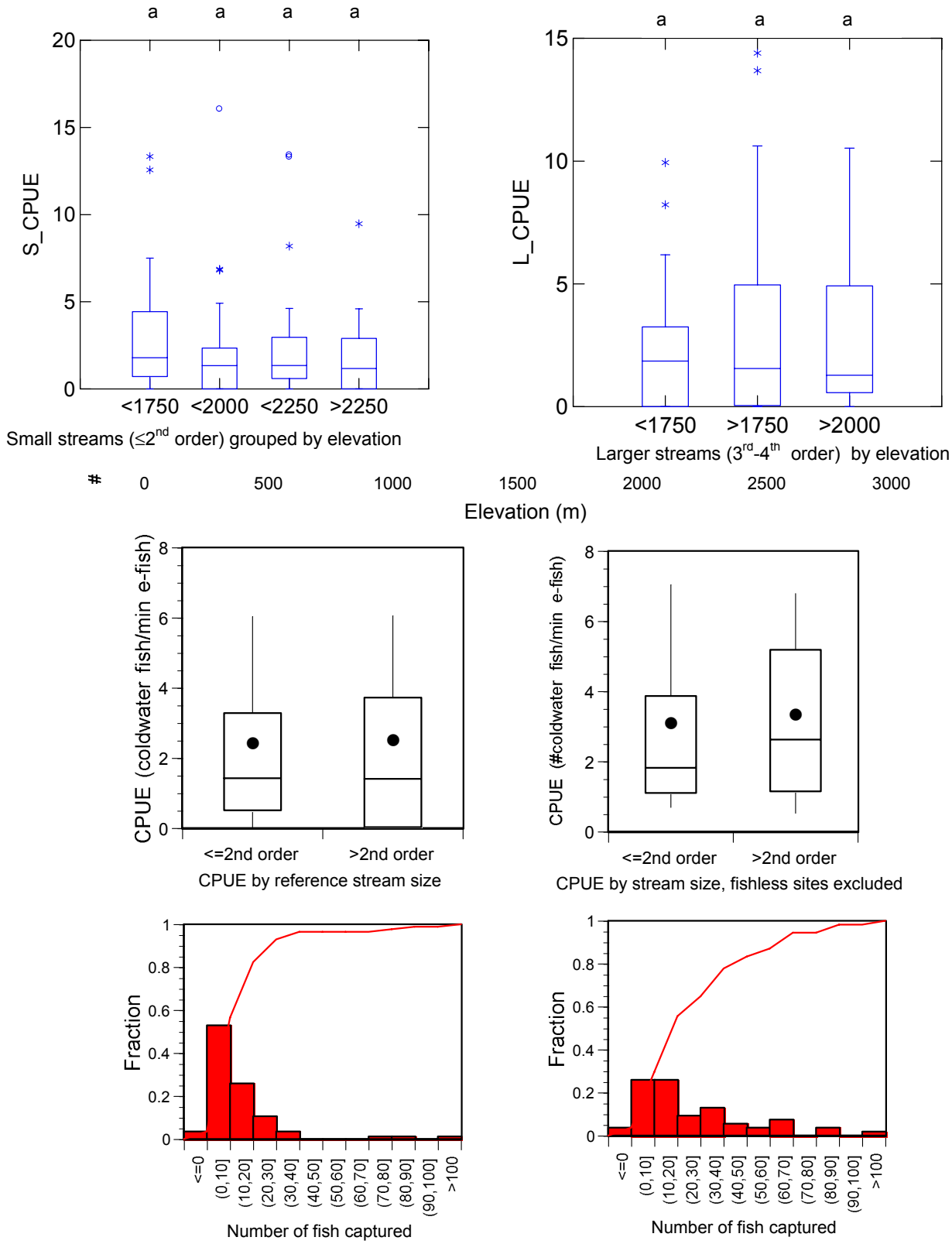


Figure 4-9. Elevation, stream size, and catch per unit effort (CPUE as # cold water fishes/minute electrofishing). In the upper box plot, groups marked with the same letter were significantly different (P<0.05). In the center box plots, CPUE is shown for all mountain reference streams, including those with no fish (left), and limited to those reference streams with fish (right).

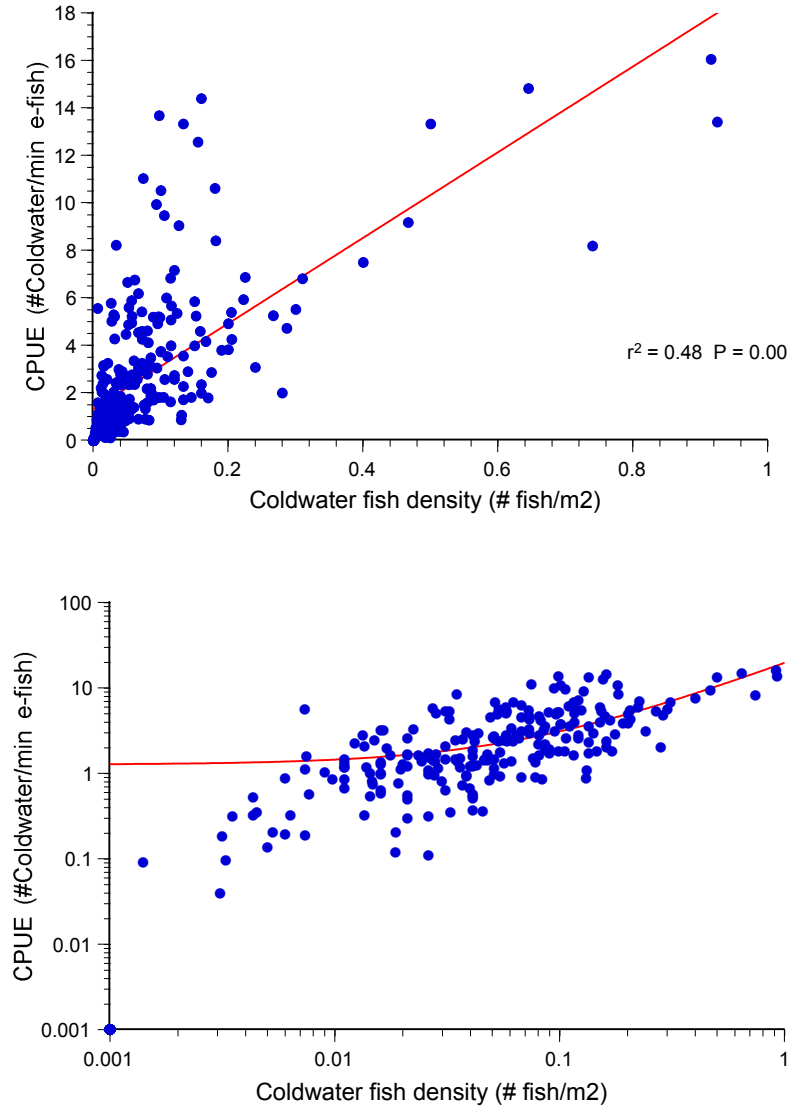


Figure 4-10. Relative densities of cold water fish were strongly correlated with catch per unit effort (CPUE), expressed as the number of cold water fish captured/minute of electrofishing. The plots are identical except that the lower plot uses a log-linear scale to spread out the data for better visibility. Comparisons limited to 1st pass of the reach, to keep data comparable between sites.

Metric evaluation and scoring for forest streams

After examining the influence of natural factors (elevation, stream size, gradient) on some potential metrics, metric values were compared at reference and test (potentially disturbed) streams (Figures 4-11 and 4-12). Six metrics that responded as predicted (i.e. higher values at reference sites) were included in the forest stream fish index (SFI):

1) # of cold water native species,

2) % cold water individuals,

3) % sensitive native individuals,

4) # of sculpin age classes,

5) # of selected salmonid age classes, and

6) relative abundance (number of cold water individuals/minute of electrofishing)

Metrics that appeared to have different ranges of values for small or medium sized streams were scored separately (Figure 4-15). Rationale for their inclusion and scoring scoring considerations follow.

Number of cold water native species – In the forest (mountain) streams, species richnesses were very low, usually only one or two species in reference headwaters streams, and one to three in intermediate-sized reference streams (Figures 4-11 and 4-12). Despite these limited ranges of values, there were clear distinctions between reference and test streams, and the absence of *any* native cold water species should be biologically meaningful. In small forest streams, presence of at least one cold water native species is scored as 1.0, since it was common for small reference streams to only have one cold water native species present (Figure 4-13). In larger forest streams, two cold water native species were expected and were scored as 1.0.

Percent cold water individuals – Reference streams in the forest ecoregion groups were usually occupied by nearly all cold water individuals with a median of 100 percent cold water adapted individuals and a mean of greater than 90 percent (Figures 4-11 and 4-12). Cold water salmon, trout and sculpins may directly compete for food or space with cyprinids such as redside shiner and speckled dace. These competitions are temperature mediated, with the cold water fishes dominating the cool water cyprinids at low temperatures (≈ 12 - 15°C) or sculpin have a competitive advantage over cool water cyprinids (Baltz et al. 1982; Reeves et al 1985, Hillman 1991, Taniguchi et al 1998). The metric was scored as a curve with greater than 90 percent cold water individuals receiving the highest scores (1.0).

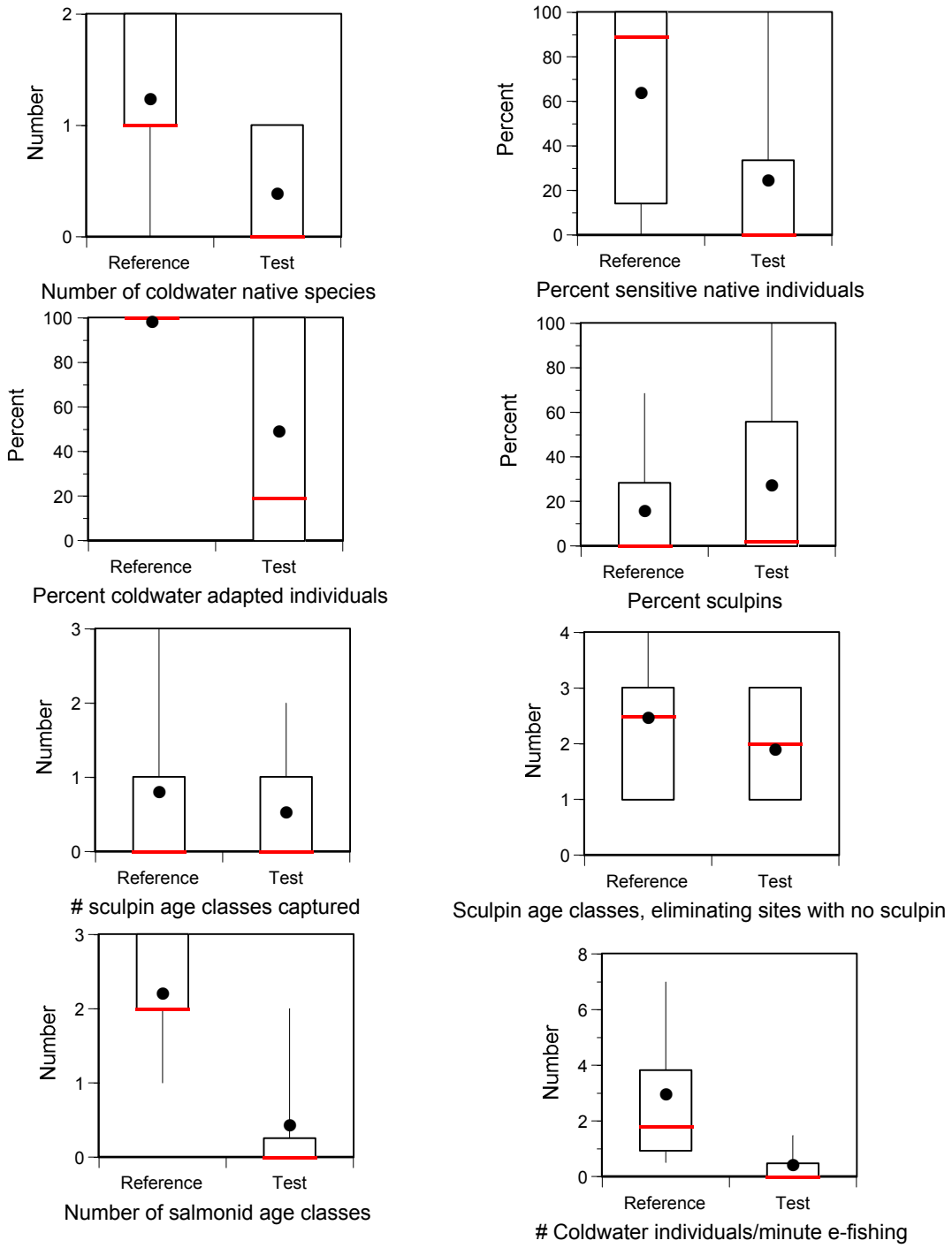


Figure 4-11. Small mountain streams: metric values for apparently least-impacted reference streams and apparently impacted test streams (Small streams = ≤2nd order).

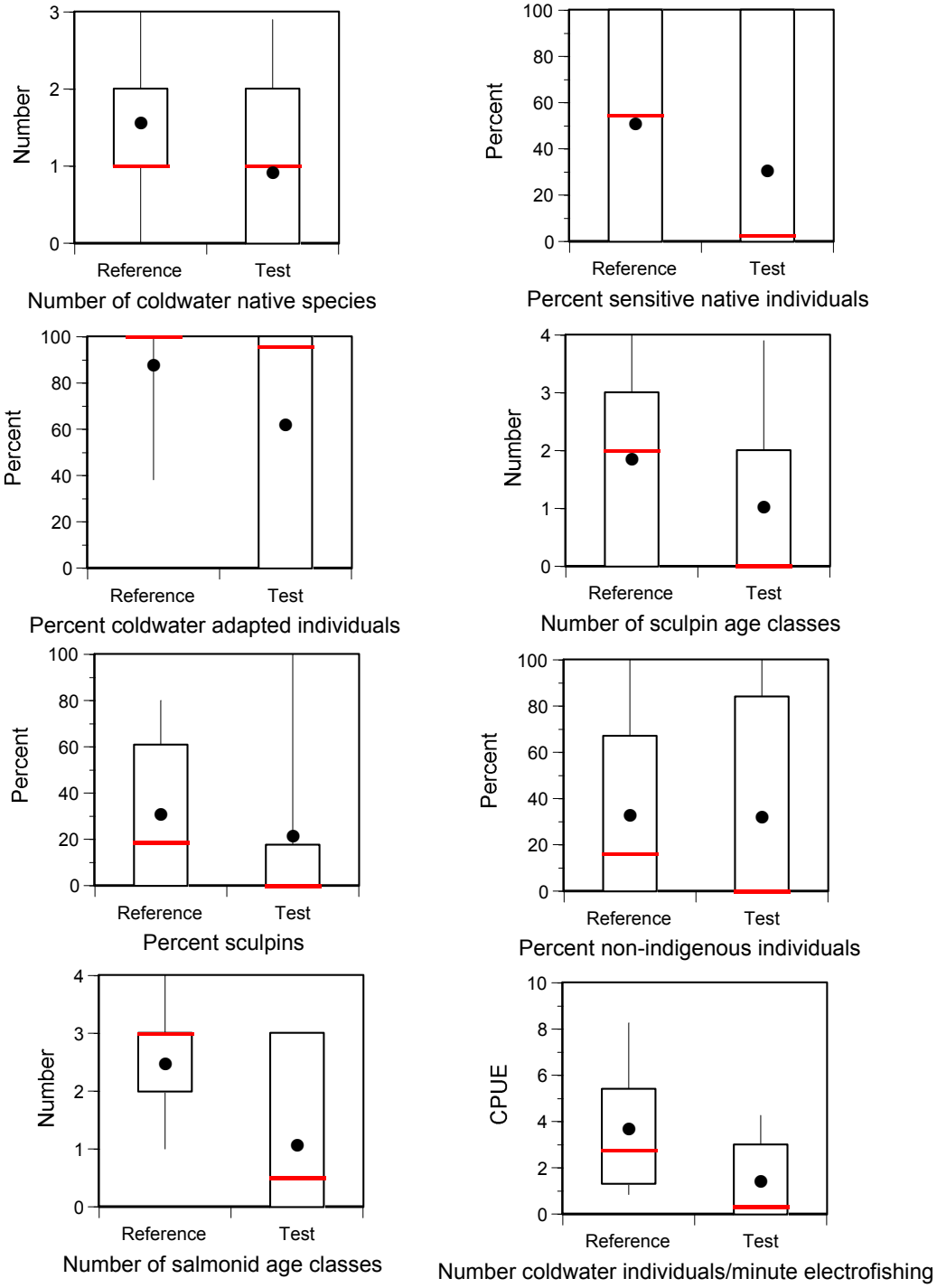


Figure 4-12. Intermediate sized mountain streams: metric values for apparently least-impacted reference streams and apparently impacted test streams (Intermediate size streams = >2nd order).

Percent sensitive native species – The representation of sensitive native species (e.g. native trout, salmon and char, shorthead sculpin) was variable, although sensitive natives were common in reference sites, and much less common in apparently impacted test sites (median percentages were 50 and 80 percent at small and large reference sites, versus 0 to 5 percent at small and large test sites respectively (Figures 4-11 and 4-12). Since they are considered sensitive to overall pollution, presence of even a small proportion of sensitive natives should indicate high quality water. Thus, the metric is scaled to increase steeply, and tapers off to 1.0 at high percentages (Figure 4-15). In other words, an assemblage made up of 40 percent sensitive natives is not assumed to reflect significantly lower water quality than an assemblage composed of 100 percent sensitive natives.

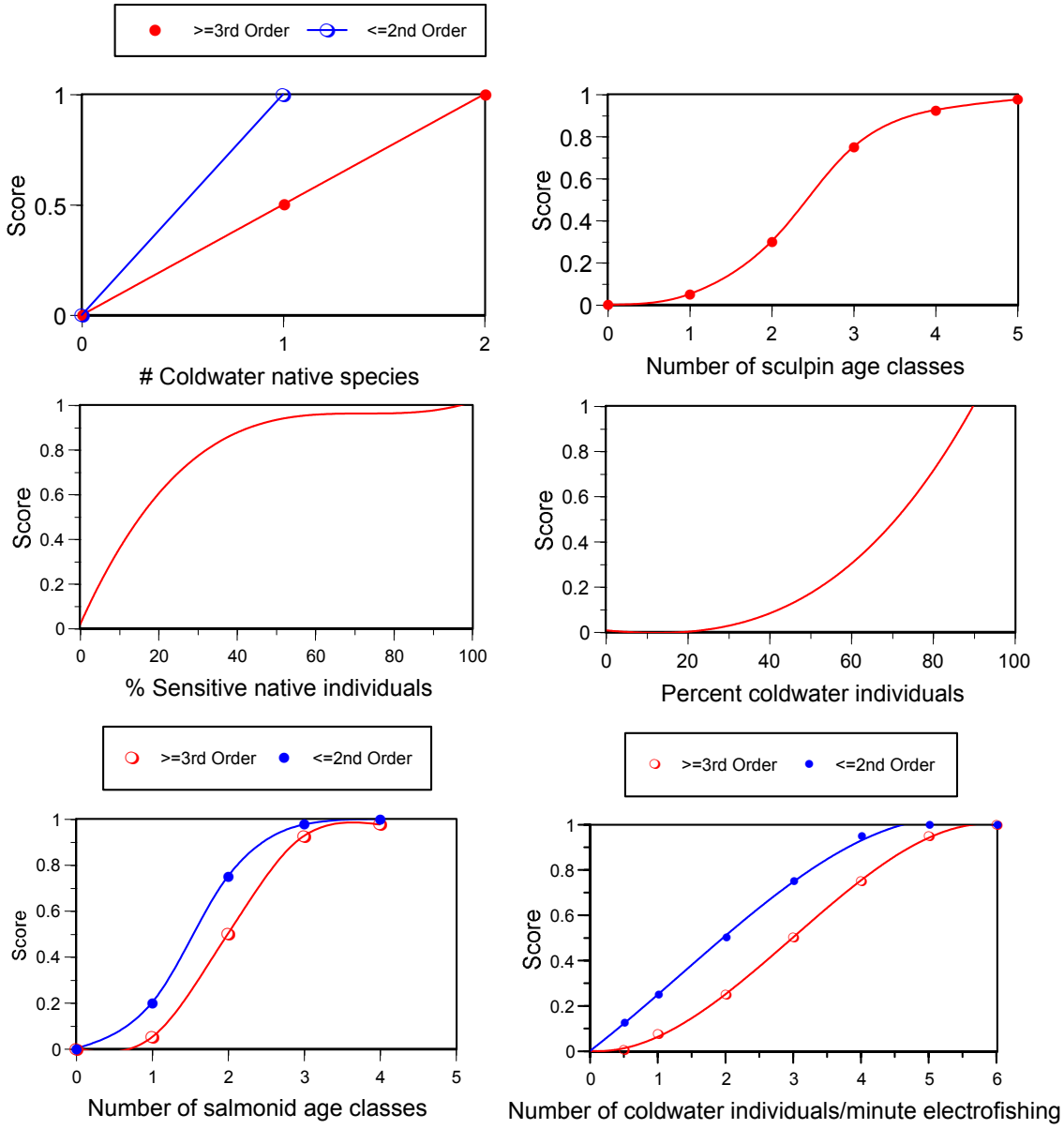


Figure 4-13. Scoring curves for metrics used in the mountain streams IBI.

Number of sculpin age classes – Multiple age classes of sculpin were encountered somewhat more often at reference, than test sites, particularly in the larger streams (Figures 4-11 and 4-12). The metric is scored on a "S" curve. It assumes that several age classes of sculpin would be present at reference sites, and if only one or two age classes are captured, that suggests that the missing age classes were not captured because they are rare or are missing. Shifts in age distribution are a common response to environmental stress on fish populations (Munnkittrick and Dixon 1989). Here, number of age classes captured is assumed to be a rough approximation of age distribution shifts. If environmental conditions reduce year-year survival and cause a shift to younger ages, or recruitment failures results in a shift to older ages, the old or young age classes will become more rare, and less likely to be captured. The metric therefore also assumes limited electrofishing efficiency, particularly in a single or 1st electrofishing pass. If one could enumerate every fish in a stream, if a species is present, more than a single age class will usually be present. The age class metric provides a rough indication of the relative abundance of different age classes. Since sculpin are sedentary benthic species that require cavities to nest in which are not highly embedded with fine sediment (Table 4-2), presence of multiple age classes is considered an indication of reasonably stable substrate without excessive sedimentation.

Interpretation of the usually ubiquitous sculpins in mountain streams is complicated since their absence could reflect *either* natural conditions or impairment. In high gradient streams (≥4%), salmonids may naturally be the only family of fish present (Figure 4-7). Therefore, in those streams, the absence of sculpin does not suggest anthoropogenic impairment; their absence is simply part of the natural variation. However, sculpin may be scarce or extirpated from disturbed streams, even though "sensitive" salmonids may still be present and even reasonably abundant. This pattern has been reported for metals (Carline et al. 1994, McCormick et al. 1994) and fine sediments (Mebane 2001). Since sculpin are commonly naturally absent from high gradient streams but usually abundant from forest streams with more moderate gradients, if for the higher gradient streams sculpin are not found, this is presumed to be natural and the sculpin age class metric is not included.

Number of selected salmonid age classes (trout, char, and salmon) – Multiple age classes of salmonids were encountered much more frequently at reference sties than test sites. Multiple (>2) age classes were encountered in the larger reference streams more often than the smaller streams (Figures 4-18, 11, 12). This pattern is presumably because of the greater space availability and space requirements for larger fish in the larger streams (Chapman 1966). Bjornn and Reiser (1991) report size segregation by salmonids in streams, with the older fish occupying deeper pools, forcing the smaller fish forced to shallow areas. Thus, the metric is scored so that the presence of 2+ age classes in small forest streams results in a high score, and 3+ ages in larger streams results in a high score (Figure 4-15). Mountain whitefish, which are excluded from this metric, were seldom encountered in the stream samples. As with sculpin, this metric could be considered a rough indication of an age distribution shift.

Relative abundance – The larger (3rd and 4th order) reference streams often had greater abundance of cold water individual fishes, than did the smaller streams (Figures 4-9, 11-12). The metric scoring is scaled accordingly, e.g. capturing three cold water fish/minute of fishing in a small stream would be scored as 0.7 points, and 0.5 on a larger stream (Figure 4-15).

Density or biomass, interpreted alone, can be a misleading indicator of habitat quality (van Horne 1983). However, in this case, relative abundance is used as one indicator of habitat or water quality, among other metrics. In addition, this measure relative abundance of cold water fishes usually discriminated well between reference sites and test sites (Figures 4-11 and 4-12).

The multimetric index for forest streams

The metrics were combined into a multimetric index on a scale from 0 to 100. The index appears to perform adequately, with most reference sites scoring higher than most test sites, with less than 25 percent of each group's scores overlapping (Figure 4-16).

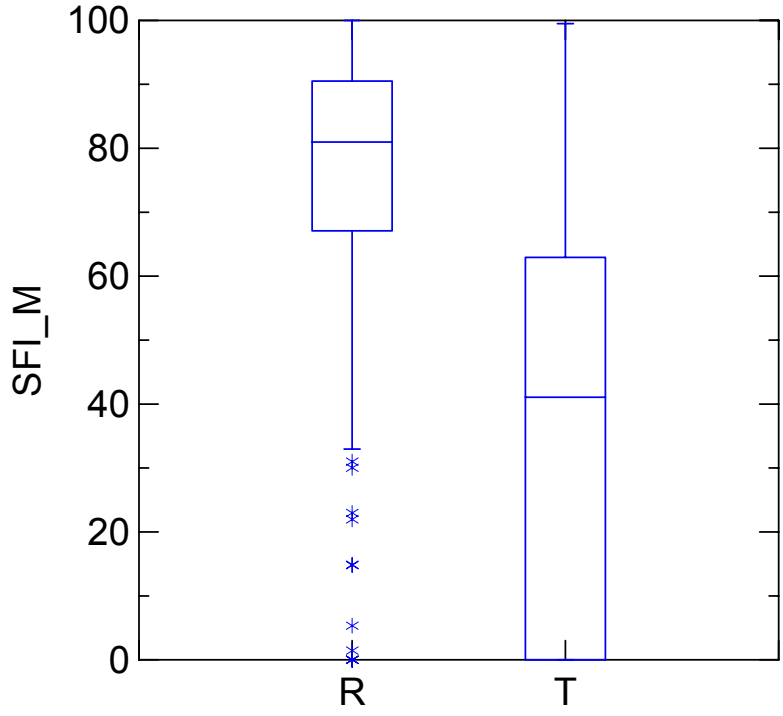


Figure 4-14. Ranges of forest SFI scores for reference (R) and test (T) sites.

Rangeland Streams

Few of the rangeland streams could be considered completely undisturbed by grazing or farming. Some of those with minimal human use were springs or were located in deep canyons and were probably not representative of non-canyon streams. Samples from springs were excluded from the index development. Maret (1997) showed that rangeland springs have a very different fauna from streams without discrete springs as their major source. Spring samples were identified by either being from known spring creeks, and from streams that (1) were named "Spring" and (2) examination of a topo map showed the sample was collected near the mapped spring source.

Rangeland streams were typically occupied by a mixed assemblage of cold water and cool water species (Table 4-4). Cyprinids were usually numerically dominant as number of individuals; as presence of species, there was often about an even mix of cold water and cool water species present. The metrics tested (and subsequent index) for these streams were similar to the original IBI concept and ecological structure, based on taxonomic richness, habitat, and trophic guild composition (Figure 4-15, Table 4-1). The median or mean values of several metrics responded as expected for reference or disturbed streams. However, most candidate metrics had considerable overlap between values for reference and apparently impaired test sites.

Few reference rangeland streams were believed to be undisturbed according to Table 4-3 criteria. Although many streams still have natural features, a century of grazing and water development may have fundamentally altered fluvial or potential vegetation features from their historical reference condition, resulting in low ecological integrity (Quigley et al. 1996). Thus, the possible loss of the historic reference condition may lessen the distinction between "reference" sites (i.e. best of what's left) and "test" sites may lead to metric responses being dampened. Because of this potential, candidate metrics were included in the index development, based upon IBI concepts, even though two (number of native species and percent non-indigenous individuals) were not fully empirically distinguished. Curiously, in earlier preliminary analysis, reference sites tended to have higher native species counts than apparently impaired sites. However, after adding a large number of sites from IDFG surveys of the Owhyee Highlands streams, these differences vanished. Even though these results are ambiguous, the desirability of conserving native species suggests that measuring native species could be useful, and the metric is currently included in the multimetric index.

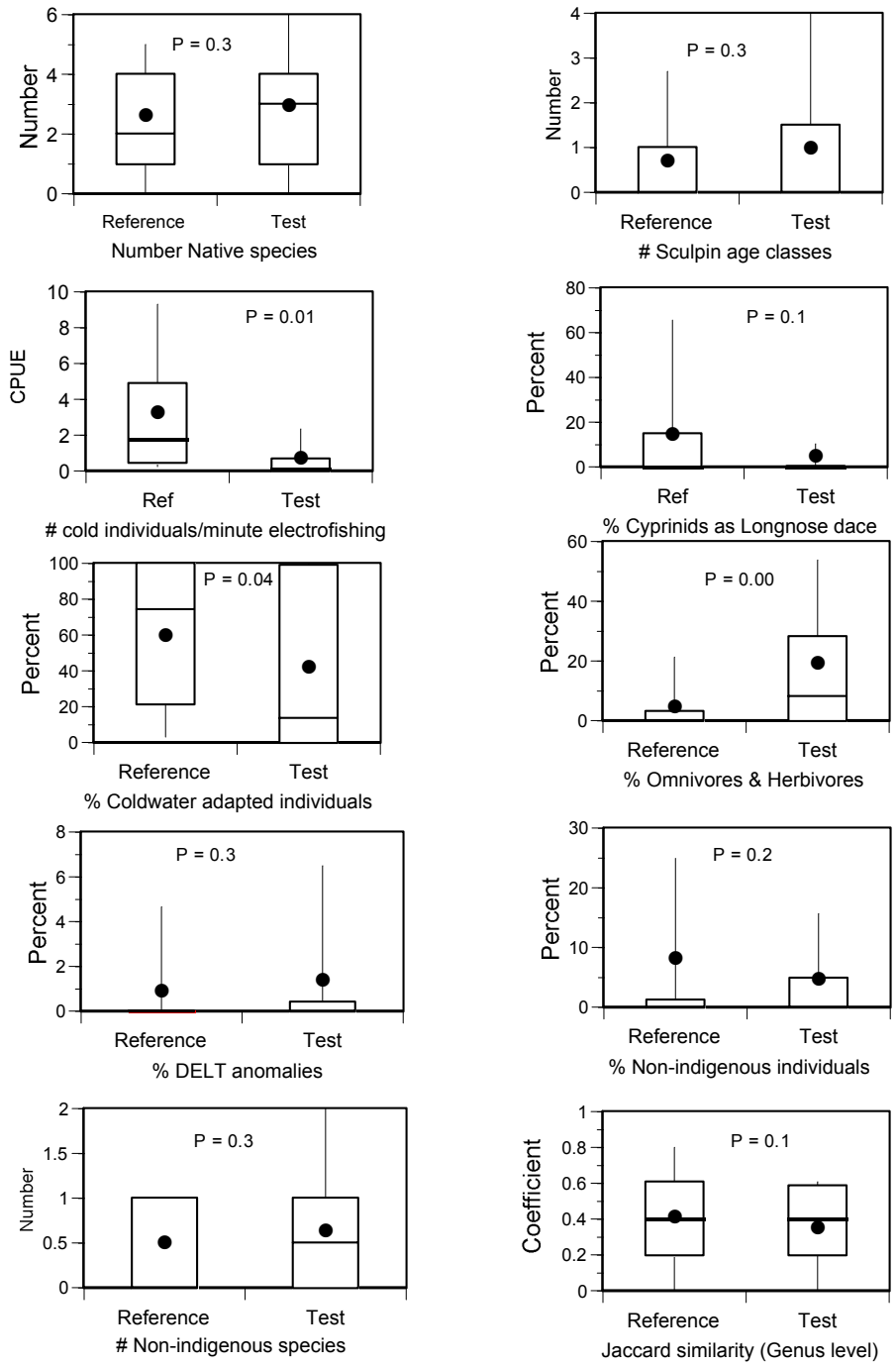


Figure 4-15. Candidate metrics ranges, for minimally and apparently impacted sites rangeland (basin) sites (n=51 and 32 for reference and test sites respectively).

Metric evaluation and scoring for rangeland streams

Six metrics were included in the rangeland stream fish index ("SFI-Range"):

1) Percent cold water individuals,

2) Of the cyprinids, percent that were longnose dace,

3) Percent omnivores and herbivores

4) Percent DELT anomalies

5) Jaccard community similarity coefficient, and

6) Number of cold water individuals captured per minute of electrofishing.

Rationale for the metrics selection and scoring follow.

Percent cold water individuals – This metric showed strong differences between reference sites, with a median of 70 percent cold water individuals; and test sites, with a median of 10 percent cold water individuals (Figure 4-15). The metric is scored linearly between 0 to 30 percent cold water individuals, reflecting the concept that rangeland streams are expected to naturally have a mix of cold water and cool water adapted species (Figure 4-6). Thus, a stream with 100 percent cold water species would not necessarily have higher biological integrity. Instead, it probably would have been misclassified.

Of the cyprinids, percent that are longnose dace – Native cyprinids (dace, shiners, chub, pikeminnows) were ubiquitous in rangeland streams, and were nearly always collected in perennial rangeland streams, both from disturbed and reference streams. Cyprinids occurred in about 90 percent of reference rangeland streams (Table 4-4). Among the native cyprinids, on the average longnose dace were found in higher percentages in reference streams than in disturbed streams. Longnose dace were seldom the dominant cyprinid (Figure 4-15). Longnose dace distribution may be limited by excessive sedimentation or flow reductions (Propst 1982). This metric is scored linearly over the range of expected percentage of occurrence in reference streams (0 to 15 percent of the cyprinids). If cyprinids are present, and no longnose dace occur, a score of zero results; if longnose dace make up 15 percent or greater of the cyprinids, a maximum score is assigned (Figure 4-16).

Percent Omnivores and Herbivores – Omnivores and herbivores comprised less than 10 percent of the sample in most rangeland streams, and they were more abundant in apparently impacted test streams than reference streams (Figure D-5, Appendix D). The metric is scored with a "ski jump" shaped curve which is flat on the top, steepens, and then is flat at the bottom to follow the expected patterns in rangeland streams (Figure 4-15). Omnivores and herbivores are expected to be present in rangeland streams but at low percentages; thus the flat top of the curve gives a maximum score up unto a threshold of 10 percent. From 10 to 40 percent, the scoring curve steeply drops, then flattens out to reflect that streams with greater than 40 percent omnivores and herbivores are very different from reference and get a

low score. Conceptually, this "ski jump" curve is similar to having a straight line dropping from 10 to 40 percent, or using the "5,3,1" scoring bin approach, where the reference condition (less than 10 percent) is given a score of 5, the departure from reference zone (10 to 40 percent) is given a score of 3, and the significant departure from the reference condition (greater than 40 percent) is given a score of 1. The "ski jump" curve has the advantage of providing continuous scores rather than having a large, and probably not biologically meaningful, score jump between 5 and 3 for values of 9.5 percent and 10 percent.

Percent Deformities, Eroded Fins, Lesions, and Tumors (DELT anomalies) – DELT anomalies were rare in all sites, but were a little less rare in test rather than impacted sites (Figure 4-15). The metric is scored as a steeply declining exponential curve, to reflect the expectation that in reference sites, less than 1 percent of the fish samples are expected to show anomalies (Figure 4-5). The inclusion of the DELT anomaly metric is also supported by other studies from similar ecoregions. Munn and Gruber (1997), working in the Columbia Basin ecoregion of Washington and Idaho, found increased detections of organochlorine pesticide residues in fish in watersheds with high percentages of agriculture. Examination of their raw fish assemblage data[10] also showed higher prevalences of DELT anomalies than in non-agricultural watersheds. However, no quantitative dose-response relationship between the residue concentrations or frequency of detection was apparent. Fish samples from rivers in Idaho with high percentages of agriculture upstream of the sample location also had higher occurrences of DELT anomalies (Mebane 2000).

Jaccard community similarity coefficient (JC) – This metric is commonly used in ecological studies to measure the degree of similarity in taxanomic composition between two stations. In this case, we are interested in the comparison to the average taxa composition for rangeland reference streams, not individual stations. Chandler et al. (1993) and Stevenson and Bahls (1999) recommend using average community composition of a group of reference stations to calculated compositional similarity indices.

To calculate the coefficient, all taxa counts were transformed to binary taxa presence or absence data . The five most frequently occurring genera (Table 4-4) at all the reference sites for the rangeland ecoregions were considered the taxa likely to be present at streams with species composition similar to that of reference streams. In the Jaccard coefficient (Table 4-2), these five most commonly occurring genera were treated as the taxa present at the reference "station," and then using, the taxa composition of each comparison site (those sites described as "test" or "other") Jaccard coefficients were calculated. Similarity coefficients ranged from 0.0 to 0.7, with most values ranging between 0.1 and 0.5 (Figure 4-5). The metric was scored linearly with JC of 0 to 0.6 equating to a score of 0 to 1. The value of 0.6 was selected as the maximum score based upon the following factors:

- The range of the data
- Community samples may be noisy
- Replicate fish assemblage samples typically have a similarity range between 0.6 and 1.0 (Maret 1997, Gauch 1982)

[10] Provided by M. Munn, U.S. Geological Survey, Tacoma, WA

Since the comparison value is from a group of reference stations rather than a single reference station, the likelihood of a single comparison station having all the reference species present is low, so the lower bound of the range of reported replicate similarities would more likely actually occur.

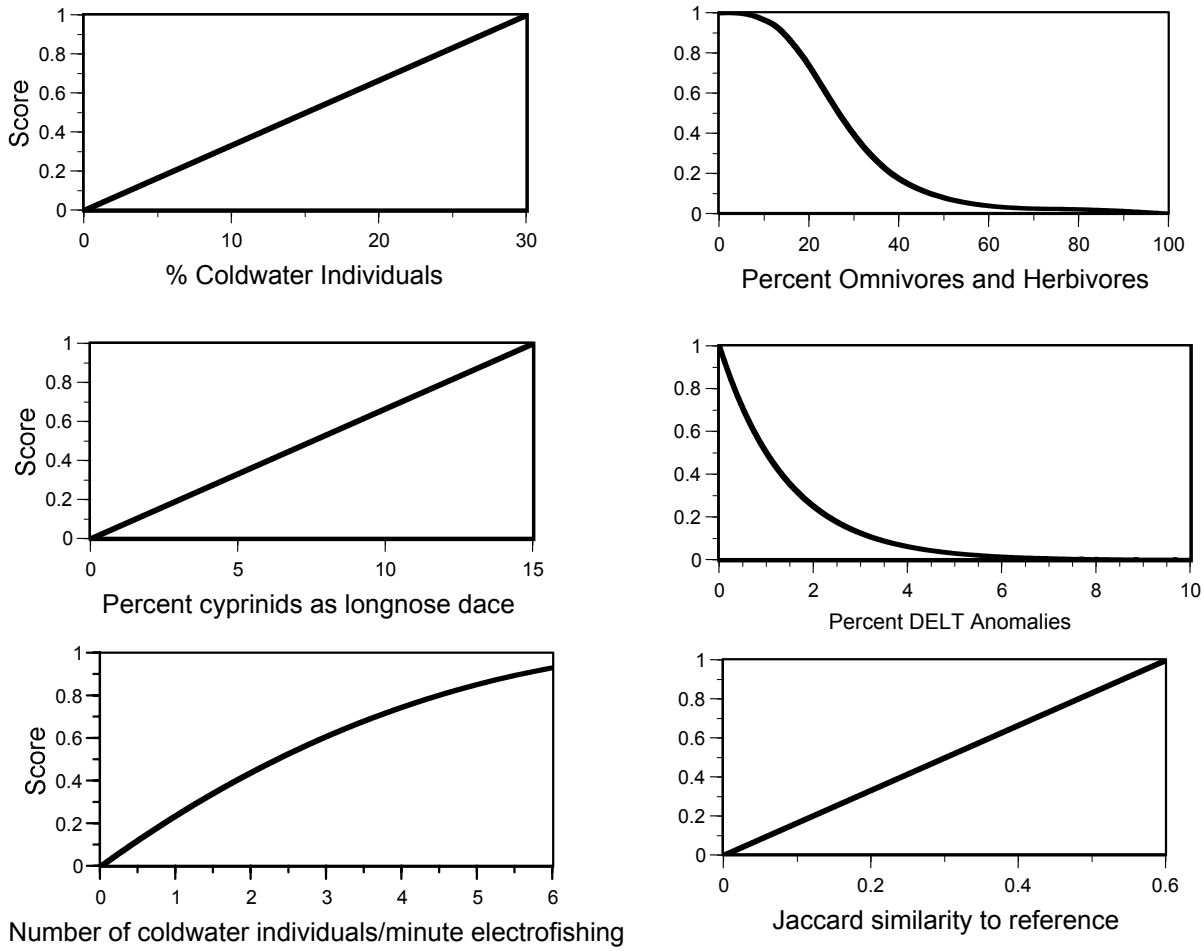


Figure 4-16. Scoring curves used in the rangeland stream fish index.

The multimetric index for rangeland streams

As with the forest streams, to combine the individual metrics into a multimetric index, the unitless metric scores were added together and adjusted to have a maximum possible score of 100. Metric scores were weighted in the index according to how well they discriminated between reference and impaired sites. Metrics that discriminated relatively weakly ($P < 0.1$) were multiplied by 0.5 before being added together into the index. This was done to reduce the influence of these metrics on the overall score, compared to the more strongly discriminating metrics[11].

[11] No weighting was necessary in the forest index because all selected metrics discriminated between reference and test sites at $P < 0.05$.

When combined in this manner, and summarized with box plots, the index performed reasonably well (Figure 4-17). Scores for reference sites ranged from 50 to 100, with a median score of about 82. Scores for test sites ranged from 0 to 90 with a median score of about 55. If we consider the body of the data to be the inside of the box plot boxes (i.e. the interquartile range from the 25th to 75th percentile of scores), then we note that there is some overlap of the boxes, indicating that the index's efficiency to distinguish apparently impaired and reference sites is somewhat limited.

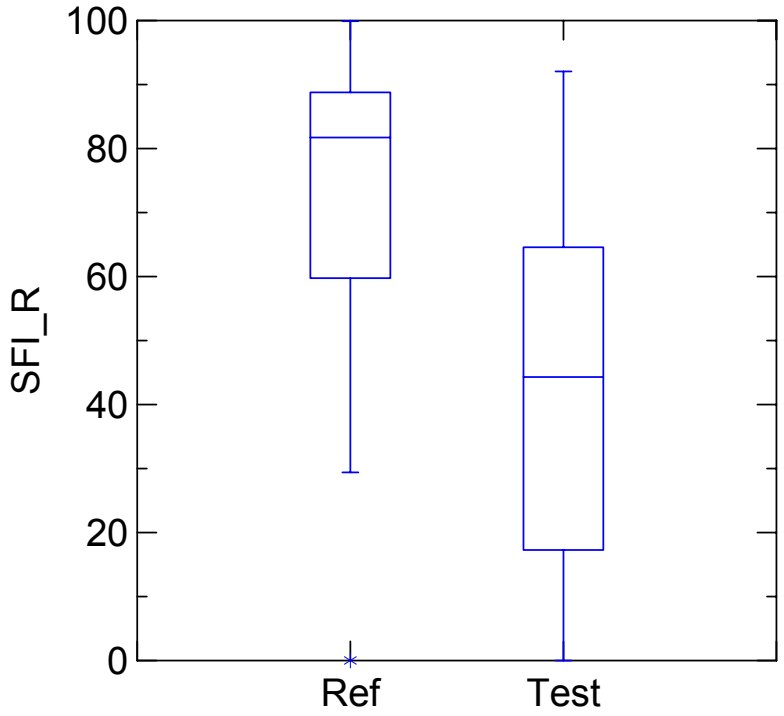


Figure 4-17. Ranges of rangeland fish IBI scores for reference (R) and test (T) sites.

Classification of Stream Types – Revisited

Discriminant analysis of stream classes using index metrics

The previous results (Figures 4-5 to 4-16) used simple scatter and box plots to examine the data and evaluate fish assemblage variables to see if they would serve as meaningful metrics, i.e. variables that responded to environmental degradation. Whereas initially, the stream classifications were evaluated with discriminant analysis to see if reference sites differed in terms of fish species composition (Figure 4-4), now we are considering whether using the values of 11 metrics from both indexes, the streams separate into the four pre-defined groups: forest streams (reference and test), and rangeland streams (reference and test). As with the groupings by species composition in Figure 4-4, the stream class groupings by using metrics have both shared and distinct characteristics (Figure 4-17). Forest reference streams are tightly clustered in the center of the plot, but overlapping clusters show that some forest test streams and some rangeland reference streams share characteristics of the forest reference streams, and with each other. Both the rangeland reference streams and the forest test streams are more variable than the forest reference streams. The rangeland test streams are most variable of all, but also most distinct from the other groups.

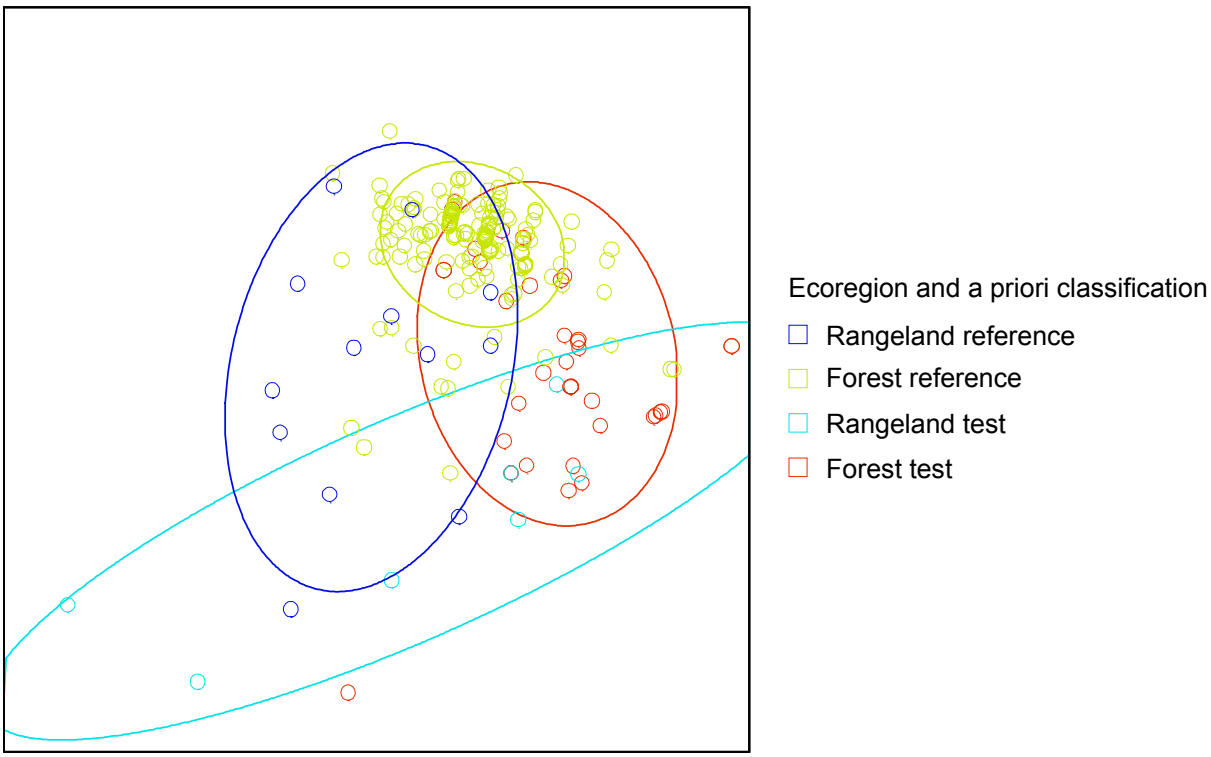


Figure 4-18. Canonical correlations of all fish metrics from both indexes grouped by reference and test classifications and by forest and rangeland ecoregion groups.

Correlations between watershed disturbance, habitat, and fish metrics: methods

A companion project to this one is to evaluate stream habitat measures and to revise a stream habitat index provides information relevant to the stream fish indexes (Fore and Bollman 2000). Idaho currently has a habitat index for streams consisting of 11 quantitative and qualitative channel morphology, riparian, and substrate features (DEQ 1996; described in Mebane 2001). Fore and Bollman (2000) tested this index, and about 36 individual stream habitat measures with measures of disturbance at the site and watershed scale, and with biological conditions at the sites. They then developed a new habitat index using the best component metrics. The habitat measures were largely evaluated by testing for significant correlations between land cover and land use measures, and macroinvertebrate or fish metrics. The fish metrics they used were based on an early version of this report, and so are similar to those used here in the forest/montane SFI. The rangeland SFI could not be compared to Fore's and Bollman's results, although some of the metrics could be compared.

Both Fore and Bollman's work and this effort included evaluations of the responses of fish metrics to human disturbances, but with different approaches and using data from different sites. In this report, a qualitative checklist of disturbance factors was used with interviews with local biologists to identify apparently reference or impacted streams (Table 4-3). In contrast, Fore and Bollman supposed nothing *a priori,* and based their evaluation primarily on correlations between quantitative stream and watershed measures. They were provided matched habitat and fish data from DEQ surveys for 140 sites based on 2 factors:

1. Sites were targeted from the typic parts of their ecoregions as mapped by Omernik and Gallant (1986), in order to exclude transitional sites near borders of ecoregions.

2. Sites located near the most downstream point of the watershed, so that they could relate land cover data (which was calculated at the watershed level) to stream site condition data.

Further, the data Fore and Bollman used are from different sites than in this report, except for a few sites, which by chance overlapped.[12] Because of the different approaches, and different data used, the results can be compared without circularity. Also, using their data set and the forest/rangeland stream classification scheme, I tested the stream fish index metrics for correlations with their new stream habitat index, and with land use. Land use was evaluated as percentage of the watersheds in agricultural use (cultivated crops, not including open range grazing) because of previous regional research showing significant biological relationships to broadscale agricultural use but less so to other common land uses (e.g. rangeland, forestry, urbanization) (Maret 1997, Schomberg et al. 1998).

[12] As of the end of the 1999 field season, fish data from over 1000 stream sites had been collected as part of the DEQ BURP program. At the time this project started, the data were not readily available from the BURP relational database, and so raw data from over 400 of those sites were entered into a spreadsheet and metrics and index scores were calculated for them. Fore and Bollman's data including the fish metrics were provided from the BURP database. Twelve sites common to both projects were checked to see if the metric values matched. They did. The only exceptions were age classes which often differed by 1. This difference is attributed to the difference between database calculating the estimated age classes using size bins from Appendix 3, and here, where they were estimated by size bins and by judging clusters of sizes.

Correlations between watershed disturbance, habitat, and fish metrics: results

The percentages of the watersheds in agricultural use were significantly correlated with several fish metrics when all sites were pooled (Table 4-5). No correlations were significant when evaluated separately for the forest and rangeland sites, or when evaluated separately for only the Northern Basin and Range (NBR) ecoregion (which by chance is where most of the agricultural watersheds fell). However, the correlations for the rangeland or NBR sites were in the expected direction, and with sample sizes of only 16 and 12, the lack of significant correlations is not surprising. There is very little agricultural use in the forest/mountain streams' watersheds.

Correlations between fish metrics and habitat were often present. Generally, forest streams showed stronger correlations with the habitat index, than did the rangeland streams (Table 4-5). Component habitat measures tested against fish measures by Fore and Bollman (2000) varied greatly by ecoregion (Table 4-5, "Individual Habitat Measures" column). For example, the number of salmonid age classes was often significantly correlated with either the habitat index or component measures, but with only one individual measure in the sites from the Northern and Middle Rockies. This latter result was puzzling since salmonid age classes performed well here in forest streams (Figures 4-11 and 4-12). Using the same data set as Fore and Bollman, I tested correlations between several of the better performing habitat measures and salmonid age classes for forest streams. Rather than one, there were six significant ($p<0.05$) correlations with salmonid age classes: large woody debris, percent substrate less than 2mm, Wolman substrate size classes, channel shape, pool:riffle ratio, and percent canopy cover. Since these differences were even more unexpected, I re-ran the correlations using the same ecoregional stratifications as Fore and Bollman. The resulting Spearman coefficient values were identical to those reported by Fore and Bollman. The remaining difference between our tests is that they stratified streams using ecoregions, and I stratified streams using a combination of ecoregions and elevation. The differences remain puzzling but intriguing.

While statistical significance does not always indicate biological significance and the converse, the above patterns suggest some metrics are often significant in a variety of circumstances.

Table 4-5. Pearson correlations for fish metrics, watershed disturbance, and Habitat index ($p<0.1$ = +, $p<0.05$= ++); and numbers of significant associations between the metrics and with discrete habitat measures .

Metric	**Land Use**	**Habitat Index**		**# of Significant correlations with Individual Habitat Measures** (36 tested)		
Ecoregion (Sample size)	Pooled (84)	Forest (89)	Rangeland (45)	NR/MR (varies)	SRB (varies)	NBR (varies)
Native taxa richness		++		6	5	1
% Non-indigenous individuals				5	4	1
% Omnivores and Herbivores		+		1	1	1
# Cold Native species	++	++		3	10	1
# Sculpin age classes	+	++	++	4	6	1
% Sensitive native individuals	+			1	10	5
% Cold individuals	++	+		2	7	6
# Salmonid age classes	++	++	++	1	9	17
CPUE of cold water individuals		++		2	10	3

Table sources: Land use and Habitat Index calculated using same data set as Fore and Bollman (2000). Individual habitat measures were compiled from Fore and Bollman 2000, appendices 1-3.

Table notes: NBR- Northern Basin and Range; SRB-Snake River Basin; NR/MR – Northern and Middle Rockies; see figure 1 for locations.

Individual habitat measures- Fore and Bollman used Spearman rank order coefficients, with $p<0.05$ = significant associations. Since the Systat® statistics program used here did not support probability calculations for Spearman correlations, Pearson correlations were used. The r values between the Spearman and Pearson coefficients were very similar for all tests, suggesting the probabilities likely are similar too.

Comparison between multimetric fish and habitat indexes

Comparing the forest fish index, rather than individual metrics, to the habitat index, shows that sites with high habitat scores tended to be accompanied by fish index scores that were higher and less variable than sites with low habitat scores (Figure 4-18). Splitting the habitat scores at their medians, and plotting the above and below the median fish scores, shows an association between the habitat and fish indexes. Sites with high habitat index scores tended to be accompanied by fish index scores that were higher and less variable; fish index scores were more variable and somewhat lower at sites with low habitat index scores. Habitat scores were considered “high” or low if they were above the median value.

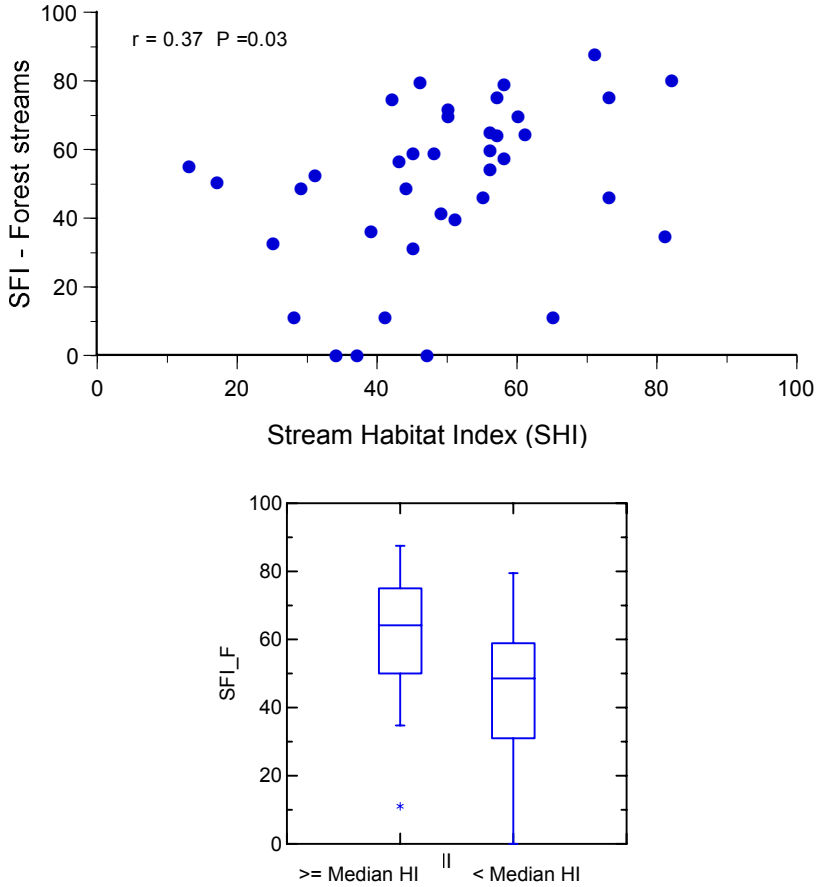


Figure 4-19. Habitat and fish index relationships for forest streams.

These results show that habitat and fish relationships are often apparent, but are inconsistent. Explanations for this are elusive – do the inconsistencies result our inability to define and measure the correct fish and habitat attributes? Are fish-habitat relationships highly variable? Is it measurement error, problems of scale, or more than one of the above? Assessment scale seems likely to have some bearing on the noise in the above relationships. Much of the above data is at a site scale (100m reach), and could be influenced by access to refugia or disturbance at a stream scale. As Dunham and Vinyard (1997) note "ignoring stream [scale] effects can lead to erroneous conclusions about site level habitat variables."

Stream fish indexes and sediment comparisons

Excessive sedimentation is a significant cause of water quality impairment in North America. In the United States, 34 percent and in Idaho, 93 percent of waters listed as impaired are attributed to excessive sedimentation (EPA 1994, 1995b). The particle size of deposited stream bed sediments affects the flow resistance in the channel, the stability of the bed, and the amount of available aquatic habitat types. These in turn have significant effects on macroinvertebrate and fish communities (Minshall 1984; Waters 1995).

Thus the substrate is a fundamental part of the stream environment, and siltation is a ubiquitous concern. However, there is no consensus method for characterizing sediment in streams for biological surveys. Over 10 methods for evaluating sediment in streams are in use in North America, ranging in complexity from visual estimates to liquid nitrogen freeze cores (McDonald et al. 1991). Our program uses Wolman pebble counts to characterize substrate particle sizes. Pebble counts of stream channel transects were developed as a method of characterizing the particle size distribution of the stream bed in order to calculate stream hydrology features: flow resistance, channel capacity, and streambed stability (Wolman 1954, Kondolf 1997). Recently, pebble counts have been recommended as an efficient, and repeatable means for evaluating the suitability of stream substrates for aquatic life (Fitzpatrick et al. 1998; Conquest et al. 1994; Bauer and Burton 1993; McDonald et al. 1991). However, few tests have been reported between surface sediment sizes and results have been inconclusive. In Mebane (2001), I found that high percentages of fine grained surface sediments interrupted salmonid and sculpin life cycles. Sculpins consistently avoided areas with abundant fine sediments in the stream channel or deposited on the banks — the more motile salmonids only responded to fine sediments in the stream channel. In contrast, Fore and Bollman (2000) reported that correlations salmonid age classes and surface fine sediments were variable, highly significant in the Snake River and Northern Basin and Range ecoregions but not in the Northern Rockies ecoregions.

Here, I grouped forested sites by whether their index scores were in the range of reference sites, using the 25th percentile of scores from reference sites as the threshold for whether the sites were similar to reference conditions. Then the ranges of fine sediment, measured either across the submerged portion of the stream channel (instream) , or measured across the bankfull width (instream plus bank deposits) were compared from sites with scores similar to reference to those with lower scores (Figure 4-19 top). In both cases, sites with higher SFI scores tended to have lower percentages of fine grained (less than 6mm) sediments. Similar comparisons with the Fore and Bollman (2000) data set, were not statistically significant although the plot of bankfull sediment less than 6mm versus SFI had the same direction of differences. Unfortunately, instream fine sediments less than 6mm were missing from their data set, so like comparisons could not be made. The insignificant results for SFI vs. instream fines less than 2mm might be related to the practical difficulty of measuring very small particles in pebble counts, small sample size, or the lack of biological significance. The latter seems unlikely since many workers have reported on the relatioship between fine sediment and salmonid fish populations, although there is less agreement on what the best threshold for “fines” are for this purpose, ranging from less than 10mm to less than 0.85 mm (Chapman and McCleod 1987, Chapman 1988, Waters 1995).

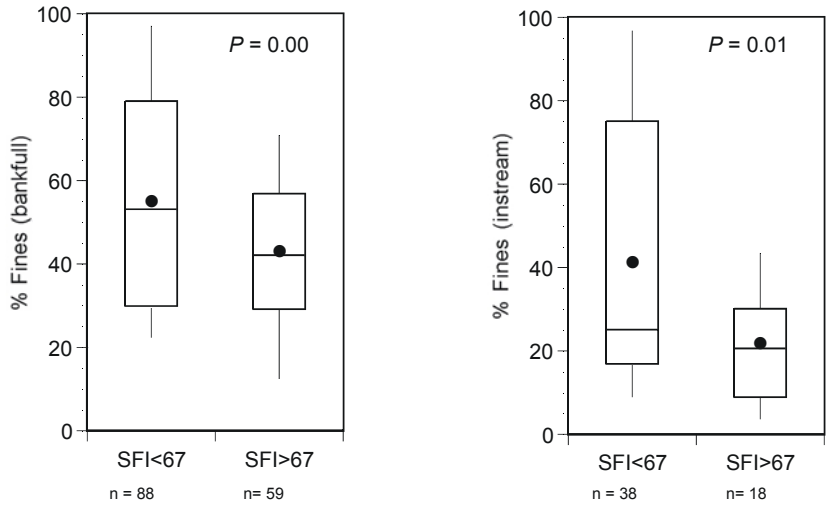


Figure 4-20 (top)

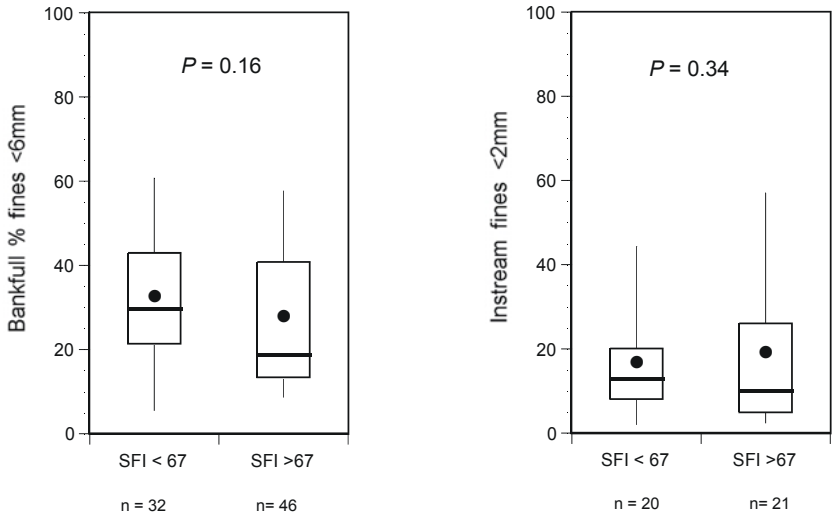


Figure 4-20 (bottom)

Figure 4-20. Top: Percentages of channel widths covered by fine-grained (<6mm) sediment occurring at sites with SFI scores <67> (forest streams).
For these tests, sites with SFI score >67 are considered similar to reference condition, scores <67 are considered potentially impaired (67 was the 25th percentile SFI score for reference sites). "Bankfull" includes bed materials located both in the submerged channel and on the banks; "instream" includes bed materials from the submerged portion of the channel only. P values indicate the probability that the means are equal using t-test.
Bottom: Similar comparison using the Fore and Bollman (2000) data set. Percentages of bankfull channel widths covered by <6mm sediment and instream width covered by <2mm surface sediments. Data for instream fines <6mm were not readily available

Native Amphibians: A Supplemental, Qualitative Metric

Had amphibians been consistently captured and identified in the data, quantitative amphibian-related metrics would have been evaluated. They were not. However, inclusion of amphibians into an IBI has several desirable features. First, the presence of native amphibians may be a qualitative indication of functional riparian and instream habitat. Further, in cold water streams with low fish species diversity, broadening the fish assemblage to a vertebrate assemblage of fish and amphibians would increase the potential species diversity somewhat. Lastly, amphibians have been in general decline in recent years (need cite), and state-wide systematic observations of their occurrences could provide useful information on their status.

The presence of native amphibians is scored as bonus points in either the rangeland or the forest stream index. Hopefully, by including native amphibian presence in the index, that will provide useful information on riparian and stream habitat condition, and perhaps more importantly, encourage future survey crews to better seek out (and key out) amphibians in riparian and stream habitats. Note that this qualitative metric is a "presence" metric, not a "presence or absence" metric. Because amphibian distributions may be naturally patchy, because some survey crews did not attempt to capture amphibians, and because many amphibians are riparian, rather than aquatic species and thus may not be captured in routine electrofishing, it would not be right for the absence of native amphibians to cause a lower index score. That is, supplemental points are added to the final index scores, absence of amphibians is not considered a negative factor, and their contribution to index scores were not considered in any index testing or establishing biological impairment thresholds.

In particular, one native amphibian, *Ascaphus truei*, the tailed frog, is highly specialized for life in clear, cold mountain streams. Tailed frog populations have declined in the Pacific Northwest primary because of timber harvesting (Bull and Carter 1996, Waters 1995). Declines in tailed frog populations are probably because of higher water temperatures, increased siltation, or greater bed movement. They are the only amphibian species of the Pacific Northwest known to spawn in fast moving water, attaching their eggs to the bottoms of rocks. Other amphibians usually spawn in lentic, or semi-lentic, slow moving water. Three age classes of tailed frog tadpoles will occur in occupied streams, they do not usually metamorphose until the end of year-four (Nussbaum et al 1983). In a study of 80 streams in the Blue Mountains ecoregion of northeast Oregon, Bull and Carter (1996) found that the percentage of cobble and boulders, proportion of the stream with at least a 30m buffer on both sides from roads or timber harvest, and stream gradient were strong predictors of tailed frog presence or absence from their study area. They also found clear trends of decreasing adult frogs with increasing timber harvest. No frogs were found in 30 percent of streams which had received a heavy amount of timber harvest, whereas all streams that had received a low or moderate amount of timber harvest contained frogs. Bull and Carter conclude that that timber harvest would unlikely significantly influence populations if a no-cut buffer was retained and the integrity of the stream structure was retained. The natural distribution of the tailed frog is another reason for treating its presence as a positive/neutral factor, rather than a positive/negative metric. According to Nussbaum et al. (1993), tailed frogs are widely (but

unevenly) distributed across the areas shown in Figure 1 as the Northern Rockies and Blue Mountain ecoregions, but are not known to occur in other ecoregions of the state.

Because of these unique characteristics that specifically relate to stream quality, presence of tailed frogs is weighted more heavily than other native amphibians (10 points added to the base stream fish index of 100 points for tailed frogs, 5 points for other native amphibians).

DISCUSSION

The purpose of this analysis was to examine fish data from small streams in Idaho (primarily 2nd to 4th order) and, if feasible, construct a multimetric index reflecting the biological condition of the assemblage. The results so far indicate that multimetric stream fish indexes are feasible, and may be a useful interpretive tool for stream bioassessment. Considerations for the use of the indexes in water resource management and possible improvements follow.

Considerations for Setting Impairment Thresholds

EPA has defined a water body as being biologically impaired if the attributes of one or more major biological groups (assemblages) has been modified significantly beyond the natural range of the reference condition (EPA 1995). This definition provides a rational, general starting place. However, at the state or regional scale, a more explicit definition is needed. For example, with a large data set, the range of values of any measure will be large. In the case of both the rangeland and forest stream fish indexes, the range of scores at reference sites was from 0 to 100. Rather than these absolute ranges, statistical distributions of the natural range of reference conditions should be considered. Still, statistical definitions do not relieve the assessor from making a judgement of how significant a "significant modification" is. Perhaps conservation biologists may give quantitative advice on the necessary proportion of streams with fish assemblages in their natural reference condition to maintain viable metapopulations. More often, an impairment threshold will likely need to be made based upon social or policy judgements.

Approaches vary with different situations, investigators, and decision makers. Kilgour et al. (1998) argued that the 5th percentile of the normal distribution provided an objective, and natural definition that was supported by a nearly universal custom of selecting 95th percentile statistical significance thresholds. If no minimally reference sites are available, one could assume that a maximum score represented best attainable and set an impairment threshold as a percentage of the possible score (see e.g. Hughes et al. (1998), who used 75 percent of the possible score as an impairment threshold). A consequence of the percentile of reference approach to setting impairment thresholds is a tradeoff between Type I errors (concluding a site differs from reference when it truly does not) and Type II errors (failing to detect a that site differs from reference when it truly does). When setting a 5th percentile of reference as the impairment threshold, we are by definition making a 5 percent Type I error, since those reference sites below the 5th percentile are still from the reference site group. The smaller we set our Type I error rate, by selecting lower cutoff scores, the larger the type II error becomes. For rangeland streams, setting the impairment threshold at the 5th percentile of

reference would include 70 percent of the impaired sites, or if the threshold were set at the 25th percentile, then 78 percent of the impaired sites would be detected (Table 4-6). Forest streams show a similar pattern, although the differences in Type II error are broader, ranging from 57 to 22 percent over the same range (Table 4-7). In both forest and rangeland streams, Type I and Type II errors were most balanced and their sums (total error term) were lowest at the 25th percentile of reference. Of course these comparisons assume that all reference sites are truly have few human disturbances, and all test sites have fish assemblages that were truly altered by humans, and all misclassifications are due to inaccuracies in the index. Instead, it could also be true that the index is correct and the sites were misclassified, or a combination of factors.

Table 4-6. Comparison of percentile distributions of fish index scores at forest reference and test streams.

Rank Among Reference Sites	Forest Reference Sites	Test Sites	% of Disturbed Sites with IBI <Reference Percentile	"Type II" Error Rate	"Type I" Error Rate	Combined Error Rate
n	230	47				
Minimum	0	0				
5th percentile	34	0	43%	57%	5%	62%
10th percentile	43	0	59%	41%	10%	51%
25th percentile	67	0	78%	22%	25%	47%
Median	81	41	88%	12%	50%	62%
75th percentile	91	63				
90th percentile	97	86				
Maximum	100	100				

Table 4-7. Comparison of percentile distributions of fish index scores at rangeland reference and test streams.

Percentiles of Site Scores	Rangeland Reference Scores	Test Sites	% of Disturbed Sites with IBI <Reference Percentile	"Type II" Error Rate	"Type I" Error Rate	Combined Error Rate
n	46	30				
Minimum	0	0				
5th percentile	39	0	40%	60%	5%	65%
10th percentile	49	0	58%	42%	10%	52%
25th percentile	62	18	74%	26%	25%	51%
Median	82	44	92%	9%	50%	59%
75th percentile	88	63				
90th percentile	94	77				
Maximum	100	92				

An alternate approach to setting impairment thresholds would be to set both an impairment threshold for the indexes, and a scoring scheme with other ecological indicators [macroinvertebrates and habitat], which are also scored on a 0 to 100 scale. For example, if any one index was below the 5th percentile of reference (or a percentile of all possible scores), the stream would be considered impaired, or both the fish and macroinvertebrate indices were below a percentile of reference (e.g. 10th, 25th, or xth), the stream would be considered impaired. This type of approach would both identify streams that had any one assemblage modified beyond the range of natural variability, and use macroinvertebrate, fish and habitat information together to assess stream quality. This approach could also be used with upper percentile scores to identify streams with exemplary biological integrity to protect from degradation (in water quality jargon, identify high quality streams in an antidegradation context).

Classification of Stream Types – Possible Refinements

Scale

The goal of this effort was to develop stream fish indexes with statewide or at least broad applicability. To meet this goal, I used a broad classification of streams as being either in the cool-desert, rangeland stream group or in the cold-mountain forest stream groups (Figure 4-20). Some additional scoring delineations by stream size and major river basin (to decide whether a species should be considered native in that basin), and stream size are included in the index scoring. However, streams in a large state such as Idaho could be further broken down by a host of additional factors, such as parent geology, stream geomorphology (e.g. Rosgen 1996), or additional climatic refinements. One has to consider a tradeoff between precision, and broad applicability. Indexes developed for smaller areas would likely have improved precision over a broadscale model.

According to Dunham et al. (ms.), "[t]he history of habitat modeling to predict abundance or occurrence of stream fishes has shown that models based on sampling a range of temporal and spatial scales often have low predictive ability, and that models with high predictive ability have low transferability across different times or places." Their observation would be germane to developing IBI models as well. Developing an IBI model with a smaller set of more homogenous streams would likely provide more precision than the current model, many idiosyncratic models would be needed to describe different streams or river basins. The current approach gains the generality required for efficient application over a wide variety of streams, at the likely cost of lower precision. If higher precision is necessary, for example, for impact assessment or restoration monitoring, a paired watershed or similarly geographically focused assessment scheme would likely be needed, such as a Before-After-Control-Impact (BACI) design (e.g. Smith et al. 1993). In that case, a more site-specific model could be useful in addition to, or instead of this model.

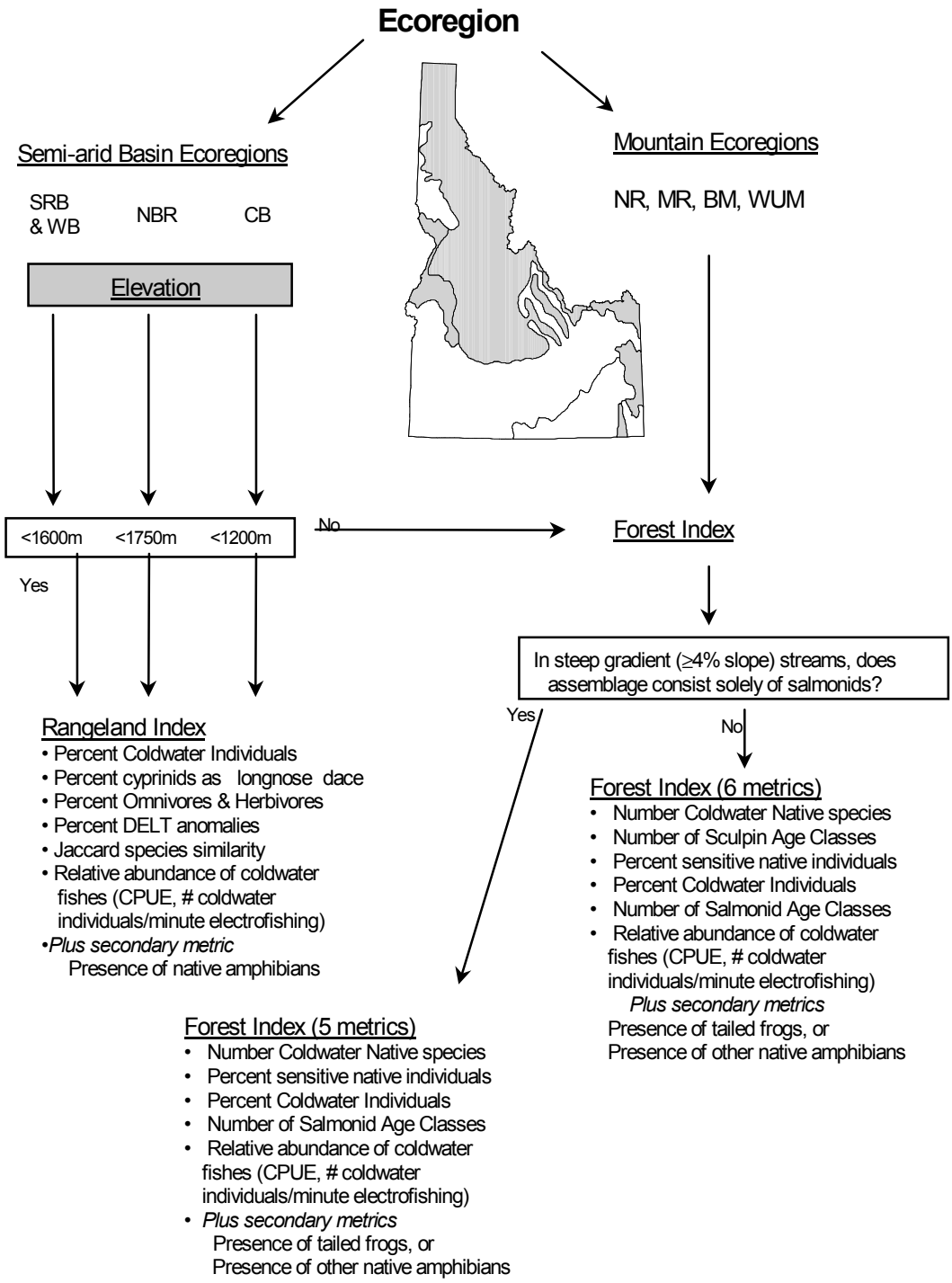


Figure 4-21. Flowchart of stream fish index structure.

Expected changes in ecoregion classifications

Omernik and his colleagues are in the process of revising and mapping more detailed ecoregions for Idaho. Among the changes are more detailed delineation of the current "Northern Basin and Range" ecoregion into sub-ecoregions showing "basins" and "ranges" (James Omernik, personal communication). Also, desert mountain ranges such as the Owhyee range in southwest Idaho would no longer just be considered part of the huge Snake River Basin/High Desert ecoregion which currently sprawls from the Idaho/Wyoming border to the eastslope of the Oregon Cascades (Omernik and Gallant 1986). In the present report, the delineation between high desert mountain streams and lower desert basin streams was added in a very coarse fashion through the addition of elevation as a factor determining whether a stream sample site would be expected to have a more montane biology or a lowland, basin biology (Figure 4-1, Figure 4-20). When the revised ecoregions are published, it would be interesting to overlay them with the site classifications shown in Figure 1, and consider whether this classification could be described (or should be revised) following the new ecoregions.

Numbers of fish in a sample: patterns and consequences

Two fundamental assumptions of a multimetric index based on attributes of a fish assemblage are 1) that there is a fish assemblage present and if so, 2) it was representatively sampled. At some point, one has to decide "how many fish in a sample are needed to suppose that the fish assemblage was adequately sampled?" Compared to fish samples from rivers or streams in more productive parts of the country, the numbers of fish per sample were relatively low with medians of 28 and 15 fish captured at rangeland and forest sites respectively. Oligotrophic, small mountain streams, in particular often had low numbers of fish captured. Fore et al. (1994) examined statistical properties of a warm water IBI used in streams in Ohio. They noted that Ohio samples with less than 400 fish tended to have more variable IBI scores. Clearly this rule of thumb for what constitutes a "small" number of fish in a sample would have to be revised in the forest-mountain streams of Idaho where the 95th percentile of numbers of fish caught in a sample was only 168.

Low numbers of fish in a sample could be the result of 1) inefficient sampling, 2) low densities from severely polluted conditions, or 3) low densities form marginal physical habitat conditions, such as steep gradients, low flows, or freeze-outs. After the fact, it is difficult or impossible to know which reason was responsible (although one might assume that meticulous or sloppy and incomplete datasheets reflects on sampling effort as well). Results from inefficient sampling should be rejected, yet a simple rule of rejecting samples with low counts of fish would also discard samples from which fish were rare, losing valuable assessment information. Sheldon (1987) writes that often stream fishes are rare, with absolute population numbers in the hundreds. Fragmentation and isolation of stream habitats due to flow removal, impassible culverts, or impoundments, for example, will increase the risk of local stream extinctions. Thus, flagging sites with unusually sparse fish numbers could be useful for identifying streams warranting follow-up investigation.

This still leaves the question of how many fish in a sample makes a sparse sample? I made some informal tests by entering hypothetical data for several common species associations with increasing sample sizes, increasing age classes, but maintaining relative species percentages. At less than 10 fish/sample, for different species combinations, a doubling of sample size resulted in score changes of up 18 points, between 10 and 20 fish, a doubling increased scores by about 8 to 11 points, when over 20 fish were in a sample, a doubling of sample size increased scores by about 3 to 7 points. When over 40 fish were in a sample, further increases the number of fish in a sample made little difference in the score. This exercise suggests that a sample with less than 10 fish should be flagged as sparse to caution the user.

CONCLUSIONS

Overall, the stream fish indexes for rangeland and mountain streams of Idaho show promise as tools to help interpret fish assemblages from a bioassessment perspective. The indexes should be complementary to the macroinvertebrate indexes (Jessup and Gerritsen 2000) and the habitat index (Fore and Bollman 2000). In order to be broadly applicable, the structure and calculations of the SFI are fairly complex, compared to most other IBIs (see articles in Simon 1999). However, this complexity was a factor complicating its development only, rather than its use. The decision rules and calculations are automated, and are transparent to the user (Figure 4-20). The output is a simple index value from 0 to 100, which can be dissected further, or left as a summary, depending on the interest level of the user.

Recommendations

The indexes in their present form could be useful; however, several short and longer-term recommendations could improve their utility.

Short term (1)

Investigate existing data for index variability and sensitivity. Because our site-numbering scheme, it was difficult to identify repeated sites. Assuming sites repeated at similar times of the year, without significant environmental perturbations should be similar, index values should be calculated and evaluated on these.

Long term (1)

Encourage interagency cooperation in sampling. Some USFS, BLM, and IDFG data sets from areas of interest where excluded because non-salmonids were not captured and recorded. Non-game fish are part of the stream community too. The rationalization that the salmonids are the most sensitive indicator species may not hold in all situations.

Long term (2)

Encourage consistent amphibian collection (or at least capture, documenting, and release). DEQ's extensive BURP program does not currently maintain a stream vertebrate database, only a fish database. Amphibian observations are relegated to field notes. This could easily be and should be rectified.

Long term (3)

Target reference streams to evaluate interannual variation.

Long term (4)

Investigate direct observation of fish through snorkeling. Well-meaning resource managers have restricted routine electrofishing surveys in their belief that they are avoiding population loss by not allowing electrofishing. Because of these perceptions, some salmonid population trends monitoring is done through snorkeling, with mixed results. Few examples have been reported of attempting to survey the entire assemblage, instead of just target species, or water column species. Pearsons et al (1992) and Torgerson (2000) reported some success using snorkeling to survey fish assemblages. This may be worth investigating, because of some attitudes toward electrofishing.

Long term (5)

Rate of anomalies may be a useful indication of environmental degradation, however both DEQ's current data and database management are weak in this area. USGS fish data tended to have higher rates of anomalies than did data form DEQ, IDFG or university collections. There are at least two explanations for this: (1) the USGS sampled more degraded waters than others, or (2) the USGS workers found more anomalies because they were specifically looking for anomalies instead of happening to notice them. Field crews should be trained on potential anomalies, and to take a few seconds to specifically examine each fish. Anomalies were more common on non-salmonids, such as suckers, which may receive less attention than the salmonids. Specific anomalies need to be tracked in the database, rather than just "anomalies" and details relegated to text fields, if at all. Blackspot disease and lip tumors do not have similar biological significance.

Longer-term (6)

Since this is an empirical effort, the metrics and index streams should be re-evaluated when more data are available, and revised accordingly, particularly for the rangeland streams.

ACKNOWLEDGMENTS

A number of people contributed data, ideas, and encouragement for this project. Particular thanks go to Kevin Meyer, of the Idaho Department of Fish and Game Nampa Research Station for sharing their extensive fish surveys and associated land use data. Terry Maret and Mark Munn of the U.S. Geological Survey shared data from their stream surveys. Jack Skille, Daniel Stewart, Bob Steed, Darren Brandt, David Hull, and Steve Robinson of the Idaho Department of Environmental Quality supervised most of the data collection and recommended candidate reference or disturbed streams for analysis. Critical reviews by Steve Canton and Jim Chadwick (Chadwick Ecological Services), Leska Fore (Statistical Design), and Don Zaroban (DEQ) were helpful. Some of the analyses were inspired by discussions with Phil Larsen and Bob Hughes (EPA National Health and Environmental Research Laboratory). Cyndi Grafe and Michael McIntyre provided encouragement throughout the project.

REFERENCES

Baltz, D. M., P.B. Moyle, and N.J. Knight. 1982. Competitive interactions between benthic stream fishes, riffle sculpin (*Cottus gulous*, and specked dace, *Rhinichtys osculus*. Canadian Journal of Fisheries and Aquatic Sciences. 39:1502-1511.

Behnke, R.J. 1992. Native trout of western North America. American Fisheries Society Monograph 6, Bethesda, MD, 275 pp.

Bond, C.E. 1963. Distribution and ecology of freshwater sculpins, genus *Cottus*, in Oregon. Ph.D. Thesis. University of Michigan, 186 pp.

Brocksen, R.W., G.E. Davis, and C.E. Warren. 1968. Competition, food consumption, and production of sculpins and trout in laboratory. Journal of Wildlife Management. 32:51-75.

Bull, E.L., and B.E. Carter. 1996. Tailed frogs: distribution, ecology, and association with timber harvest in northeastern Oregon. U.S. Forest Service. PNW-RP-497. 11pp.

Burton, T.A., E. Cowley, G.W. Harvey, and B. Wicherski. 1991. Protocols for evaluation and monitoring of stream/riparian habitats associated with aquatic communities in rangeland streams. Water Quality Monitoring Protocols Report No.4. Idaho Division of Environmental Quality. Boise. 31 pp.+ appendices.

Carline, R.F., C.J. Gagen, and W.E. Sharpe. 1994. Brook trout (*Salvelinus fontinalis*) population dynamics and mottled sculpin (*Cottus bairdi*) occurrence in relation acidic episodes in streams. Ecology of Freshwater Fish. 3:107-115.

Chandler, G.L., T.R. Maret, and D.W. Zaroban. 1993. Protocols for assessment of biotic integrity (fish) in Idaho streams. Water Quality Monitoring Protocols Report No.6. Idaho Division of Environmental Quality. Boise. 25 pp.

Chapman, D.W. 1988. Critical review of variables used to define effects of fines in redds of large salmonids. Transactions of the American Fisheries Society. 117:1-21.

Cuffney, T.F., M.R. Meador, S.D. Porter, and M.E. Gurtz. 1997. Distribution of fish, benthic invertebrate, and algal communities in relation to physical and chemical conditions, Yakima River basin, Washington, 1990. Water Resources Investigations Report 96-4280. U.S. Geological Survey, Raleigh, North Carolina.

DEQ. 1996. 1996 water body assessment guidance. Water Quality Assessment and Standards Bureau. Idaho Division of Environmental Quality, Boise. 94 pp.

Dunham, J.B, B.S. Cade, and J.W. Terrell. manuscript. Limitations to analyzing the effects of limiting factors: influence of spatial and temporal variation on regression quantile models of fish abundance in streams. U.S. Forest Service Rocky Mountain Research Station, Boise, ID and U.S. Geological Survey, Midcontinent Ecological Sciences Center, Fort Collins, CO.

Dunham, J.B. and G.L. Vinyard. 1997. Incorporating stream level variability into analyses of site level fish habitat relationships: some cautionary examples. Transactions of the American Fisheries Society. 126:323-329.

Engelman, L. 1996. Discriminant analysis. pp. 361-407. in Wilkinson, L (ed.) *Statistics*: Systat® 6.0 User's Manual. SPSS Inc., Chicago, IL 761 pp.

EPA. 1995a. Guidelines for preparation of the 1996 state water quality assessments (305(b) reports). EPA 841-B-95-001. U.S. Environmental Protection Agency, Washington, D.C.

Erman, D.C. 1986. Long-term structure of fish populations in Sagehen Creek, California. Transactions of the American Fisheries Society. 115:682-692.

Finger, T.R. 1982. Interactive segregation among three species of sculpins (*Cottus*). Copeia. 1982:680-694.

Fisher, T.R. 1989. Application and testing of indices of biotic integrity in northern and central Idaho headwater streams. M.Sc. Thesis. University of Idaho, Moscow, Idaho. 180 pp.

Flebbe, P.A. 1996. A regional view of the margin: salmonid abundance and distribution in the southern Appalachian Mountains of North Carolina and Virginia. Transactions of the American Fisheries Society. 123:657-667.

Fore, L. and W. Bollman. 2000. Evaluation of Idaho's habitat index for wadeable streams. Report to the Idaho Department of Environmental Quality, Boise. 42 pp.+ appendices.

Fore, L.S., J.R. Karr, and L.L. Conquest. 1994. Statistical properties of an index of biological integrity used to evaluate water resources. Canadian Journal of Fisheries and Aquatic Sciences. 51:1077-1087.

Frey, D.G. 1977. Biological integrity of water–an historical approach. In R.K. Ballantine and L.J. Guarraia (eds.). The integrity of water, United States Environmental Protection Agency, Washington, D.C. pp. 127-140.

Gauch, H.G. Jr. 1982. Multivariate analysis in community ecology: New York, Cambridge University Press 298 pp. (as cited by Maret 1997)

Halliwell, D.B., R.W. Langdon, R.A. Daniels, J.P. Kurtenbach, and R.A. Jacobson. 1999. Classification freshwater fish species of the northeastern United States for use in the development of indices of biological integrity, with regional applications. pp. 301-338 *in* Simon (1999).

Haro, R.J., and M.A. Brusven. 1994. Effects of cobble embeddedness on the microdistribution of the sculpin Cottus beldingi and its stonefly prey. Great Basin Naturalist. 54:64-70.

Harshbarger, J.C. and J.B. Clark. 1990. Epizootiology of neoplasms in bony fish of North America. Science of the Total Environment. 94:1-32 (as cited by Hawkins et al. 1995)

Hawkins, C.P. 1983. Density of fish and salamanders in relation to riparian canopy and physical habitat of streams of the northwestern United States. Canadian Journal of Fisheries and Aquatic Sciences. 40:1173-1185.

Hawkins, C.P. 2000. Compositional similarity as an intuitive, interpretable, and ecologically meaningful way of describing degree of biological impairment (abstract). Bulletin of the North American Benthological Society. 17(1)130-131.

Hawkins, W.E., W.W. Walkeer, and R.M. Overstreet. 1995. Carcinogenicity tests using aquarium fish. pp. 421-448. *In* Rand, G.M. (ed.) Fundamentals of aquatic toxicology: effects, environmental fate, and risk assessment. Second edition. Taylor and Francis, Washington, D.C.

Herger, L.G., W.A. Hubert, and M.K. Young. 1996. Comparison of habitat composition and cutthroat trout abundance at two flows in small mountain streams. North American Journal of Fisheries Management. 16:294-301.

Hillman, T.W. 1991. The effects of temperature on the spatial interaction of juvenile chinook salmon and the redside shiner and their morphological differences. Doctoral dissertation. Idaho State University, Pocatello.

Horness, B.H., D.P., Lomax, L.L. Johnson, M.S. Myers, S. M. Pierce, and T.K. Collier. 1998. Bioindicators of contaminant exposure and sublethal effects: studies with benthic fish in Puget Sound, Washington. Environmental Toxicology and Chemistry. 18:872-882

Howlin, S., R.M. Hughes, and P.R. Kaufmann. Manuscript. A biointegrity index for cold water streams of western Oregon and Washington.

Hughes, R.M., 1995. Defining acceptable biological status by comparing with reference conditions. *in* Davis, W.S. and T.P. Simon (eds.). 1995. *Biological assessment and criteria: tools for water resource planning*. CRC Press, Boca Raton, Florida. pp. 31-48.

James, F.C. and C.E. McCulloch. 1990. Multivariate analysis in ecology and systematics: Panacea or Pandora's box? Annual Reviews in Ecology and Systematics. 21:129-159.

Jessup, B. and J. Gerritsen. 2002. Development of a multimetric index for biological assessment of Idaho streams using benthic macroinvertebrates. Report of Tetra Tech, Inc. Ownings Mills, MD to the Idaho Department of Environmental Quality, Boise.

Johnson, J.H. 1985. Comparative diets of Paiute sculpin, speckled dace, and subyearling steelhead trout in tributaries of the Clearwater River, Idaho. Northwest Science. 59:1-9.

Karr, J.R. 1991. Biological integrity: a long-neglected aspect of water resource management. Ecol. Appl. 1:66-84.

Karr, J.R. 1999. Defining and measuring river health. Freshwater Biology 41:221-234.

Karr, J.R., K.D. Fausch, P.L. Angermeir, P.R. Yant, I.J. Schlosser. 1986. Assessing biological integrity in running waters: a method and its rationale. Illinois Natural History Survey Special Publication 5.

Kilgour, B.W., K.M. Somers, and D.E. Matthews. 1998. Using the normal range as a criterion for ecological significance in environmental monitoring and assessment. Ecoscience. 5:542-550.

Kruse, C.G., W.A. Hubert, and F.J. Rahel. 1997. Geomorphic influences on the distribution of Yellowstone cutthroat trout in the Absaroka Mountains, Wyoming. Transactions of the American Fisheries Society 126:418-427.

Kruse, C.G., W.A. Hubert, and F.J. Rahel. 1998. Single-Pass Electrofishing Predicts Trout Abundance in Mountain Streams with Sparse Habitat. North American Journal of Fisheries Management. 18:940–946.

Li, H.W., C.B. Schreck, C.E. Bond, and E. Rexstad. 1987. Factors affecting changes in fish assemblages of Pacific Northwest streams. pp. 193-202 in Matthew, W.J. and D.C. Heins (eds.) *Community and evolutionary ecology of North American Stream Fishes.* University of Oklahoma Press, Norman.

Li, H.W., G.A. Lamberti, T.N. Pearsons, C.K. Tait, J.L. Li and J.C. Buckhouse. 1994. Cumulative effects of riparian disturbances along high desert trout streams of the John Day Basin, Oregon. Transactions of the American Fisheries Society. 123:627-640.

Lyons, J., L. Wang, and T.D. Simonson. 1996. Development and validation efforts of an index of biotic integrity for cold water streams in Wisconsin. North American Journal of Fisheries Management. 16:241-256.

Magurran, A.E. 1988. *Ecological diversity and its measurement.* Princeton University Press, Princeton, NJ. 178 pp.

Maret, T.R. 1995. Water quality assessment of the upper Snake River basin, Idaho and western Wyoming–Summary of aquatic biological data for surface water through 1992. U.S. Geological Survey Water-Resources Investigations Report 95-4006.

Maret, T.R. 1997. Characteristics of fish assemblages and related environmental variables for streams of the upper Snake River basin, Idaho and Western Wyoming. U.S. Geological Survey Water-Resources Investigations Report 97-4087. 50pp.

Maret, T.R., C.T. Robinson, and G.W. Minshall. 1997. Fish assemblages and environmental correlates in least disturbed streams of the Upper Snake River basin. Transactions of American Fisheries Society. 126:200-216.

Maret, T.R., T.A. Burton, G.W. Harvey, and W.H. Clark. 1993. Field testing of new monitoring protocols to assess brown trout spawning habitat in an Idaho stream. North American Journal of Fisheries Management. 13:567-580.

Matthews, R.A. 1993. Statistical ecology minicourse workbook. Institute of Environmental Toxicology and Chemistry. Western Washington University, Bellingham.

McCormick, F.H. B.H. Hill, L.P. Parrish, and W.T. Willingham. 1994. Mining impacts on fish assemblages in the Eagle and Arkansas Rivers, Colorado. Journal of Freshwater Ecology. 9(3):175-179.

McPhee, C. 1966. Influence of differential angling mortality and stream gradient on fish abundance in a trout-sculpin biotype. Transactions of the American Fisheries Society. 95:381-387.

Mebane, C. 2002. River Fish Index. Chapter 4 in Grafe, C.S. (ed.) Idaho River Ecological Assessment Framework: an integrated approach. Idaho Department of Environmental Quality.

Mebane, C.A. 2001. Testing bioassessment metrics: macroinvertebrate, sculpin, and salmonid responses to stream habitat, sediment, and metals. Environmental Monitoring and Assessment. 67:292-322.

Meehan, W.R. 1996. Influence of riparian canopy on macroinvertebrate composition and food habits of juvenile salmonids in several Oregon streams. Res. Pap. PNW-RP-496. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 14 pp.

Meffe, G.K. 1991. Failed invasion of a Southeastern blackwater stream by bluegills: implications for conservation of native communities. Transactions of the American Fisheries Society. 120:333-338.

Moyle, P.B. 1994. Biodiversity, biomonitoring, and the structure of stream fish communities. In Loeb, S.L., and A. Spacie, (eds.) Biological Monitoring of aquatic systems. CRC Press. Pp. 155-170

Munkittrick, K.R. and D.G. Dixon. 1989. A holistic approach to ecosystem health using fish population characteristics. Hydrobiologia. 188/189:123-135.

Munn, M.D. and S.J. Gruber. 1997. The relationship between land use and organochlorine compounds in streambed sediment and fish in the central Columbia Plateau, Washington and Idaho, USA. Environmental Toxicology and Chemistry. 16:1877-1887

Murphy, M.L. and W.R. Meehan. 1991. Stream ecosystems. American Fisheries Society Special Publication 19:17-46.

Northcote, T.G. and G.L. Ennis. 1994. Mountain whitefish biology and habitat use in relation to compensation and improvement possibilities. Reviews in Fisheries Science. 2:347-371.

Nussbaum, R.A., E.D. Brodie, Jr., R.M. Storm. 1983. Amphibians and reptiles of the Pacific Northwest. University of Idaho Press, Moscow.

Omernik, J.M. and A.L. Gallant. 1986. Ecoregions of the Pacific Northwest. EPA 600/3-86/033. U.S. Environmental Protection Agency, Corvallis, OR.

Pearsons, T.N., H.W. Li, and G.A. Lamberti. 1992. Influence of habitat complexity on resistance to flooding and resilience of stream fish assemblages. Transactions of the American Fisheries Society. 121:427-436.

Platts, W.S. 1979. Relationships between stream order, fish populations, and aquatic geomorphology in an Idaho river drainage. Fisheries 4(2):5 – 9.

Propst, D.L. 1982. Warmwater fishes of the Platte River Basin, Colorado; distribution, ecology, and community dynamics [Ph.D.]. Fort Collins, CO: Colorado State University. 282 p.

Quigley, T.M., R.W. Haynes, and R.T. Graham., tech. eds. 1996. Integrated scientific assessment of ecosystem management in the interior Columbia basin and portions of the Klamath and Great Basins. Gen. Tech. Rep. PNW-GTR-382. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR. 303 pp.

Rahel, F.J. 1990. The hierarchical nature of community persistence–a problem of scale. The American Naturalist. 136:328-344.

Rahel, F.J. 2000. Homogenization of fish faunas across the United States. Science. 288:854-857.

Rahel, F.J., and W.A. Hubert. 1991. Fish assemblages and habitat gradients in a Rocky Mountain-Great Plains stream: biotic zonation and additive patterns of community change. Transactions of the American Fisheries Society. 120:319-332.

Reeves, G.H. F.H. Everest, and J.D. Hall 1987. Interactions between the redside shiner (*Richardsonius balteatus*) and the steelhead trout (*Salmo gairdneri*) in western Oregon: influence of water temperature. Canadian Journal of Fisheries and Aquatic Sciences. 44:1603-1613.

Robinson, C.T. and G. W. Minshall. 1992. Refinement of biological metrics in the development of biological criteria for regional biomonitoring and assessment of small streams in Idaho, 1991-1992. Report to the Idaho Division of Environmental Quality. Stream Ecology Center, Department of Biological Sciences, Idaho State University, Pocatello, Idaho. 100 pp. (as cited in Maret 1995).

Robinson, C.T. and G. W. Minshall. 1995. Biological metrics for regional biomonitoring and assessment of small streams in Idaho. Report to the Idaho Division of Environmental Quality. Stream Ecology Center, Department of Biological Sciences, Idaho State University, Pocatello, Idaho. 193 pp.

Rosgen, D.L. 1996. Applied river morphology. Wildland Hydrology. Pagosa Springs. 380 pp.

Royer, T.V., and G.W. Minshall. 1996. Development of biomonitoring protocols for large rivers in Idaho. Report to the Idaho Division of Environmental Quality. Department of Biological Sciences, Idaho State University, Pocatello, 55 pp.

Sanders, R.E., R.J. Miltner, C.O. Yoder, and E.T. Rankin. 1999. The use of external deformities, erosion, lesions, and tumors (DELT anomalies) in fish assemblages for characterizing aquatic resources. pp. 203-224 *in* Simon (1999).

Schomberg, J.D., G.W. Minshall, and T.V. Royer. 1998. The use of landscape scale analysis in river biomonitoring. Final report to the Idaho Division of Environmental Quality. Stream Ecology Center, Department of Biological Sciences, Idaho State University, Pocatello, Idaho. 132 pp.

Sheldon, A.L. 1987. Rarity: patterns and consequences for stream fishes. pp. 203-209 in Matthew, W.J. and D.C. Heins (eds.) Community and evolutionary ecology of North American Stream Fishes. University of Oklahoma Press, Norman.

Simon, T.P. (ed). 1999a. Assessing the sustainability and biological integrity of water resources using fish communities. CRC Press. Boca Raton, Florida. 671 pp.

Simon, T.P. 1999b. Assessment of Balon's reproductive guilds with application to midwestern North American freshwater fishes. pp. 97-122 *in* Simon (1999a).

Smith, E.P. D.R. Orvos, and J. Cairns, Jr. 1993. Impact assessment using the before-after-control-impact (BACI) model: concerns and comments. Canadian Journal of Fisheries and Aquatic Sciences. 50:627-637.

Tait, C.K., J.L. Li, G.A. Lamberti, T.N. Pearsons, and J.W. Li. 1994. Relationships between riparian cover and the community structure of high desert streams. Journal of North American Benthological Society. 13:45-56.

Taniguchi, Y., F.J. Rahel, D.C. Novinger, and K.G. Gerow. 1998. Temperature mediation of competeive interactions among three fish species that replace each other along longitudinal gradients. Canadian Journal of Fisheries and Aquatic Sciences. 55:1894-1901.

Torgersen, C. 2000. Longitudinal patterns in fish assemblage and stream habitat relationships: part 1, spatially continuous analysis and the influence of scale (abstract). Bulletin of the North American Benthological Society. 17(1)120.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife Management. 47(4):893-901.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences. 37:130-137.

Whittier, T.R., R.M. Hughes, D.P. Larsen. 1988. Correspondence between ecoregions and spatial patterns in stream ecosystems in Oregon. Canadian Journal of Fisheries and Aquatic Sciences. 45:1264-1278.

Wydoski, R.S. and R.R. Whitney. 1979. Inland fishes of Washington. University of Washington Press. Seattle.

Zaroban, D.W., M.P. Mulvey, T.R. Maret, R.M. Hughes, and G.D. Merritt. 1999. A classification of species attributes for Pacific Northwest freshwater fishes. Northwest Science. 73:81-93.

Chapter 5.
Evaluation of Idaho's Habitat Index for Wadeable Streams

Leska S. Fore[13] and Wease Bollman[14]

INTRODUCTION

The CWA requires states to restore and maintain the physical, chemical, and biological integrity of surface waters. In support of this objective, states must submit biennial reports to Congress on the condition of their water resources. To satisfy these requirements for streams, data related to the physical, chemical, and biological condition of a stream are typically summarized with a multimetric index (Southerland and Stribling 1995). Water quality standards and criteria are then defined, and if a water body fails, it is listed as "impaired" for "failing to meet its designated uses" (Ransel 1995).

Two aspects of the CWA are addressed when physical features of a stream are measured (Bauer and Ralph 1999). First, physical monitoring provides an assessment of the physical integrity of the stream site. Second, physical monitoring can be related to the beneficial uses that streams are expected to support. In the case of Idaho, the beneficial uses for many streams include support of aquatic life. Thus, physical monitoring serves two separate, but related, goals of the CWA. In parallel with this dual role of physical assessments, we tested the relevance of Idaho's physical habitat measures based on two approaches. First, we tested whether habitat measures were related to independent measures of human disturbance, as they should be if they are good indicators of physical integrity. Second, we tested whether habitat measures were associated with measures of biological integrity for fish and invertebrates, as they should be if they truly support aquatic life.

Good physical habitat is necessary for high biological integrity of aquatic communities; thus, evaluation of physical stream habitat is often a component of stream assessment. In a broad, ecological sense, the word "habitat" refers to all the physical, chemical, and biological factors that influence a biological assemblage. When applied to monitoring protocols, "habitat" typically refers more specifically to physical or vegetative features found in the channel and riparian area that influence aquatic biota, particularly fish (Barbour et al. 1998). Hence, indexes designed to measure the physical condition of a stream are referred to as "habitat indexes." Idaho's habitat index was intended to measure the physical condition of a stream site by summarizing the physical changes associated with human activities such as logging (Platts and Nelson 1989, Connolly and Hall 1999), agriculture (Roth et al. 1996, Waite and Carpenter 2000), livestock grazing (Li et al. 1994, Clarkson and Wilson 1995), and urban development (Yoder and Smith 1999).

[13] Statistical Design, 136 NW 40th St., Seattle, Washington 98107.
[14] Rhithron Biological Associates, 1845 South 12th West, Missoula, Montana 59801.

The goal of this project was to first test the current version of Idaho's habitat index for its correlation with human disturbance and biological condition. After testing the overall index, its component measures, and additional measures, we selected the best measures based on their correlation with either human disturbance or biological condition to develop the Stream Habitat Index (SHI). We also evaluated various classification schemes for stream sites based on physical, geographic, and biological features of the streams and their watersheds. We used data from sites with multiple visits to evaluate and compare the repeatability, or statistical precision, of the various habitat measures. Finally, we recommended changes that would improve Idaho's stream assessment process.

METHODS

Data Sets

As part of BURP, DEQ has used standardized protocols to sample physical habitat measures at stream sites since 1994. The protocol has changed slightly over the years, but most of the elements in the field form have been measured consistently across the state and through time (BURP 1999). Approximately 3,800 sites have been sampled. Benthic invertebrate samples were collected at most sites, but fish were collected from a smaller subset of sites. DEQ's goal is to ultimately sample every stream in Idaho; in other words, they intend to census all the streams of the state.

For this study we used three subsets of data from the larger state-wide database. The first subset was used to test whether habitat measures correlated with human disturbance and biological metrics. The second subset was use to test the precision and repeatability of habitat measures through time. The third subset was used to define scoring criteria for the habitat measures included in the SHI.

For the first subset of data, approximately 270 sites were selected from the BURP database (Figure 5-1). Sites were selected if they were near the "pour point" in their watersheds; that is, near the most downstream point of the watershed. We selected these sites because we were interested in relating land cover data to stream site condition; land cover was calculated at the level of the watershed. Thus, by selecting sites near the pour point, we included sites that were downstream of all disturbance in the watershed. Fish bioassessment metrics were provided for only 94 sites in the original data set of 270 sites; later an additional set of 59 sites was added, but land cover was not calculated for these additional sites.

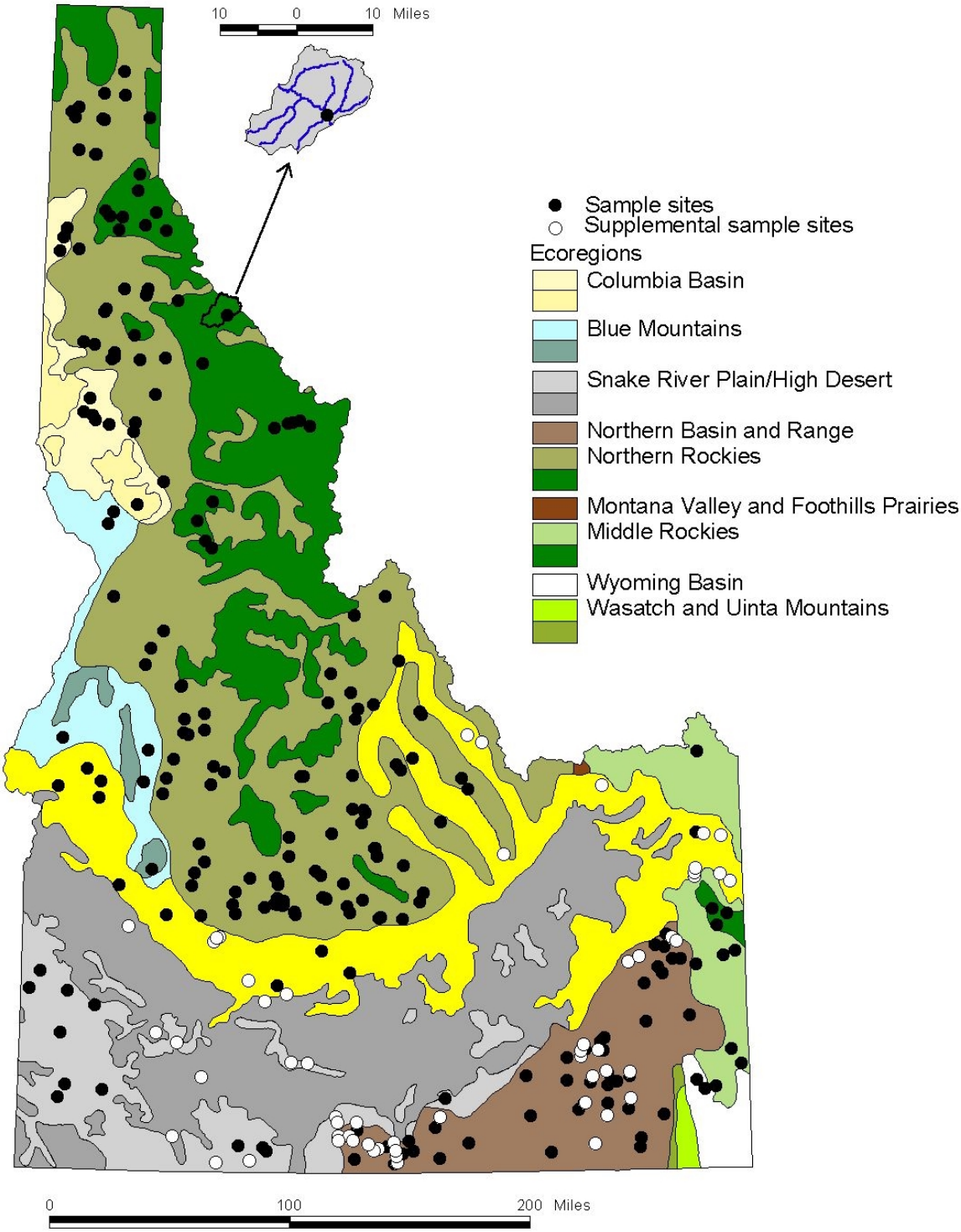


Figure 5-1. Distribution of sample sites.
Sites used to relate land cover data to stream site condition were located across the state in the major ecoregions. Supplemental sites did not have land cover data. Inset illustrates the location of a sampling site within the watershed.

For this subset of 329 sites, not all had complete data (Table 5-1). For example, habitat measures for the original habitat index were included for 296 sites. Stream order data, important for stratification analysis, were provided for 223 sites. Bioassessment metrics based on fish communities were available for 140 sites. Complete data were provided for about 65 sites.

Table 5-1. Selected variables and the number of sites for which data were available from the larger BURP data set.

Variable	Number of Sites
Total number of sites	329
Land use	270
Original habitat index	296
Fish metrics	140
Macroinvertebrate metrics	296
Stream order	223
Rosgen class	293
Number of observed activities	184

The second subset of data included approximately 20 sites sampled a total of three times: once in a previous year which varied according to sites and twice in 2001 with site visits approximately one month apart. The sites were located across the state in each of the major ecoregions. Sites were selected to represent reference condition; however, human disturbance was later discovered at some sites. Three sites visited in 1993 and 1994 had some measures missing and SHI could not be calculated for these site visits.

The third subset of data was used to define scoring criteria for the SHI. We selected 1,494 sites sampled during 1997 and 1998 because the data records were most complete for these years and included the largest number of habitat measures, particularly transect data for Wolman pebble counts.

In general, information for all three data sets fell into roughly three categories.

1) Physical habitat measures included the components of the original habitat index currently used by DEQ; hydrologic features such as sinuosity, depth, flow, and gradient; and geographic features such as elevation, Rosgen stream class (Rosgen 1994), and ecoregion (Omernik 1995).

2) Land use/land cover measures included the number of near-site human activities affecting the reach (e.g., agriculture, forestry, roads) and watershed-level measures derived from satellite data summarized as percent land cover in agriculture, urban development, forest, riparian cover, and grassland.

3) Biological data included the bioassessment metrics for fish and benthic invertebrate assemblages. At the time of this report, final indexes were not available.

Idaho includes parts of eight ecoregions (Omernik and Gallant 1986). However, only three regions have large areal extents in Idaho; these are the Snake River Basin /High Desert ecoregion, the Northern Basin and Range ecoregion and the Northern Rockies ecoregion. We eliminated four ecoregions with few or no sites from the data set, and considered the Northern Rockies and Middle Rockies ecoregions as a single montane ecoregion. All testing and analysis were based on data from the Snake River/High Desert ecoregion (SRB), the Northern Basin and Range ecoregion (NBR), and the Northern and Middle Rockies region (NR/MR).

Habitat Data

Habitat data provided for this study included measures incorporated into the current habitat index (HI) in use by the state, as well as other data from field forms. The original HI, modeled after Hayslip (1993) included 15 individual measures, which are the components of two assessment indexes. Each of the two indexes is specific for either streams dominated by riffles and runs or those dominated by glides and pools. Individual measures are either scored in the field, based on the direct observation of the field crew, or they are scored from worksheets, using calculations from the raw data measured in the field. Where possible, we used both the raw data as well as the assigned scores to evaluate habitat measures.

Only 27 of the 329 sites were identified as low gradient (glide/pool prevalence). Therefore we could not adequately test two of the HI measures that were unique to low gradient reaches, namely, pool substrate character and pool variability.

From the field data sheet, we identified 26 additional habitat measures (Table 5-2). In addition to the HI measures, habitat data included Wolman pebble count data for sites visited after 1995 made within and outside the wetted perimeter, counts of large woody debris, and measures related to pool quality.

Table 5-2. Habitat measures that were evaluated, their predicted response to human disturbance, whether the measure was included in the original habitat index for high (H) or low (L) gradient streams, whether the measure was new, and whether the measure was scored by eye in the field or based on measurements made in the field.

Habitat measure	Predicted Direction	Current Index	New	Scored by Eye	Scored from Data
1. Epifaunal substrate/cover					
Instream cover	Decrease	H, L		X	
Large organic debris	Decrease		X		X
Submerged cover (in pools)	Decrease		X	X	
Undercut banks (in pools)	Decrease		X	X	
2. a. Embeddedness					
Percent fines < 6 mm	Increase	H	X		X
Percent fines < 2 mm	Increase		X		
Embeddedness	Increase	H		X	
Number of Wolman size categories	Decrease		X		X
b. Pool substrate		No data			
Pool substrate	Increase	L		X	
3. a. Velocity and depth					
Velocity/depth ratios	Increase	H	X		X
3. b. Pool variability		No data			
Pool variability	Increase	L		X	
4. Sediment deposition					
Substrate size (in pools)	Decrease		X		X
5. Channel flow status					
Width/depth ratio	Increase	H, L			X
Channel shape (undercut)	Decrease	H, L		X	
6. Channel alteration					
None					
7. a. Riffle frequency					
Pool/riffle ratio	Decrease	H			X
b. Channel sinuosity					
Channel sinuosity	Decrease	L		X	
8. Bank stability					

Habitat measure	Predicted Direction	Current Index	New	Scored by Eye	Scored from Data
% Unstable banks	Increase	H, L			X
9. Bank vegetation protection					
Bank vegetation protection	Decrease	H, L			X
Canopy cover	Decrease	L		X	X
Disruptive pressures	Increase	H, L		X	
10. Riparian vegetative zone					
Zone of influence	Decrease	H, L		X	
11. Other pool measures					
Pool quality index	Decrease		X		X
Number of pools	Decrease		X		X
Max pool depth	Decrease				
Tail out depth	Decrease				
Pool length	Decrease				
Max pool width	Decrease				
Residual depth (of pools)	Decrease		X		X
Substrate size	Increase				
Undercut bank	Decrease				

Land Use Data

Land use data represented an independent measure of human disturbance within the watershed. Watersheds were defined as the land areas within 6th level hydrologic unit codes. Sites within watersheds were located as near as possible to the pour point. Thus, we hoped that the land cover data represented the cumulative large scale impairments to which the draining stream was subjected. Land uses calculated from the satellite data were: percent area used for agriculture, forestry, and urbanization; and percent of area that is riparian vegetation, forested, grassland, shrubland, water, wetland, barren, ice or snow, and alpine meadows. We considered agriculture and urbanization to be disturbed conditions, and riparian and forested cover to be positive signals of relatively undisturbed conditions in the SRB and NBR ecoregions.

Human disturbance was more difficult to quantify in the NR/MR ecoregions, where agriculture is less prevalent. We had no method for quantifying the extent of logging, mining, roads, or other impacts more characteristic of these parts of the state. For the NR/MR regions, therefore, DEQ personnel assigned *a priori* ratings for sites, based on their observations of human disturbance at the sites and in the watersheds. The following criteria were used: 1) proximity of roads, 2) extent of riparian vegetation, 3) complexity of riparian

structure, 4) channel morphology features, 5) channel complexity, 6) complexity of habitat structure, 7) sources of potential chemical stressors, 8) channel flow manipulation, 9) evidence of sedimentation, 10) presence of pipes, drains, ditches and/or tile, and 11) evidence of non-point source problems from human disturbance. Sites were rated either "reference," for those that were least or minimally impacted, "test," for those that were considered impacted or degraded, or "other" for those sites for which verification was needed.

Biological Data

Biological data used in this analysis consisted of the 11 fish metrics used in the stream fish index (see chapter 4), 9 metrics included in the stream macroinvertebrate index (see chapter 3), and 1 additional macroinvertebrate metric. Fish metrics were: number of native species, percent non-indigenous individuals, percent omnivores and herbivores, percent DELT anomalies (deformities, eroded fins, lesions, and tumors), number of cold water native species, number of sculpin age classes, percent sensitive native individuals, percent cold water individuals, number of cold water individuals, number of salmonid age classes, and catch per unit effort of cold water individuals. We tested all fish metrics in all three regions, even though two fish indexes, each comprised of different metrics, are under development for basin streams and mountain streams in Idaho (see chapter 4). The macroinvertebrate metrics were: total taxa richness, Ephemeroptera (mayfly) richness, Plecoptera (stonefly) richness, Trichoptera (caddisfly) richness, percent Plecoptera, the Hilsenhoff Biotic Index, percent 5 dominant taxa, clinger taxa, sensitive taxa, and long-lived taxa.

Data Analysis

In order to test the validity of the Idaho habitat index as a measure of physical disturbance, we investigated four questions.

1) How can we best stratify sites to avoid confounding human disturbance with natural variability? We tested classification schemes based on Rosgen stream class, ecoregion, and stream order.

2) Do the habitat measures provide a good measure of physical disturbance? We chose habitat measures based upon demonstrated correlation with independent measures of human-caused disturbance, including land use in agriculture and urbanization, enumeration of near-site human activities, and, in the montane regions, estimates of disturbance based on the best professional judgment of regional managers.

3) Are the habitat measures related to biological condition? To evaluate this, we tested the component habitat measures and the overall index for correlation with fish and macroinvertebrate metrics.

4) How precise is SHI? We evaluated the precision of SHI and its component measures using data from repeat visits to the same sites.

Classification of sites

We used discriminant function analysis (DFA) to compare different classification schemes. DFA builds a model from a dependent categorical variable, such as an ecoregion, and a set of independent variables, such as habitat measures. DFA creates new linear functions from the original set of independent variables in such a way that groups are separated as far apart as possible. For example, we tested how well habitat measures (the set of independent variables) could discriminate between groups when the sites were grouped according to ecoregion. After defining a solution, one can also test how well the derived model classifies the sites, for example, according to ecoregion. The classification efficiency summarizes the percentage of stream sites that were assigned correctly to their true ecoregion by the model.

We compared three classification schemes; that is, three dependent grouping variables, based on ecoregion, Rosgen class, and stream order. Only the three large ecoregions were used, SRB, NBR, and NR/MR. For Rosgen class we used only the largest classes: A, B, C, and F. We used four categories of stream order: 1, 2, 3, and > 3.

On the other side of the equation, we used five different sets of independent variables: 1) the 10 habitat metrics selected for the SHI, 2) 5 land cover measures, 3) 11 fish metrics, 4) 10 macroinvertebrate metrics, and 5) 7 geographic features.

A combination of three classification schemes and five sets of independent variables yielded 15 separate DFA models to compare. We evaluated each of the 15 models based on their classification efficiency. We used a forward stepwise model that restricted the entry of independent variables into the model. We also used a standard model and found that the results (i.e., the classification efficiencies) were only slightly improved with a stepwise model.

Description of habitat measures

We evaluated the individual measures comprising the habitat index within each region by testing each measure for correlation with disturbance, with fish metrics, and with invertebrate metrics. We evaluated habitat index measures comprising the original habitat index (HI), all of the measures comprising the pool quality index, and several new measures, such as the number of Wolman size classes, which we derived from transect data. In all, 39 habitat measures were tested, though it was not possible to adequately test all of the measures because data for all measures were not collected for all sites. Consequently, sample sizes became too small in many cases for valid tests, particularly for measures related to pools.

For convenience, we grouped 31 of the 39 individual habitat measures according to the 13 categories used in the EPA's Rapid Bioassessment Protocols habitat assessment document (Barbour et al. 1998). The individual habitat measures are grouped and described below (Table 5-2). Eight additional measures related to pool quality did not fit into this scheme and are described last.

1. Epifaunal substrate/available cover. Four different habitat measures were concerned with relative quantity and variety of natural structures in the stream: instream cover (from the

original HI), large organic debris, percent submerged cover, and percent undercut banks (the latter two from the pool quality index). The latter three of these were scored from data collected in the field, while instream cover was a measure scored in the field.

2a. Embeddedness. Monotonous benthic substrate limits the diversity and richness of both fish and invertebrates. We evaluated seven measures related to the extent to which rocks (gravel, cobble, and boulders) and snags are covered or sunken into the silt, sand, or mud of the stream bottom. We included in this category measures that were related to the heterogeneity of the substrate composition. The seven measures included embeddedness (from the original HI), percent fines, which we evaluated in five different ways, and number of Wolman size classes.

We tested the raw measurement of percent fines as included in the bottom substrate evaluation of the original HI. We also tested the score associated with the raw data. Both of measures were based on fine sediments less than 6.5 mm in size and enumerated by means of the modified Wolman pebble counts within and outside the wetted stream perimeter. To refine the parameter, we recalculated percent fines based on particles less than 2.5 mm in size, and generated measures of percent fines within the entire width of the streambed (within wetted width plus outside wetted width), within the wetted width only, and outside the wetted width only. We evaluated the number of modified Wolman particle size classes collected within the wetted width as an approximation of the heterogeneity of substrate in the sampled transect. The embeddedness measure and the bottom substrate measure are field-scored measures; that is, estimates made by eye, while all of the others in this category were evaluated using raw measurements.

2b. Pool substrate characterization. We were unable to test any measures in this category because very few sites with pool/glide dominance were included in the data; these were the only sites for which the assessment was made. This measure differs from the pool substrate measure (listed under 11 below) because it is measured for a pool/glide dominated site, not strictly within a pool.

3a. Velocity/depth combinations. Patterns of velocity and depth were assessed in the original HI with the velocity/depth combinations measure. We tested the field score, estimated in the field, that summarized the number of combinations present at the stream site of slow or fast flow paired with shallow or deep water.

3b. Pool variability. We were unable to test any measures in this category because very few sites with pool/glide dominance were included in the data; these were the only sites for which the assessment was made.

4. Sediment deposition. The average size of substrate in pools from the pool quality index was the only relevant measure in this category.

5. Channel flow status. Although discharge measurements were available in the data, these measures do not directly relate to the degree to which the channel is filled with water. No measures directly relating to this category were available for testing. Instead, we tested three measures relating to the dimensions of stream channels: the width/depth ratio measurements,

the scores associated with the width/depth ratios from the current habitat index, and the field-scored channel shape assessment which is also from the current habitat index.

6. Channel alteration. No measures relating to this category were available for testing.

7a. Frequency of riffles. The pool/riffle ratio measure, from the original HI, seemed to be the best measure relating to larger-scale habitat heterogeneity.

7b. Channel sinuosity. Stream sinuosity was evaluated in the field as low, medium, high, or braided.

8. Bank stability. The measure from the original HI evaluates whether stream banks are eroded (or have the potential for erosion), using an estimation of the percent of a streambank in stable condition and whether or not it is covered by vegetation. We tested the percentage of stable streambanks, as well as the score associated with the percentage from the original HI.

9. Bank vegetation protection. The amount of vegetative protection afforded to the stream bank and the near-stream portion of the riparian zone is evaluated in the original HI by 3 measures: the percent of stream bank covered by vegetation (stable or unstable), canopy cover, and the field-scored disruptive pressures. We evaluated the percent and the associated scores for bank cover.

10. Riparian vegetative zone width. The width of natural vegetation from the edge of the stream bank through the riparian zone was included in the original HI by the field-scored zone of influence.

11. Other pool measures. Several additional habitat measures were associated with pool quality. We tested nine measures: a pool quality index (developed by DEQ), number of pools, maximum pool depth, tail out depth, pool length, maximum pool width, residual depth, substrate size, and percent of undercut banks.

Where data for multiple pools were given for a single site, an average value of each measure was tested. We also tested values for the "best" pool present at a site, determined by scoring five measures for individual pools and selecting the pool with the highest score. To calculate the pool quality index, scores were applied as suggested in the field data form based on residual depth, average substrate size, overhead cover, percent undercut banks, and percent submerged cover (BURP 1999). The number of pools measured at each site varied from zero to four. We tested the sum of the number of pools as an additional habitat measure.

Evaluating habitat measures

We selected habitat measures based on their significant association with 6 measures of human disturbance (5 in the SRB), 11 fish metrics, and 10 invertebrate metrics. Habitat measures with significant tests in the most categories were selected for a revised habitat index. We used nonparametric tests based on ranks to avoid any concerns about the underlying distributions of the variables: these were Spearman's *r* for tests of correlation and the Mann-Whitney U-test for two-sample comparisons. We used one-sided tests and did not

included tests as significant if they were in the direction opposite of what was predicted. For example, if the number of salmonid age classes significantly increased with urbanization, we did not count it as a significant test.

We evaluated the repeatability of SHI and its component measures graphically by plotting the three repeat measures from each site. We also calculated the coefficient of variation (C.V.) as an estimate of each measure's statistical precision. To estimate the standard deviation (s.d.) we used data from the 20 sites visted twice in 2001 and a one-way ANOVA. To estimate the mean, we used the larger data set because these sites represented a more complete range of values. Then we calculated C.V. as,

$$\text{C.V.} = \left(\frac{s.d.}{\overline{X}} \right) \times 100\% .$$

The C.V. provides a convenient way of comparing the precision of measures that have different ranges of values because each measure's variance is divided by its mean. A higher C.V. indicates lower precision, or greater dispersion; lower C.V. values indicate higher precision and are preferred.

We used statistical power analysis to determine the amount of change in SHI required to indicate a statistically significant difference. We calculated the minimum detectable difference (MDD) for the index based on a two-sample *t*-test with three replicates with alpha equal to 0.05 and power (1 – beta) of 0.80 (Zar 1984; Peterman 1990). We estimated the variance using ANOVA.

$$\text{MDD} = \sqrt{\frac{2s_p^2}{n}} \left(t_{\alpha,\nu} + t_{\beta(1),\nu} \right),$$

where s^2 = estimated variance for repeat visits, $n = 3$, t = Student's t for alpha = 0.05 (two-sided), beta = 0.20 (one-sided) and $\nu = 2\ (n - 1) = 4$.

Scoring criteria were developed for each metric based on the percentiles for the larger data base. We used data from 1,494 riffle sites sampled in 1997 and 1998 with the number of sites in each region as follows: 393 sites in the SRB, 169 sites in the NBR, and 932 sites in the NR/MR ecoregion. Histograms of the ranges of measures within each ecoregion were plotted to compare the distributions of values for each measure. Cumulative distribution functions for each measure by ecoregion were plotted to illustrate differences in the distribution of values.

We assigned scores based on percentiles of the distributions for each measure. We re-scaled the measures to range from 0-10 using the 10th, 50th, and 90th percentiles to establish cut-off values for 0, 5, and 10 respectively. Cut-off values for the remaining scores were based on a simple division of the values for the measure when the distribution was uniform, or even, across the range. When the values were skewed, for example, for large organic debris, divisions were defined so that they better followed the shape of the distribution.

Five measures (instream cover, embeddedness, channel shape, disruptive pressures, and zone of influence) were originally field-scored from 0 to 20 or 0 to 10. The field-scoring scheme limited how much we could re-scale the measures. In these cases, we grouped values to approximate an even distribution based approximately on the percentiles. For example, for channel shape the scores of 0, 1, 14, and 15 were much less likely to occur than the middle values, 4 to 10. Therefore, we combined the less likely values into a single score. Field scores from 0 to 1 were scored as 0 and values from 14 to 15 were scored as a 10. Where reasonable, metrics were assigned the same scoring criteria across ecoregions.

RESULTS

Classification of Sites

DFA models correctly classified 37 to 84 percent of stream sites depending on the model used (Table 5-3). The best combination included ecoregion as the dependent (grouping) variable and land cover as the independent (predictive) variable, illustrating how patterns of land use follow geographic features. Ecoregion also provided the best classification results for fish (74%), invertebrates (78%), and geographic features (72%). For habitat measures, classification based on ecoregion and Rosgen class did equally well. The sample sizes were similar across comparisons, except for models based on fish metrics as the independent variables; these had about half as many stream sites.

Table 5-3. Percentage of Idaho sites correctly classified by discriminant function analysis (DFA) for different grouping variables and different sets of predictor variables.
Each cell in the table below represents a unique DFA. Sample size for each test are shown. Grouping variables were ecoregion (SRB, NBR, and NR), stream order (1st, 2nd, 3rd, and > 3rd), and Rosgen class (A, B, C, and F). Independent variables used to define groups were 10 habitat measures selected for the revised habitat index, 5 land use measures (% agriculture, forested, riparian, and urban, number of human activities), 11 fish metrics, 10 invertebrate metrics, and 7 geographic features (elevation, gradient, flow, valley shape, sinuosity, width and depth).

Grouping variable	Habitat measures	Land use	Fish	Invertebrates	Geographic
Ecoregion	63%	84%	74%	78%	72%
***N* =**	*154*	*147*	*94*	*215*	*212*
Order	47%	37%	63%	46%	54%
***N* =**	*161*	*167*	*62*	*167*	*166*
Rosgen	64%	43%	58%	50%	64%
***N* =**	*152*	*227*	*95*	*227*	*226*

Evaluating Human Disturbance

Human disturbance was quantified for each region using the percent land use in agriculture and urbanization and the number of near-site activities. We used the percent land cover in forests and riparian vegetation to indicate less disturbed habitat conditions. The SRB had the lowest incidence of agricultural land use, where percent cover ranged from 0 to 8 percent of the watershed; the mean value was 0.7 percent (Figure 5-2, top).The sites in the SRB were not representative of conditions in this region because agriculture is typically much higher. The NBR ecoregion had the highest incidence of agricultural land use, ranging from 0 to 56 percent; the mean value was 18 percent. Agricultural land use in the NR/MR regions ranged up to 26 percent, but the mean value was 0.8 percent, similar to that of the SRB.

Urban land use was not high in any of the regions we studied; highest values in the SRB and NRB were less than 1 percent, while in the NR/MR regions, the maximum urban land use was 3 percent (Figure 5-2, middle). Ranges of forested land uses were much larger in all regions (Figure 5-2, bottom). In the SRB, as much as 82 percent of watersheds was forested, which was, again, not representative because this ecoregion is dominated by shrubland. In the NBR ecoregion, up to 69 percent of land was forested and up to 99 percent in the NR/MR region.

We also developed a filter for each ecoregion based on extreme values for human disturbance measures. We used the highest percent urban, percent agriculture, and number of activities in each region to filter out the most disturbed sites. In the SRB we used percent urbanization greater than 0, agriculture greater than 7 percent, and number of near-site activities greater than 3 percent. Only 4 sites satisfied these criteria, so the filter was not used to test habitat measures. For the NBR we used percent urbanization greater than 0, agriculture greater than 25 percent, and number of activities greater than three. A sample size of 15 was large enough for testing this measure. For the NR/MR very few sites had values for urbanization or agriculture greater than 0 percent. For this region we used the status calls based on best professional judgment of regional managers.

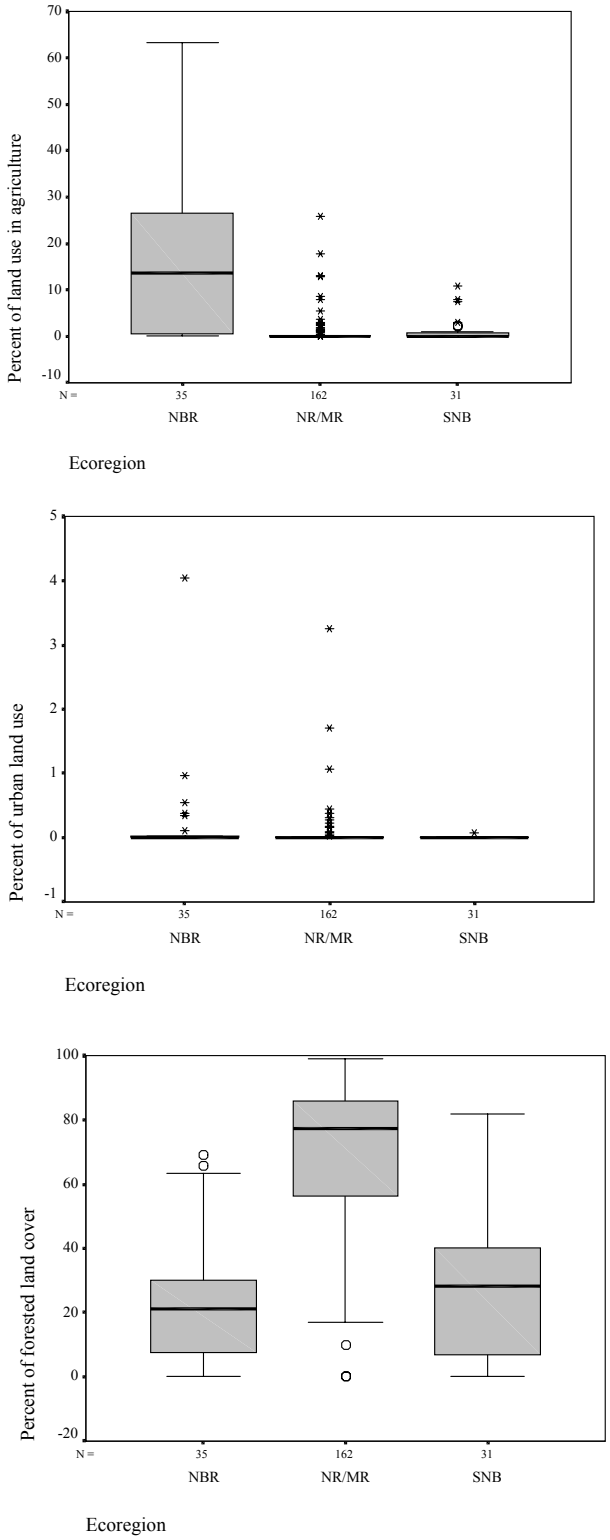


Figure 5-2. Comparison of land cover by for different ecoregions (n=228). Outliers are represented by circles, and extreme outliers by stars.

Habitat Measure Testing

We summarized the results of statistical testing because so many tests were performed: 39 habitat measures with 5 land use measures, and 21 biological metrics (Appendices H-J). Rather than evaluate and describe each test separately, we added the number of significant results in each category (human disturbance, fish condition, and invertebrate condition) within each ecoregion and evaluated the performance of habitat measures based on the totals (Table 5-4).

Table 5-4. Number of significant associations for habitat measures and human disturbance, fish metrics, and invertebrate metrics.
Each cell has the number of significant tests for each habitat measure and either 6 measures of human disturbance (5 for SRB), 11 fish metrics, or 10 macroinvertebrate metrics. Total number of significant associations are summarized for each ecoregion and the percentage of tests that they represent. The table summarizes results found in Appendices H-J. + Measure indicates inclusion in the original index while * measure indicates selection for the SHI.

	SRB			**NBR**			**NR/MR**		
Habitat measure	**Land use**	**Fish**	**Bugs**	**Land use**	**Fish**	**Bugs**	**Land use**	**Fish**	**Bugs**
Original habitat index	2	6	4	5	2	8	2	2	8
1. Epifaunal substrate/cover									
+ * Instream cover	1	7	5	5	1	10	1		8
* Large organic debris	1	2	4	4		5	2	2	10
Submerged cover (pools)			2		3	2	1	1	
Undercut banks (pools)		1	1		1	6	1		
2. Embeddedness									
% fines < 6.5 mm (raw)		9	1	4	3	9	1	4	7
+ % fines < 6.5mm (scored)		9	1	4	3	9	2	4	6
% fines ≤ 2.5 mm		10	4	4	3	4	1	2	

	SRB			NBR			NR/MR		
Habitat measure	**Land use**	**Fish**	**Bugs**	**Land use**	**Fish**	**Bugs**	**Land use**	**Fish**	**Bugs**
* % fines ≤ 2.5 mm WW		9	6	4	3	6	1	3	7
% fines ≤ 2.5 mm OW		6	5	3	4	5		4	1
+ * Embeddedness	1	3	3	5	1	9	2		5
* Number of Wolman size categories		6	3	3	1	6	1		4
3. Velocity and depth									
+ Velocity/ depth ratios				5	1	7			2
4. Sediment deposition									
Substrate size (in pools)	1	1	2		1			2	7
5. Channel dimensions									
Width/depth ratio (raw)			2				3	1	3
+ Width/depth ratio (scored)							3	1	3
+ * Channel shape				1	4	5	2	2	8
6. Channel alteration									
7. a. Riffle frequency									
Pool/riffle ratio (raw)				2	1	2	1	1	1
+ Pool/riffle ratio (scored)				2	1	2	1	1	1
b. Channel sinuosity									
Channel sinuosity					4		1	2	

	SRB			NBR			NR/MR		
Habitat measure	**Land use**	**Fish**	**Bugs**	**Land use**	**Fish**	**Bugs**	**Land use**	**Fish**	**Bugs**
8. Bank stability									
Bank stability (raw)		2				4	2		9
+ Bank stability (scored)		3				2	3		9
9. Bank vegetation protection									
* Bank vegetation (raw)	1	3	3			2	2		9
+ Bank vegetation (scored)	1	3	2			3	3		8
* Canopy cover (raw)	1	5	4	2	3	8	1		6
+ Canopy cover (scored)	1	3	3	1	3	5	2		4
Canopy cover		2		1					8
+ * Disruptive pressures	1			3	1	6	2	2	10
10. Riparian vegetative zone									
+ * Zone of influence				1	3	4	2	1	7
11. Other pool measures									
Pool quality index			1				2	1	7
Number of pools					1	3	1	2	9
Max pool depth						2	1		
Tail out depth							1		1

	SRB			NBR			NR/MR		
Habitat measure	**Land use**	**Fish**	**Bugs**	**Land use**	**Fish**	**Bugs**	**Land use**	**Fish**	**Bugs**
Pool length							1		
Max pool width								2	
Residual depth (of pools)				1		2	1		
Substrate size	1		1	1		1	1	1	8
% Cover			4					1	5
Undercut bank			1			1	1		2
Total significant	**10**	**84**	**58**	**56**	**46**	**130**	**51**	**40**	**175**
% of tests significant	**5%**	**19.1%**	**14.5%**	**23.3%**	**10.5%**	**32.5%**	**21.2%**	**9.1%**	**43.8%**

Six habitat measures were significantly correlated with at least one measure of human disturbance in all three ecoregions; these were instream cover, large organic debris, embeddedness, percent canopy cover, disruptive pressures, and substrate size in pools. Most measures were also correlated with several biological metrics in all regions; these were the strongest performing measures. Four habitat measures related to percent fines were correlated with fish and invertebrates in all three regions and in most cases with land use as well. Five habitat measures were significantly associated with at least six of the nine possible categories used to test; these were number of Wolman size classes, channel shape, pool/riffle ratio, bank vegetation, and zone of influence. These five tended to be associated less often with measures in the SRB region.

In general, the SRB sites produced very few correlations between habitat measures and either watershed-scale measures of disturbance or the near-site disturbance measures, probably because of the limited range of conditions represented by our subset of sites. Only 5 percent of tests were significant, the percentage expected due to chance alone. In contrast, 23 percent of the statistical comparisons were significant in the NBR and 21 percent in the NR/MR region.

About the same number of significant associations between habitat measures and fish metrics occurred in the NBR and NR/MR (11 % and 9 % of tests, respectively). In the SRB, fish metrics were significantly correlated more often (19%) and were the most responsive to habitat measures of the three sets of variables. Among the individual fish metrics, of interest is the contradictory behavior of the sculpin age classes metric in the NBR, where associations with habitat measures, some of them strong, almost invariably were directed contrary to expectations; that is, numbers of sculpin age classes increased as disturbance increased.

In general, habitat measures were correlated most often with invertebrate metrics. Associations were significant for 15 percent of the tests in the SRB, 33 percent in the NRB and 44 percent in the NR/MR.

1. Epifaunal substrate/available cover. Field-scored instream cover and number of pieces of large organic debris were significantly associated with the greatest number of disturbance measures and biological metrics for all three ecoregions. Fish metrics were less responsive to increases in instream cover than expected in all regions except the SRB, where it was significantly correlated with four cold water fish metrics, sculpin age classes, and the percent of sensitive individuals. Large organic debris increased in all ecoregions as the percent of forested land cover increased. Instream cover was included in the both the original and revised SHI. Large organic debris was a new measure included in the SHI.

2. Embeddedness. The measure of fines less than or equal to 2.5 mm inside the wetted width performed slightly better than either measure of fines based on the larger size (< 6.5 mm) or on the measure of fines outside the wetted width. Several measures of percent fines and embeddedness were associated with human disturbance in all three regions and with many fish and invertebrate metrics in all three regions. The number of Wolman size classes, which we interpret as a measure of substrate heterogeneity, was correlated with biological metrics in the SRB, with land use and metrics in the NRB, and with land use and macroinvertebrate metrics in the NR/MR.

Measures of percent fines were strongly associated with numerous macroinvertebrate metrics in all three regions. Among the fish metrics, the percent of cold water individuals gave unexpected results for five of the seven measures in this category.

The bottom substrate measure (percent fines < 6.5 mm) from the original HI was replaced by percent fines less than or equal to 2.5 mm inside the wetted width. The embeddedness measure, a component of the original HI, was retained in the SHI. We added the Wolman size classes measure to the SHI.

3. Velocity/depth combinations. This measure was strongly correlated with five of six measures of disturbance as well as with seven macroinvertebrate metrics in the NBR, but was not related to disturbance measures or biology in either of the two other regions. Therefore, this measure was not included in the SHI.

4. Sediment deposition. Average substrate size in pools was significantly correlated with seven of 10 invertebrate metrics in the NR/MR, but failed to show a strong association with fish. In the other two regions, this measure did not generally correlate with measures of land use or with biological metrics.

5. Channel dimensions. Measures of width/depth ratios were correlated with human disturbance and biological metrics in the NR/MR only (except for two invertebrate metrics in the SRB). These measures were not included in the SHI. Channel shape was correlated with disturbance and fish and macroinvertebrate metrics in NBR and the NR/MR, but not in the SRB. We retained channel shape in the SHI because of its strong associations with many measures in two ecoregions.

6. Channel alteration. No measures were tested.

7. Riffle frequency and sinuosity. The pool/riffle ratio, which we interpreted as a measure of larger-scale habitat heterogeneity, was correlated with a small number of measures of disturbance and biological conditions in the NBR and NR/MR. It was not correlated with any measures in the SRB. The number of salmonid age classes was the only fish metric that responded to changes in this measure in any region. Sinuosity was only correlated with fish metrics in two ecoregions. Neither measure was retained for the SHI because of the very small number of overall significant associations.

8. Bank stability. Raw measures and scores associated with streambank stability were significantly correlated with disturbance measures only in the NR/MR region, where they were also associated with nine of the 10 macroinvertebrate metrics. In the other two regions, these measures were not significantly correlated with disturbance measures, nor were they related to more than a very few fish or macroinvertebrate metrics; therefore bank stability was not retained for the SHI.

9. Bank vegetation protection. Bank vegetation cover, tested as either a percentage or scored measure, was significantly correlated with invertebrate metrics in every ecoregion, with fish metrics in the SRB, and with disturbance in the SRB and NR/MR. Canopy cover had significant correlations in every category except fish in the NR/MR. The disruptive pressures measure was significantly associated with at least one measure of disturbance in every ecoregion and with fish and macroinvertebrate metrics in the NBR and NR/MR. Bank cover and disruptive pressures, components of the original index, were retained for the SHI. The canopy cover measure was added to the SHI.

10. Riparian vegetative zone width. This field-scored measure was not associated with any disturbance or biological measure in the SRB, but was significantly associated with all three in both the NBR and NR/MR. We retained zone of influence in the SHI because of its correlation with land use, fish, and macroinvertebrate metrics in two ecoregions.

11. Pool quality. Only one of the 10 pool quality measures we tested was correlated with disturbance in all three regions, namely, substrate size. In general, most of the significant tests occurred for the NR/MR region. The pool quality index was associated with disturbance and macroinvertebrate metrics in the NR/MR. Although fish typically prefer pools, no measures related to pool quality were associated with more than one or two fish metrics in any of the regions. Very small sample sizes for many of the tests, especially for fish in the SRB, and for both fish and invertebrates in the NBR, severely compromised our ability to test these measures. Though associated with disturbance and biological metrics, we did not include pool substrate size in the SHI because it was conceptually redundant with percent fines.

Selecting Measures for the Revised Habitat Index

The 10 best habitat measures were selected based on their association with human disturbance and biological condition. Five habitat measures were significantly associated with land use in all three regions and with many biological metrics in each region as well; these were instream cover, large organic debris, embeddedness, canopy cover, and disruptive pressures. These were the strongest measures. In the next tier were the different versions of percent fines, all of which were associated with land use measures in two regions and with many biological metrics in all regions. Among these, we selected percent fines less than or equal to 2.5 mm inside the wetted width.

Next were five measures that had significant associations in at least 6 categories. Number of Wolman size categories was correlated with land use in two regions and with biological metrics in all three and was added to the index. Channel shape was correlated with all measures in two regions and was retained in the index. Pool/riffle ratio had significant associations in all categories for two regions, but only one or two in each. The small number of significant associations led to its elimination from the index. Bank vegetation was associated with biological metrics in all three regions and was retained. Zone of influence was associated with all measures in two regions and was also retained in the index. Other measures had fewer significant associations in fewer categories and were therefore not included.

The range of values differed for each of the habitat measures; therefore, we used scoring criteria to re-assign each habitat measure a new value from 0 to 10 in order to standardize the scoring scale (Table 5-5). Seven of the 10 metrics had similar ranges (Appendix L) and distributions (Appendix M) for the three different ecoregions, and three required different scoring criteria for different ecoregions. For instream cover, disruptive pressures, and zone of influence, scoring criteria remained the same as for the original HI, because it was not possible to rescale these field-scored measures. For embeddedness, scoring criteria were linearly rescaled from the 0-to-20 scale used in the original HI to 0-to-10. The channel shape measure was scored in the original HI on a scale of 0-to-15; it was rescaled to 0-to-10 based on the distribution of original HI scores.

Higher values for large organic debris and lower values for percent fines in the NR/MR necessitated different scoring criteria. Canopy cover was highest in the NR/MR, and lowest in the SRB; and, therefore, was scored to reflect those differences in each ecoregion.

Table 5-5. Scoring criteria for the SHI.
Habitat measures marked with an asterisk (*) were based on habitat measures that were estimated by eye in the field for the original habitat index. Scoring criteria for seven habitat measures were the same for all three ecoregions; scores for three habitat measures depend on ecoregion and are listed separately.

Table 5-5-A. Snake River Basin

Habitat Measure	Score										
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**0**
Instream cover*	0	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	17-18	19-20
Large organic debris (number pieces)	0	1	2	3	4	5-9	10-14	15-19	20-24	25-39	≥40
Percent fines <2mm in wetted width	≥60	59.9-50	49.9-40	39.9-30	29.9-25	24.9-20	19.9-15	14.9-10	9.9-7	6.9-5	<5
Embeddedness *	0	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	17-18	19-20
Wolman size classes (number)	1-3	4				5	6	7	8	9	10
Channel shape *	0-1	2-3	4	5	6	7	8	9	10-11	12-13	14-15
% Bank vegetation cover	<30	30-39.9	40-49.9	50-59.9	60-69.9	70-79.9	80-84.9		85-89.9	90-94.9	95-100
% Canopy cover	<5	5-9.9	10-14.9	15-19.9	20-29.9	30-39.9	40-49.9	50-59.9	60-69.9	70-84.9	≥85
Disruptive pressures *	0	1	2	3	4	5	6	7	8	9	10
Zone of influence*	0	1	2	3	4	5	6	7	8	9	10

Table 5-5-B. Northern Basin and Range
Scoring criteria for three habitat measures that differed by ecoregion. Other habitat measures for NBR are as shown in Table 5-5-A.

Habitat Measure	Score										
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**0**
Large organic debris (number pieces)	0	1	2	3	4	5-9	10-14	15-19	20-24	25-39	≥40
Percent fines <2mm in wetted width	≥60	59.9-50	49.9-40	39.9-30	29.9-25	24.9-20	19.9-15	14.9-10	9.9-7	6.9-5	<5
% Canopy cover	<5	5-9.9	10-14.9	15-19.9	20-29.9	30-39.9	40-49.9	50-59.9	60-69.9	70-79.9	≥80

Table 5-5-C. Northern and Middle Rockies
Scoring criteria for three habitat measures that differed by ecoregion. Other habitat measures for NMR are as shown in Table 5-5-A.

Habitat Measure	**Score**										
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**0**
Large organic debris (number pieces)	0	1-3	4-7	8-12	13-17	18-26	27-36	37-48	49-60	61-73	>73
Percent fines <2mm in wetted width	≥40	35-39.9	30-34.9	25-29.9	20-24.9	15-19.9	10-14.9	7-9.9	5-6.9	3-4.9	<3
% Canopy cover	<10	10-19.9	20-24.9	25-29.9	30-39.9	40-49.9	50-59.9	60-69.9	70-79.9	80-89.9	≥90

Table 5-6. Correlation values (Spearman's r) for the original habitat index and the SHI. Correlation coefficients are only shown for significant correlations. Sample sizes are given for all tests.The SHI does not include the habitat measure for Wolman size classes, and the original measures for percent fines < 6.5 mm was used instead of the new measure based on fines < 2 mm. An 'x' indicates significant correlation in the opposite direction predicted.

Table 5-6-A. Measures of human disturbance and land cover

		Percent Urban	**Percent Ag**	**Percent Forest**	**Percent Ripar**	**Number of Activities**
NR/MR	Original HI					-0.22**
	N=	162	162	162	162	113
	SHI		-0.158*			-0.259**
	N=	160	160	160	160	111
SRB	Original HI		-0.39*			-0.38*
	N=	31	31	31	31	26
	SHI		-0.376*			
	N=	31	31	31	31	26
NBR	Original HI	-0.36*	-0.56**	0.47**	0.43**	
	N=	35	35	35	35	21
	SHI	-0.451**	-0.63**	0.576**	0.376*	
	N=	35	35	35	35	21

Table 5-6-B. Habitat indexes and fish metrics

	Native Taxa	**% Non-Indigenous**	**% Omni + Herb**	**% Anom-alies**	**Cold Natives**	**# Sculpin Ages**	**% Sens. Native**	**% Cold Individ.**	**# Salmon. Ages**	**CPUE-cold**	**# Cold Individ.**
NR/MR											
Original HI			x						0.25*		
	60	60	60	60	60	60	60	60	60	60	60
SHI									0.233*		
	60	60	60	60	60	60	60	60	60	60	60
SRB											
Original HI			-0.26*		0.46**		0.29*	0.42**	0.47**	0.53**	0.31*
	40	21	40	40	40	40	40	40	40	40	40
SHI					0.437**		0.3*	0.378**	0.5**	0.584**	
	40	21	40	40	40	40	40	40	40	40	40
NBR											
Original HI						-0.46**	0.37*		0.53**		
	34	21	34	34	34	34	34	34	34	34	34
SHI						-0.463**	0.408**		0.516**		
	34	21	34	34	34	34	34	34	34	34	34

Evaluating the Revised Habitat Index

We compared the correlations for the original index (HI) and SHI with disturbance and biological metrics (Table 5-6). Improvements were modest at best. For human disturbance one significant correlation was gained and one lost. For fish metrics, two significant correlations were lost. For invertebrate metrics, improvements were slight but consistent. Three additional invertebrate metrics were significantly correlated with the SHI and the correlations that were significant remained so with increased *r*-values. Though small, increases in the correlation coefficients were consistent for all 20 of the significant correlations.

Precision was higher for SHI than for its component metrics, with the exception of one measure: number of Wolman size classes (Table 5-7). Because the SHI was calculated as the sum of scored metrics, it is similar to an average. We expect the variability of any measure of central tendency to decrease as a function of the number of elements used in its calculation, just as the variance of the mean decreases as a function of n. Similarly, multimetric indexes such as SHI tend to have lower variance than their component measures.

Most habitat measures showed a similar range of C.V. values between 15 to 40 percent. The exception was large organic debris with a C.V. > 300%. This statistic reflects the fact that one crew may observe 35 pieces while another crew may observe 55 pieces. The difference is not particularly meaningful from a biological point of view; any amount greater than 30 pieces is a lot of organic debris for the southern part of the state. The process of scoring measures from 0 to 10 reduces the variability for measures that have skewed distributions. For large organic debris, the C.V. for the scored measure declined dramatically to 43.2 percent.

Table 5-7. Coefficients of variation for SHI and its component measures.
For the SHI and each of its component measures are shown the mean derived from the larger data set, the number of sites used to estimate the mean, the standard deviation (s.d.) for 20 sites visited twice in 2001 and the coefficient of variation (C.V.). For some measures, the C.V. estimated for Oregon data is shown for comparison (Kaufmann et al. 1999).

Measure	Mean	N	s.d.	C.V.	C.V. (Oregon)
SHI	53.7	282	8.4	15.7	NA
Instream cover	12.7	296	2.6	20.3	24
Large organic debris	15.1	296	49.3	327.3	NA
Percent fines <2mm in wetted width	21.5	167	8.2	38.3	36
Embeddedness	11.6	296	3.1	26.8	20
Wolman size classes	8.5	164	0.5	5.6	NA
Channel shape	7.1	296	1.9	26.5	NA
% Bank vegetation cover	82.4	296	18.8	22.8	25
% Canopy cover	37.5	294	15.1	40.2	33
Disruptive pressures	6.6	296	1.6	24.5	17
Zone of influence	5.8	296	1.0	16.6	27

We estimated the residual error for SHI from two ANOVA models; the first model used all three repeat visits and the second model used only the repeat visits from 2001. For the first model, the s.d. was 58.8 and for the second it was 70.8. The small difference between the two models should not be considered meaningful. We interpret these results as indicating that within year differences were similar in magnitude to differences between years (Figure 5-3). Given a s.d. estimate of 70.8, the minimum detectable difference for a two-sample *t*-test would be 25.5. SHI ranges from 0 to 100; dividing that range by 25.5 yielded approximately 4 categories of biological condition that SHI could reliably detect.

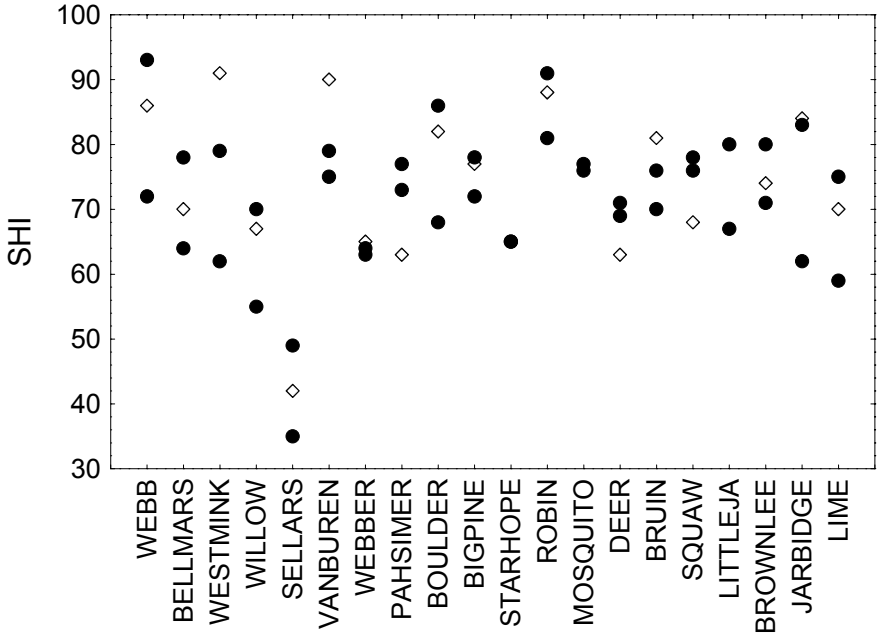


Figure 5-3. Variability of SHI for repeat visit to the same sites.
Twenty sites were sampled twice in 2001 (closed circles) and in a previous year (open diamonds). Most sites were selected as reference sites and therefore do not represent the full range of conditions for Idaho streams.

Of the component measures, the number of Wolman size classes and zone of influence were the most repeatable (Figure 5-4). Most variable, and therefore least precise, were percent fines and large organic debris. Other measures were similar in terms of repeatability.

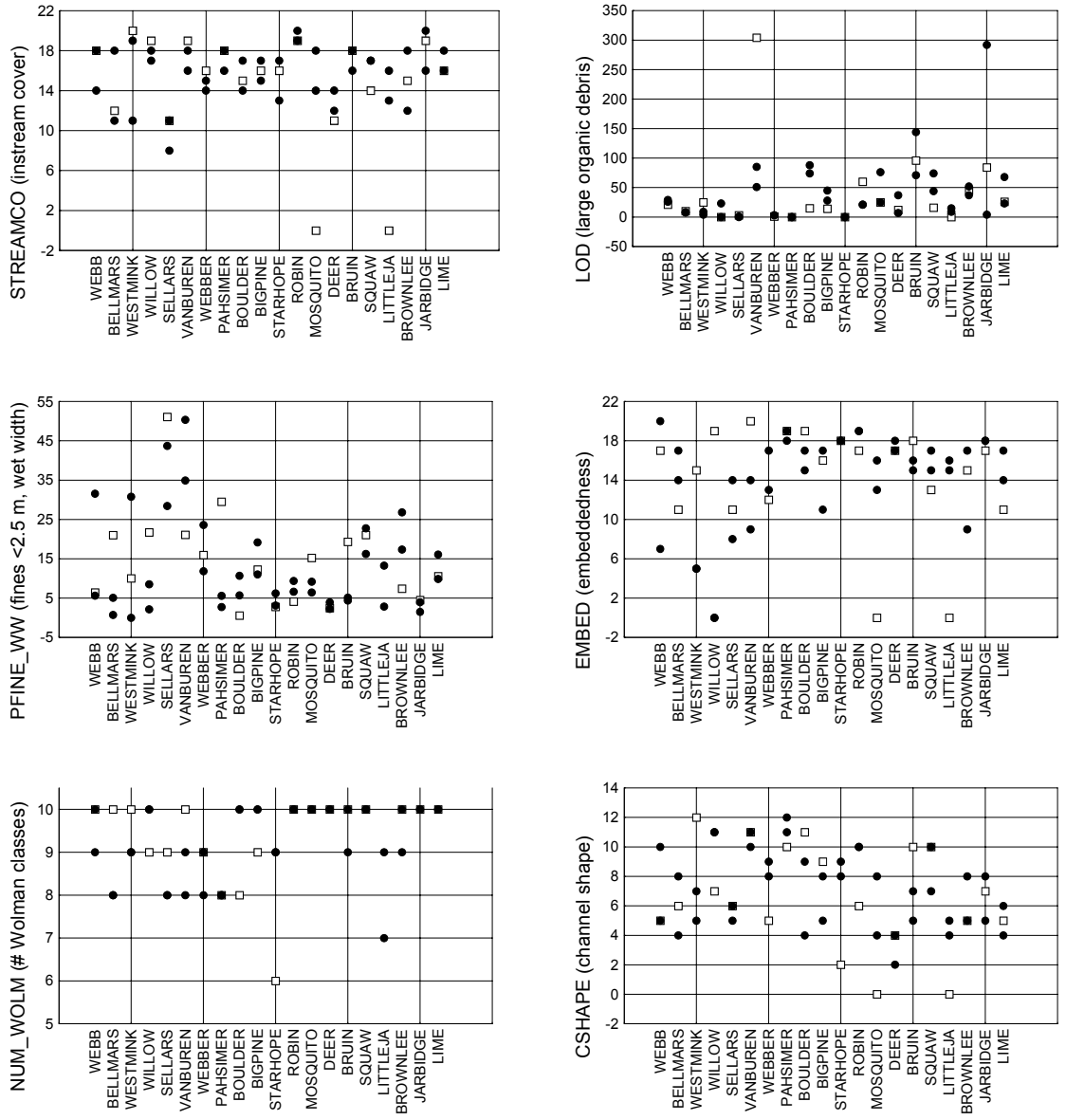


Figure 5-4. Variability of SHI's component measures.
Twenty sites were sampled twice in 2001 (closed circles) and in a previous year (open squares). Some zero values for Starhope, Mosquito and Little Jack indicate missing data.

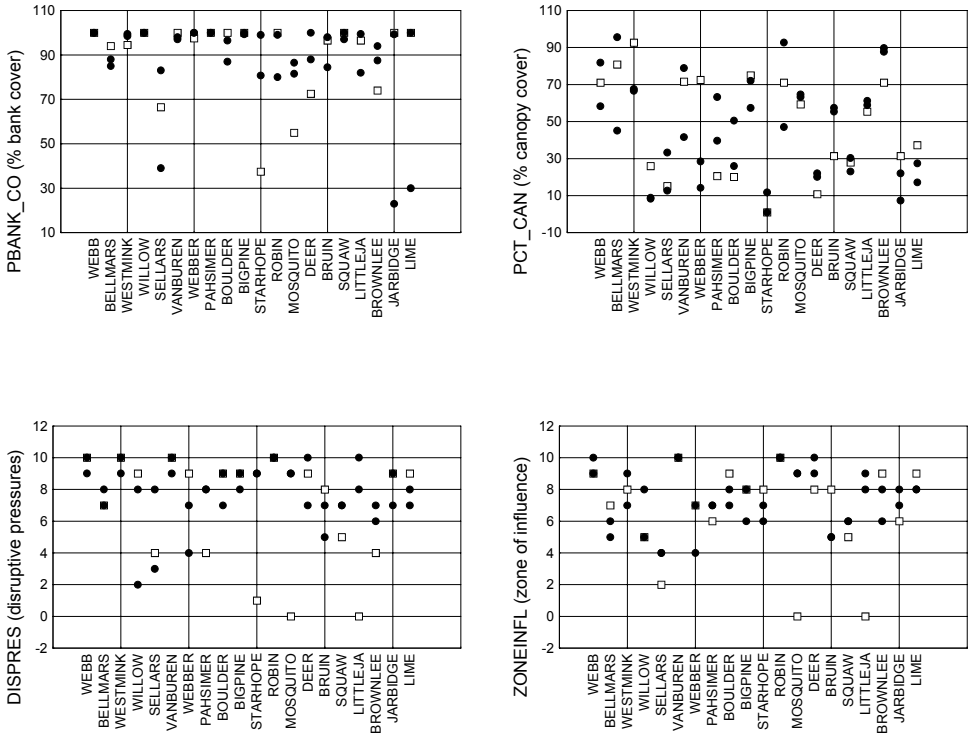


Figure 5-4. *(continued)*

DISCUSSION

The purpose of a habitat index is to summarize the physical condition of stream sites. Human activities can alter or damage stream habitat by removing or destroying vegetation around, above, or within the stream; causing channel widening; increasing sediment in the channel; and destroying overhanging banks. Different human activities affect streams differently, and the type of human activity or land use varies according to ecoregion. We tested habitat measures separately within the three dominant ecoregions because, in Idaho, human activities follow ecoregion more closely than Rosgen class or stream order. Similarly, both geographic and biological measures predicted site membership in groups when groups were based on ecoregions.

Five of the habitat measures in the original index failed to show as many significant associations with disturbance and biological metrics as did four of the new habitat measures. We eliminated these five habitat measures and replaced them with four new measures for a total of 10 measures in the SHI. Association of the overall index with human disturbance did not improve; neither did correlation with fish metrics. The association of the index with invertebrate metrics did consistently improve for all ecoregions.

Classification of Sites

We classified sites based on ecoregion because a larger proportion of sites were correctly classified using ecoregions than Rosgen class or stream order. Results agreed for four different sets of predictor variables derived from very different features of stream sites. Land cover, fish and invertebrate assemblages, and geographic features all classified sites best when sites were grouped according to ecoregion. A fifth set of variables based on habitat measures classified sites equally well for Rosgen and ecoregion, which was not surprising because many of the habitat measures we selected are used to define Rosgen classes. As for other studies (Gerritsen et al. 2000, Hawkins et al. 2000), we found that ecoregions were not a particularly robust classification system. In the end, classification was largely irrelevant because the same habitat measures were consistently correlated across ecoregions. Nonetheless, testing habitat measures within ecoregions represented a convenient way to divide the data and repeat our tests to insure that results for multiple, independent data sets were robust.

Across the three different ecoregions, most of the same habitat measures showed very similar patterns of association with disturbance and with biological metrics. To make assessments easier, we initially planned to select as many of the same habitat measures as possible for all ecoregions. At the end of the analysis, this was easy to do because the habitat measures responded very consistently across ecoregions. The range of values for some measures differed according to ecoregion and for these measures we simply modified the scoring criteria to reflect natural differences. For example, we expect more large organic debris, such as trees and rootwads, and more canopy cover, in forested watersheds of the NR/MR ecoregion.

The ecoregions differed somewhat in their patterns of correlation with measures of land use and biological metrics. In general, habitat measures were somewhat less correlated with human disturbance in the SRB than in the NBR or NR/MR regions. This was probably an artifact of the stream sites available for testing in the SRB, which included a very narrow range of disturbance. Although agriculture is widespread in the SRB, only 3 out of 31 sites had more than 5 percent of the watershed in agricultural land use. In contrast, for NBR, approximately half the sites had more than 5 percent agricultural land use in their watersheds. Three habitat measures (channel shape, disruptive pressures, and zone of influence) were not associated with disturbance or biological metrics in the SRB. However, they were associated with both disturbance and metrics in the other two regions and were included in the SHI based on the assumption that a broader range of human disturbance would probably show an association with these three measures in the SRB.

The NBR and NR/MR regions were similar in their associations with biological metrics as well. Both regions showed more correlations between habitat measures and invertebrate metrics (33% and 44%) than between habitat measures and fish metrics (10% and 9%). In the SRB the pattern reversed with more significant correlations of habitat measures with fish metrics (19%) than with invertebrate metrics (14%).

More interesting to us than the differences between ecoregions were the similarities in the patterns of correlation for the habitat measures. If a habitat measure was associated with

disturbance or biological metrics in one ecoregion, it typically showed similar associations in the other two as well. Similarly, if a habitat measure was correlated with land use, it was usually correlated with fish and invertebrate metrics as well. For the NBR and NR/MR regions, all 10 habitat measures selected for the index were significantly associated with variables in two out of three categories (land use, fish, and invertebrate metrics); and the majority of the 10 habitat measures had correlations in all three categories. When the SRB region was included, seven of the habitat measures showed significant associations in at least two of the three categories. In other words, though the strength of correlation was low overall, significant associations were strongly clustered around certain habitat measures. In the end, this pattern made it more straightforward to identify the best habitat measures for inclusion in the SHI because we did not have to pick and choose between habitat measures from different ecoregions.

Identification of New Habitat Measures

New habitat measures developed for testing fell primarily into three categories: measures of instream habitat complexity, measures associated with Wolman pebble counts, and pool measurements. Of the instream habitat measures, only large organic debris was associated with both human disturbance and biological metrics in all three ecoregions. Several measures related to substrate size classes were also related to disturbance and biological metrics across ecoregions. Most of the measures specific to pools (e.g., tail out depth, submerged cover, and undercut banks) were not consistently associated with disturbance or biological metrics; however, sample sizes for testing these measures were very small in most cases.

Although similar, the three measures of substrate condition included in the SHI were not identical and measure slightly different aspects of substrate condition. Percent fines is a gross measure of the level of sediment present. Absolute size matters to fish laying eggs and invertebrates moving about the substrate. The number of Wolman size classes measures the complexity of the available substrate. Embeddedness is a measure of the armor layer that can prevent movement of nutrients and invertebrates from the surface of the benthos to the hyporheos below.

Wolman pebble count data can be summarized in a variety of ways. The original version of the habitat index calculated percent fines (the bottom substrate measure) for values less than 6.5 mm. Various researchers have specified various particle sizes to define sediment inhibitory to salmonids (Chapman 1988, review in Bjornn and Reiser 1991). Kondolf (2000) points out that a single measure of fine sediment may not be relevant to all life stages of salmonids. Recently, Relyea et al. (2000) used particle sizes of less than 2 mm to develop an index of sensitivity to fine sediments for benthic invertebrates. Although all the measures of percent fines tested here showed strong association with both disturbance and biological condition, sizes less than 2.5 mm showed the strongest associations. We selected fines within the wetted width because this measure was significantly correlated with more measures of disturbance in the NBR and NR/MR. Fines are deposited outside the wetted width during high flow events, when runoff from snowmelt or rainfall normally carries more sediment. Thus the measure of fines outside the wetted width may be more closely related to the magnitude of flow during high flow periods.

The number of Wolman size categories quantifies the substrate complexity at a site and captures more of the shape of the distribution in contrast with single measures related to percent fines (Kondolf 2000). Erosion in the watershed and sediment in the stream channel tend to degrade this complexity and homogenize the substrate. The number of categories was extremely similar across ecoregions even though the sizes of the particles differed.

At each site, it was possible to have pool measurements for up to four pools. We tested pool measures related to the "best" pool at the site and as an average of the multiple pools. Results were similar for variables, whether measured for the one best pool or an average across multiple pools. Pool measures were associated with very few disturbance or biological variables in the SRB and NBR regions. In the NR/MR region, some of the pool measures were correlated with disturbance or biological metrics. We did not include these in the SHI or develop a separate index for the NR/MR region because most of these pool measures such as substrate size, canopy cover, and undercut bank were similar to other habitat measures already included in the index and measured for the entire reach. Pool substrate was similar to percent fines, and undercut banks in pools was similar to channel shape for the reach.

Habitat Measures and Human Disturbance

Results of our analysis indicate that the relevance of habitat measures is not limited to the site scale. Like Roth et al. (1996), we found that habitat features measured at the reach scale correlated with human disturbance measured at the watershed scale. Wang et al. (1997) also found that instream cover, bank stability, and fine sediments were strongly associated with percent agriculture, percent forested land cover, and urban land use in the watershed. Waite and Carpenter (2000) found that differences between agricultural and urban versus forested watersheds were best explained by measures of riparian quality and the amount of riffle habitat in Oregon.

Some habitat measures can be easily interpreted as the mechanisms by which landscape-level disturbance affects stream biota. Percent fines and embeddedness result from erosion upstream. Other measures, such as vegetation cover and riparian zone of influence, are both symptoms and causes of degradation at the reach scale. Forest land cover is expected to stabilize flow regimes, sediment inputs, and channel morphology, and to supply organic material. On the other hand, agricultural impacts are expected to destabilize flow, increase sediment inputs, and reduce the supply of large organic material. Urban land use leads to increased impermeable surfaces and loss of riparian vegetation, which result in altered flow regimes. These types of influences may manifest themselves in habitat measures related to sediment deposition, channel morphology, riparian zone quality, and instream habitat complexity.

For the SRB, habitat measures were correlated with percent riparian cover and number of human activities, but overall, the total number of significant results was no more than we would expect due to chance, about 5 percent. For the NBR, habitat measures were associated most often with percent forest cover; percent riparian cover; and the filter we derived based on the highest values for urbanization, agriculture, and number of activities. For the NR/MR, habitat measures were most strongly associated with forest cover and determinations based on the best professional judgment of regional managers.

In the NBR region, there were stronger associations between habitat measures and human disturbance in general. Sites in the NBR represented the greatest range in disturbance for land cover measures, which meant that greater potential differences existed for habitat measures as well. In contrast, the sites for the SRB had a narrower range of human disturbance. The land cover measures available to us were also a better match for the types of disturbance in the NBR where agriculture and urbanization are two of the most prominent human activities. In contrast, the NR/MR region has human activities that were more difficult to capture with satellite data, such as forestry, grazing, and mining.

For the NR/MR region, 14 habitat measures were also associated with riparian cover but in the opposite direction predicted; that is, as riparian cover decreased, the habitat measures improved. We cannot explain this counterintuitive result, but wonder if it was perhaps an artifact of satellite sampling. Sites in this region typically have a high degree of forest cover. When forest is present, riparian trees may be included as part of the larger forest cover. In contrast, when the forest cover is removed from the watershed, trees remaining near the stream may be classified as riparian rather than forest so that riparian area actually increases for logged watersheds.

Habitat Measures and Biological Condition

Our results show general agreement with other research findings. Fish abundance in streams has been linked to the quality and abundance of instream cover (Bjornn and Reiser 1991), large organic woody debris (e.g., Elliot 1986), overhead cover (e.g., Brusven et al. 1986), and the quality of riparian zones (Waite and Carpenter 2000). Other studies have demonstrated the correlation of fish assemblage metrics with a similar set of habitat measures we recommend for the SHI (Hughes et al. 1988, Wang et al. 1998, Detenbeck et al. 2000). Instream cover, riparian zone quality, stream bank erosion potential, and measures of channel morphology distinguished sites with high fish assemblage biotic integrity scores from those with low scores in low-gradient streams (Wang et al. 1998). Significant association between canopy cover and cold water fish metrics and the number of salmonid age classes in the NRB and SRB supports the idea that cold water obligates require riparian trees to cool water temperatures (Platts and Nelson 1989, Li et al. 1994). In the NR/MR, canopy cover was also associated with cold-water sensitive invertebrates and stoneflies.

In general, invertebrate metrics showed more significant relationships with habitat measures than fish metrics. For the NBR and NR/MR about 10 percent of tests for habitat measures and fish metrics were significant while more than 30 percent were significant for invertebrates. This result is somewhat ironic given that habitat measures were originally developed to predict fish abundance (Fausch et al. 1988, review in Barbour et al. 1998). We suggest that this difference is due to the fact that fish operate at a larger spatial scale and may use a subbasin the way invertebrates use the reach. Fish cover larger distances and may be found in physically disturbed sites because refugia exist nearby.

Some authors have interpreted this as evidence that habitat measures at the reach scale are irrelevant for fish (Porter et al. 2000). We are less inclined to agree with this conclusion because reach-scale habitat measures were correlated with disturbance at the watershed scale for our analysis and for other studies (Roth et al. 1996, Richards et al. 1996). We propose

instead that fish are difficult to measure at the reach scale because they can be anywhere in the stream system on the day of sampling. Low fish density for this study supports this idea; many sites had less than 20 fish sampled.

Other authors have noted that habitat measures tend to be better predictors of fish abundance for small scale studies than for larger scale efforts (Fausch et al. 1988, Clarkson and Wilson 1995), further suggesting that habitat measures may be irrelevant to fish. Dunham and Vinyard (1997) propose an alternative explanation based on sample design rather than imprecision of habitat measures. If fish tend to operate at the level of the subbasin, reaches within subbasins represent pseudoreplicates (Heffner, et al. 1996); in other words, sample reaches represent repeated measures of the true sampling unit, the subbasin. Thus, measures of correlation will be artificially high and variance low for sample designs based on reaches within streams or subbasins. That bias is not present when streams within larger, regional watersheds are sampled because the fish populations are more independent; consequently, the more fair test yields weaker statistical results (Dunham and Vinyard 1997).

Another issue related to sampling design might also be the source of this observation. Many studies calculate a similar list of habitat measures, typically 10-20 measures (review in Bauer and Ralph 1999). Small-scale studies often have fewer sample sites than large scale studies. If the same approximate number of habitat variables are tested, the small scale study has a much larger proportion of independent habitat variables to explain differences in sites. In this case, one runs the risk of overspecifying the model; that is, the large number of predictive variables overwhelms the number of sample sites. On the other hard, larger scale studies typically have more sites, but often about the same number of habitat measures. In that case, there are essentially fewer independent variables per site; and the explained variance is consequently lower for these models.

We conclude that there is measurement error on both sides of the equation (Terrell et al. 1996); habitat measures are rather imprecise and fish are difficult to catch. Nonetheless, the fact that habitat measures were strongly associated with many invertebrate metrics as well as associated with the even more imprecise measures of human disturbance, means that they are meaningful and should be included in the stream assessment process. We suspect that at least as much of the measurement error is associated with the fish metrics as with the habitat measures.

The habitat measures selected for the SHI were strongly associated with biological condition for several reasons. Fish and invertebrates use these habitats associated with instream cover and large organic debris to locate food, control their internal temperatures, hide from predators, and conceal themselves from prey (Reice 1980, Li et al. 1994). Connolly and Hall (1999) found that large woody debris was a better predictor of trout biomass than the history or intensity of logging in the watershed. Percent fines, embeddedness, and the number of Wolman size classes summarize the condition of the benthic substrate where most invertebrates are found and many fish lay their eggs. Monotonous benthic substrate limits the diversity and richness of both fish and invertebrates in streams (Minshall 1984). Channel shape, percent bank vegetation cover, percent canopy cover, disruptive pressures, and zone of influence were related to physical condition of the banks and the terrestrial vegetation. Terrestrial vegetation is one of the primary sources of nutrient introduction to streams. Fungi,

algae, bacteria, and shredding invertebrates release the nutrients, which then spiral through stream communities downstream (Merritt et al. 1984). Many caddisflies use terrestrial material to build cases. Wide riparian zones also buffer erosional sediment inputs.

Patterns of association for particular fish metrics with habitat measures varied by ecoregion. Fish metrics were fairly evenly spread in their response to habitat measures; the exceptions were percent non-indigenous individuals, percent omnivores/herbivores, and percent anomalies. These were significantly associated with very few habitat measures. For the NBR, three fish metrics were more correlated with habitat measures than others; these were percent sensitive natives, percent cold water individuals, and number of salmonid age classes. Number of sculpin age classes was correlated with several habitat measures, but in the opposite direction predicted. We cannot explain this result: sculpins are expected to be sensitive to a variety of disturbances including increased temperatures and loss of habitat. For the NR/MR, correlations were spread fairly evenly across the fish metrics; no single metric had particularly more or less significant correlations than any other.

Patterns of association for invertebrate metrics with habitat measures were very similar for the NBR and NR/MR regions. In the NR/MR region, all the invertebrate metrics were strongly associated with habitat measures. In the NBR, all but two were strongly associated, and these two were still quite strong; the two exceptions were Trichoptera (caddisfly) taxa richness and sensitive taxa richness. For the SRB, the strongest invertebrate measures were stonefly richness, percent stoneflies, and the HBI, which summarizes the relative abundance of generally sensitive taxa.

Statistical Considerations

Table 5-4 represents a total of 4,200 statistical tests. For that many independent tests we would expect about 5 percent of significant associations to be due to chance alone if we set our p-value to 0.05. Our tests were not necessarily independent because biological metrics are often correlated with each other and tend to respond similarly. In other words, if one invertebrate metric is significantly correlated with a measure of disturbance, other metrics are often correlated as well. Thus, in our case, we might expect even more than 5 percent of our significant results to be due to chance alone.

Erroneous conclusions related to statistical significance can occur for two reasons. First, multiple tests of significance for a given p-value (in our case p was set equal to 0.05) yield significant results due to chance alone in proportion to the p-value. In other words, if you perform 100 tests of significance at a level of $p = 0.05$, you are saying that you are willing to accept a Type I level of error, that is, a significant test statistic due to random chance, about 5 percent of the time. For 100 tests, that would be, on average, 5 incorrect results. In our case, for 4,200 tests, we expect about 210 to be the result of Type I error.

The second source of error is related to spurious correlation. Biological metrics tend to be highly correlated with each other because they respond similarly to human disturbance. Thus, if one fish metric happens to be correlated with a habitat measure, it's likely that several others will be as well. In a way, the fish and invertebrate metrics represent different measures of the same underlying factor — that is, biological response to human disturbance. Thus,

multiple significant results for fish metrics do not represent multiple independent tests of the association between a habitat measure and the fish assemblage.

Our approach was specifically designed to avoid conclusions based on Type I errors and spurious correlations. We tested habitat measures with three very different sets of measurements related to watershed and stream condition. Biological metrics and human disturbance are obviously related; metrics were initially selected based on their association with human disturbance. However, the metrics were not selected based on their correlation with watershed land cover, which was the primary method used to measure human disturbance in this study. Similarly, although fish and invertebrate metrics may be correlated because they were both selected for their association with human disturbance, they were not selected based on their association with each other. Thus, the three sets of data used to test habitat measures were independently derived though not necessarily unrelated.

If 5 percent of the statistical tests are significant, we suspect that Type I error may be the cause. But when the same 5 percent of the tests are significant for land use, fish, and invertebrates and we see the same habitat measures being significant across three different ecoregions, we are much more confident that the significance is meaningful rather than due to chance alone. A simple example illustrates why. For 100 tests with the p-value set to $p = 0.05$, we expect 5 significant test results due to chance alone. Similarly, for an independent set of 100 tests we again expect 5 significant results (at $p = 0.05$) due to chance. However, the probability that the same 5 tests from each set of 100 tests would be significant is 0.25 percent, or less than 1 percent; that is, we expect much less than one test in 200 tests (that is, two sets of 100 tests each) to be significant due to chance alone. In our case, habitat measures were selected based on their association with three sets of variables in three different ecoregions; nine categories of tests in all.

We conclude that this rather coarse sifting for significant correlations was a reasonable approach for this type of data that included a high amount of measurement error for most variables. Land cover was based on measures for the entire watershed and some of the sampling sites were not located on the main stem draining the watershed. Thus, urban land use in the watershed might not have been on the stream sampled, or it might have been upstream away from the site. For the fish and invertebrate samples the numbers collected were very small for some sites. Inadequate sampling effort can make a good site look bad in terms of taxa richness because taxa richness is related to sample size (Larsen and Herlihy 1998). For the invertebrate index, rarefaction was used to compensate for low abundance in the samples (see chapter 3, Jessup and Gerritsen 2000); these corrections were not made for our data. Similarly for fish, many of the sites had less than 20 fish collected. Finally, other studies have shown that habitat measures, particularly those based on ocular estimates rather than actual measurements, are not very consistent between different crews or sampling events (Hannaford and Resh 1995, Poole et al. 1997). In addition, many habitat measures can change as water level fluctuates (Herger et al. 1996). Thus, given the many sources of error on the other side of the equation, we suspect that habitat measures may be more strongly associated with human disturbance than the r-values indicate.

Improvement of the Habitat Index

When developing summary measures and indexes, two issues drive the selection process for component measures. Measures must be both statistically precise and biologically relevant. A measure is considered precise when repeated measurements of the same item are very similar. A relevant measure is related to the underlying processes we wish to assess, in our case, the physical and biological integrity of streams. Unfortunately, for physical habitat measures, less relevant measures tend to be the most precise (Bauer and Ralph 1999, Kaufmann et al. 1999).

Our results for precision of habitat measures were similar to those reported for other studies that found relatively lower precision for visual estimates, such as riparian condition, than for actual measurements, such as substrate size (Kaufmann et al. 1999). Estimates of precision for habitat measures in Oregon were similar to ours for Idaho. These results suggest that large improvements in precision may not be possible for these types of measures and that other methods of quantifying the same information should be evaluated.

Association of the SHI with measures of land use and biological condition did not dramatically improve. The SHI was correlated with the same number of disturbance measures as the original index. For fish metrics, two significant correlations were lost and there was no increase in the strength of correlations. For invertebrate metrics, three additional significant correlations and almost all the *r*-values increased, though very slightly. These results aren't very surprising given that six of the component measures were included in both the original and SHI. This slight improvement is tempered by the fact that the SHI was tested against the same data used to test the individual measures. Thus, we expect at least some higher correlations with the SHI because the same data were used to select measures based on their correlation.

Recommendations

1. Test conclusions from this report with an independent data set.

As data become available, we recommend additional further testing of the SHI with human disturbance and biological metrics. In general, significant correlations for this study were consistent but not strong. Additional confirmation of these patterns for independent sites would support the conclusions based on this data set.

2. Metric testing and development.

Additional habitat measures are worth testing. A measure that summarizes elements of habitat complexity might amplify the slight tendency toward statistical significance that we noticed for measures such as undercut banks, submerged cover, and pool dimensions. In addition, a simple count of the number of pools at a site could be a good measure.

Several of the measures could perhaps be improved by actually measuring them rather than estimating them. These include measuring the overhang of banks for channel shape and measuring the width of the riparian zone for the zone of influence measure. We also

recommend that field crews have very specific descriptions in hand for each scored value for habitat measures that are estimated by eye.

3. Insist that field crews enter their data in the field using hand-held computers, or data loggers.

Data entry in the field by the person taking the measurements would eliminate most of the problems we encountered working with the BURP database. Missing values are much easier to fix at the time of data entry and field computers can be programmed to prompt field crews for missing values.

CONCLUSIONS

The role of physical habitat measures in the overall process of stream assessment has not been as well-defined as the role of either biological or chemical monitoring. Even though mentioned specifically in the opening words of the CWA as part of its mandate to protect the physical, chemical and biological integrity of water resources, assessments based on physical habitat measures rarely stand alone. A long tradition of chemical sampling and monitoring for water quality assessment has only been supplemented in recent years with biological measurements (Karr 1991, Karr et al. 1999). Physical habitat measures are typically used to interpret or support biological assessments rather than as independent measures of physical integrity. As states move toward numeric biological criteria (Karr 1991, Davis et al. 1996) they must resolve the role that habitat measures will play in the assessment process.

Results from this study suggest that changes in the physical habitat are related to both human disturbance and the biological condition at a stream site. In many cases, human disturbance may be the ultimate cause, but the habitat measure is the mechanism that actually degrades the biological assemblage. Thus, we interpret habitat measures as links connecting human activities to biological degradation. Agriculture is an example of a human activity often associated with degradation of fish and invertebrate assemblages because it involves removal of riparian vegetation for crops, erosion from tillage, and widening of the channel by livestock. The influences of these activities are measured directly by components of the SHI such as percent canopy cover, percent fines and embeddedness, and stream channel shape. Fish and invertebrates depend on trees in the riparian area for shade and food, leaves for shredding insects and terrestrial insects for fish. Fines and sediment from erosion can smother fish eggs and prevent invertebrates from moving from the surface of the stream bottom to the hyporheos below. A wider stream channel means fewer overhanging banks and less habitat diversity for both fish and invertebrates. Physical habitat measures make these connections between human disturbance and biological change.

Initially, we expected that the two proposed roles for a SHI in the assessment process would select different component habitat measures. We were surprised to find that if a habitat measure was associated with human disturbance, it was usually associated with biological metrics as well; this made the selection process much easier. In other words, whether habitat measures were selected as measures of physical integrity associated independently with human influence or whether they were selected for their role in supporting beneficial uses

(i.e., aquatic life uses), the same set of measures would be selected. This further supports the idea that physical habitat measures complete the assessment process by directly measuring the mechanisms by which human disturbance is translated into changes in the biological assemblage.

ACKNOWLEDGEMENTS

This report was prepared in cooperation with the Idaho Department of Environmental Quality. Special thanks go to Cynthia Grafe who supported this project through all of its phases. Chris Mebane, Cynthia Grafe, Michael McIntyre, and Darren Brandt participated in thoughtful discussions and reviews. Billie Kerans commented on an earlier draft. Michael Edmondson helped us understand how the data were collected and recorded. Though too numerous to mention by name, we appreciate the efforts of all the people who worked in the field and carefully collected the data.

REFERENCES

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1998. Rapid bioassessment protocols for use in wadeable streams and rivers: periphyton, benthic macroinvertebrates, and fish. EPA 841-D-97-002.Office of Water, U.S. EPA. Washington, D.C.

Bauer, S.B. and S.C. Ralph. 1999. Aquatic indicators and their application to water quality objectives within the Clean Water Act. EPA-910-R99-014. U.S. EPA, Region 10. Seattle, Washington.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Chapter 4 *in* W.R. Meehan (editor) Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. American Fisheries Society Special Publication 19. Bethesda, Maryland.

BURP Technical Advisory Committee. 1999 Beneficial use reconnaissance project: workplan for wadable streams. Idaho Division of Environmental Quality. Boise, Idaho.

Brusven, M.A., W.R. Meehan, and J.F. Ward. 1986. Summer use of simulated undercut banks by juvenile chinook salmon in an artificial Idaho channel. North American Journal of Fisheries Management. 6:32-37.

Chapman, D.W. 1988. Critical review of variables used to define effects of fines in redds of large salmonids. Transactions of the American Fisheries Society. 117:1-21.

Clarkson, R.W. and J.R. Wilson. 1995. Trout biomass and stream habitat relationships in the White Mountains Areas, east-central Arizona. Transactions of the American Fisheries Society. 124:599-612.

Connolly, P.J. and J.D. Hall. 1999. Biomass of coastal cutthroat trout in unlogged and previously clear-cut basins in the central Coast Range of Oregon. Transactions of the American Fisheries Society. 128:890-899.

Davis W.S., B.D. Snyder, J.B. Stribling, and C. Stoughton. 1996. Summary of state biological assessment programs for streams and rivers. EPA 230-R-96-007. Office of Policy, Planning, and Evaluation, U.S. EPA. Washington, D.C.

Detenbeck, N.E., S.L. Batterman, V.J. Brady, J.C. Brazner, V.M. Snarski, D.L. Taylor, J.A. Thompson, and J.W. Arthur. 2000. A test of watershed classification systems for ecological risk assessment. Environmental Toxicology and Chemistry. 19:1174-1181.

Dunham, J.B. and G.L. Vinyard. 1997. Incorporating stream level variability into analyses of site level fish habitat relationships: some cautionary examples. Transactions of the American Fisheries Society. 126:323-329.

Elliott, S.T. 1986. Reduction of a Dolly Varden population and macrobenthos after removal of logging debris. Transactions of the American Fisheries Society. 115:392-400.

Fausch, K.D., C.L. Hawkes, and M.G. Parson. 1988. Models that predict standing crop of stream fish from habitat variables: 1950-85. U.S. Forest Service General Technical Report PNW-GTR-213.

Gerritsen, J., M.T. Barbour, and K. King. 2000. Apples, oranges, and ecoregions: on determining pattern in aquatic assemblages. Journal of the North American Benthological Society. 19:487-496.

Hannaford, M.J. and V.H. Resh. 1995. Variability in macroinvertebrate rapid-bioassessment surveys and habitat assessments in a northern California stream. Journal of the North American Benthological Society. 14:430-439.

Hawkins, C.P., R.H. Norris, J. Gerritsen, R.M. Hughes, S.K. Jackson, R.K. Johnson, and R.J. Stevenson. 2000. Evaluation of the use of landscape classifications for the prediction of freshwater biota: synthesis and recommendations. Journal of the North American Benthological Society. 19:541-556.

Hayslip, G.A. (editor) 1993. Region 10 in-stream biological monitoring handbook for wadable streams in the Pacific Northwest. EPA 910/9-92-013. U.S. EPA. Seattle, Washington.

Heffner R.A., M.J. Butler, IV, and C.K. Reilly. 1996. Pseudoreplication revisited. Ecology. 77:2558-2562.

Herger, L.G., W.A. Hubert, and M.K. Young. 1996. Comparison of habitat composition and cutthroat trout abundance at two flows in small mountain streams. North American Journal of Fisheries Management. 16:294-301.

Hughes, R.M., P.R. Kaufmann, A.T. Herlihy, T.M. Kincaid, L. Reynolds, and D.P. Larsen. 1988. A process for developing and evaluating indices of fish assemblage integrity. Canadian Journal of Fisheries and Aquatic Science. 55:1618-1631.

Jessup, B. and J. Gerritsen. 2000. Development of a multimetric index for biological assessment of Idaho stream using benthic macroinvertebrates. Tetra Tech, Inc.

Karr J.R. 1991. Biological integrity: a long-neglected aspect of water resource management. Ecological Applications. 1: 66-84.

Karr J.R., J.D. Allan, and A.C. Benke. 1999. River conservation in the United States and Canada: science, policy, and practice. *In* Boon, P. J., B.R. Davies, and G. E. Petts (editors) River Conservation: Science, Policy, Practice. J. Wiley.

Kaufmann, P.R., P. Levine, E.G. Robison, C. Seeliger, and D.V. Peck. 1999. Quantifying physical habitat in wadeable streams. EPA/620/R-99/003. U.S. EPA. Washington, D.C.

Kondolf, G. M. 2000. Assessing salmonid spawning gravel quality. Transactions of the American Fisheries Society. 129: 262-281.

Kozel, S.J. and W.A. Hubert. Testing of habitat assessment models for small trout streams in the Medicine Bow National Forest, Wyoming. North American Journal of Fisheries Management. 9:458-464.

Larsen, D.P. and A.T. Herlihy. 1998. The dilemma of sampling streams for macroinvertebrate richness. Journal of the North American Benthological Association. 17:359-366.

Li, H.W., G.A. Lamberti, T.N. Pearsons, C.K. Tait, J.L. Li, and J.C. Buckhouse. 1994. Cumulative effects of riparian disturbances along high desert trout streams of the John Day basin, Oregon. Transactions of the American Fisheries Society. 123:627-640.

Mebane, C. In press. Testing bioassessment metrics: macroinvertebrate, sculpin, and salmonid responses to stream habitat, sediment, and metals. Environmental Monitoring and Assessment.

Mebane, C.A. 2000. Stream Fish Index. Chapter 4 *In* Grafe, C.S. (editor). Stream ecological assessment framework: an integrated approach. Idaho Department of Environmental Quality. Boise, Idaho. pp.____

Merritt, R.W., K.W. Cummins, and T.M. Burton. 1984. The role of aquatic insects in the processing and cycling of nutrients. Chapter 6 *in* Resh, V.H. and D.M. Rosenberg (editors) The Ecology of Aquatic Insects. Praeger, New York.

Minshall, G.W. 1984. Aquatic insect – substratum relationships. Chapter 12 *in* Resh, V.H. and D.M. Rosenberg (editors) The Ecology of Aquatic Insects. Praeger, New York.

Omernik, J.M. 1995. Ecoregions: a spatial framework for environmental management. Pages 49-62 *in* Davis, W.S. and T.P. Simon (editors) Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, Florida.

Omernik, J.M. and A.L. Gallant. 1986. Ecoregions of the Pacific Northwest. EPA/600/3-86/033. U.S. EPA. Corvallis, Oregon.

Peterman, R. M. 1990. Statistical power analysis can improve fisheries research and management. Canadian Journal of Fisheries and Aquatic Sciences, 47, 2-15.

Platts, W.S. and R.L. Nelson. 1989. Stream canopy and its relationship to salmonid biomass in the intermountain West. North American Journal of Fisheries Management 9:446-457.

Poole, C.G., C.A. Frissell, and S.C. Ralph. 1997. In-stream habitat unit classification: inadequacies for monitoring and some consequences for management. Journal of the American Water Resources Association. 33(4):879-896.

Porter, M.S., J. Rosenfeld, and E.A. Parkinson. 2000. Predictive models of fish species distribution in the Blackwater Drainage, British Columbia. North American Journal of Fisheries Management. 20:349-359.

Ransel K.P. 1995. The sleeping giant awakes: PUD No. 1 of Jefferson County v. Washington Department of Ecology. Environmental Law. 25:255-283.

Reice, S.R. 1980. The role of substratum in benthic macroinvertebrate microdistribution and litter decomposition in a woodland stream. Ecology. 61:580-590.

Relyea, C.D., G.W. Minshall, and R.J. Danehy. 2000 Manuscript. Stream insects as bioindicators of fine sediment.

Richards, C., L.B. Johnson, and G.E. Host. 1996. Landscape-scale influences on stream habitats and biota. Canadian Journal of Fisheries and Aquatic Sciences. 53(Supplement 1):295-311.

Rosgen, D.L. 1994. A classification of natural rivers. Catena. 22: 169-199.

Roth, N.E., J.D. Allan, and D.L. Erickson. 1996. Landscape influences on stream biotic integrity assessed at multiple spatial scales. Landscape Ecology. 11:141-156.

Southerland, M.T. and J.B. Stribling. 1995. Status of biological criteria development and implementation. Pages 81-96 *in* Davis, W.S. and T.P. Simon (editors) Biological Assessment and Criteria, Tools for Water Resource Planning and Decision Making. Lewis Publishers. Boca Raton, Florida.

Terrell, J.W., B.S. Cade, J. Carpenter, and J.M Thompson. 1996. Modeling stream fish habitat limitations from wedge-shaped patterns of variation in standing stock. Transactions of the American Fisheries Society. 125:104-117.

Waite, I.R. and K.D. Carpenter. 2000. Associations among fish assemblage structure and environmental variables in Willamette Basin streams, Oregon. Transactions of the American Fisheries Society. 129: 754-770.

Wang, L., J. Lyons, P.Kanehl, and R. Gatti. 1997. Influences of watershed land use on habitat quality and biotic integrity in Wisconsin streams. Fisheries. 22(6): 6-12.

Wang, L., J. Lyons, and P. Kanehl. 1998. Development and evaluation of a habitat rating system for low-gradient Wisconsin streams. North American Journal of Fisheries Management. 18: 775-785.

Yoder, C.O. and Smith. 1999. Using fish assemblages in a state biological assessment and criteria program: essential concepts and considerations. Pages 17-56 *in* T.P. Simon (editor) Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities. CRC Press. Boca Raton, Florida.

Zar, J. H. 1984. Biostatistical Analysis, 2nd edition. Prentice-Hall, Inc., Englewood Cliffs, NJ.

Chapter 6.
Data Assessment and Reporting

Cynthia S. Grafe[15]

INTRODUCTION

To be meaningful to managers and the public, biological and physical habitat data need to be translated into logical information that communicates the assessment results. Both numeric criteria evaluations and multimetric index results are used to evaluate cold water aquatic life.

For the SMI, SFI, and SHI, DEQ rates different categories of condition and then averages these ratings into one score. DEQ uses minimum index thresholds that identify significant impairment signals that may be lost through averaging scores. This approach is applied according to available data during the assessment process. If there are not enough data types to calculate two different indexes, then the water body is not assessed until more data are gathered. Figure 6-1 illustrates the process for applying this process.

METHODS

Stream Index Scoring

DEQ uses BURP-compatible data to calculate the SMI, SFI, and SHI. DEQ may also use physicochemical data to identify numeric criteria violations of water quality standards (see Section 5 Grafe et al. 2002) and/or other available data to support or modify assessment interpretations (see Section 4 Grafe et al. 2002). The details of index development and supporting analyses may be found in Jessup and Gerritsen (Chapter 3), Mebane (Chapter 4), and Fore and Bollman (Chapter 5).

DEQ assigns a rating of 1, 2, or 3 to condition categories (see Tables 6-1 through 6-3). This rating assignment allows DEQ to effectively integrate multiple index results into one score. The final score derived from these multiple data sets is then used to determine use support.

The SMI and SFI are direct biological measures of cold water aquatic life. Tables 6-1 and 6-2 summarize the scoring criteria for these indexes. The scoring criteria are assigned according to each bioregion reference condition. Bioregions are typically derived from groupings of ecoregions.

---

[15] Idaho Department of Environmental Quality, 1410 N. Hilton, Boise, ID 83706. This approach is modified from an approach originally developed by C. Grafe, D. Brandt, and C. Mebane. Input from M. McIntyre and D. Essig contributed to the current data integration approach used in small streams and rivers.

Table 6-1. SMI bioregion scoring criteria*

	Bioregion Classification			
Condition Category	**Northern Mountains**	**Central and Southern Mountains**	**Basins**	**Condition Rating**
Above the 25th percentile of reference condition	≥65	≥59	≥51	3
10th to 25th percentile of reference condition	57 – 64	51 – 58	43 – 50	2
Minimum to 10th percentile of reference condition	39 – 56	33 – 50	33 – 42	1
Below minimum of reference condition	<39	<33	<33	Minimum Threshold

*Scoring for all the indexes is rounded to the nearest whole number.

Table 6-2. SFI bioregion scoring criteria

	Bioregion		
Condition Category	**Rangeland**	**Forest**	**Condition Rating**
Above the median of reference condition	≥82	≥81	3
25th percentile to median of reference condition	62 – 81	67 – 80	2
5th to 25th percentile of reference condition	39 – 61	34 – 66	1
Below 5th percentile of reference condition	<39	<34	Minimum Threshold

Although fundamentally the SHI scoring system is based on similar concepts used for the other indexes, DEQ does not use a minimum threshold for this index. This is different from the SMI and SFI for two reasons. First, and most importantly, Fore and Bollman (2000) and Bauer and Ralph (1999 and 2000) reported significant variability among physical habitat measures. Although DEQ believes physical habitat is a useful interpretive tool, the agency is cautious about using the SHI solely to determine aquatic life use support. Second, the SHI comprises non-biological components and consequently, is not a direct measure of the aquatic life use. DEQ did use the SMI reference and impaired data set to generate a scoring system for each SHI ecoregion

Table 6-3. SHI scoring criteria.

Condition Category	Northern Rockies	Northern Basin and Range	Snake River Basin/ High Desert	Condition Rating
Above 25th percentile of reference condition	≥66	≥63	≥58	3
10th to 25th percentile of reference condition	58 – 65	50 – 62	55 – 57	2
Below 10th percentile of reference condition	<58	<50	<55	1

Index Data Integration Approach and Use Support Determination for Rivers and Streams

DEQ believes that water bodies require an integration of multiple data types to assess ecosystem health. With this in mind, DEQ does not use any one piece of evidence to solely assess aquatic life use support. The multiple data integration approach is applied according to available data during the assessment process. If there are not enough data types to calculate two different indexes, then the water body is not assessed until more data are gathered or other Tier I data can be used according to policies described in the Water Body Assessment Guidance, Second Edition (Grafe et al. 2002). Figure 6-1 illustrates the process of applying this approach.

The index integration approach uses the following steps to determine use support of cold water aquatic life for streams and rivers.

Step 1
Identify any numerical water quality standard violation as determined by using the criterion evaluation and exceedance policy (see Grafe et al. 2002).

If there is a numeric criteria violation, then DEQ automatically determines the water body is not fully supporting.

Step 2
Calculate the index scores and determine if there are at least two indexes.

If there are less than two indexes, then the water body is not assessed unless other Tier I data is available (Grafe et al. 2002). Additional data should be gathered.

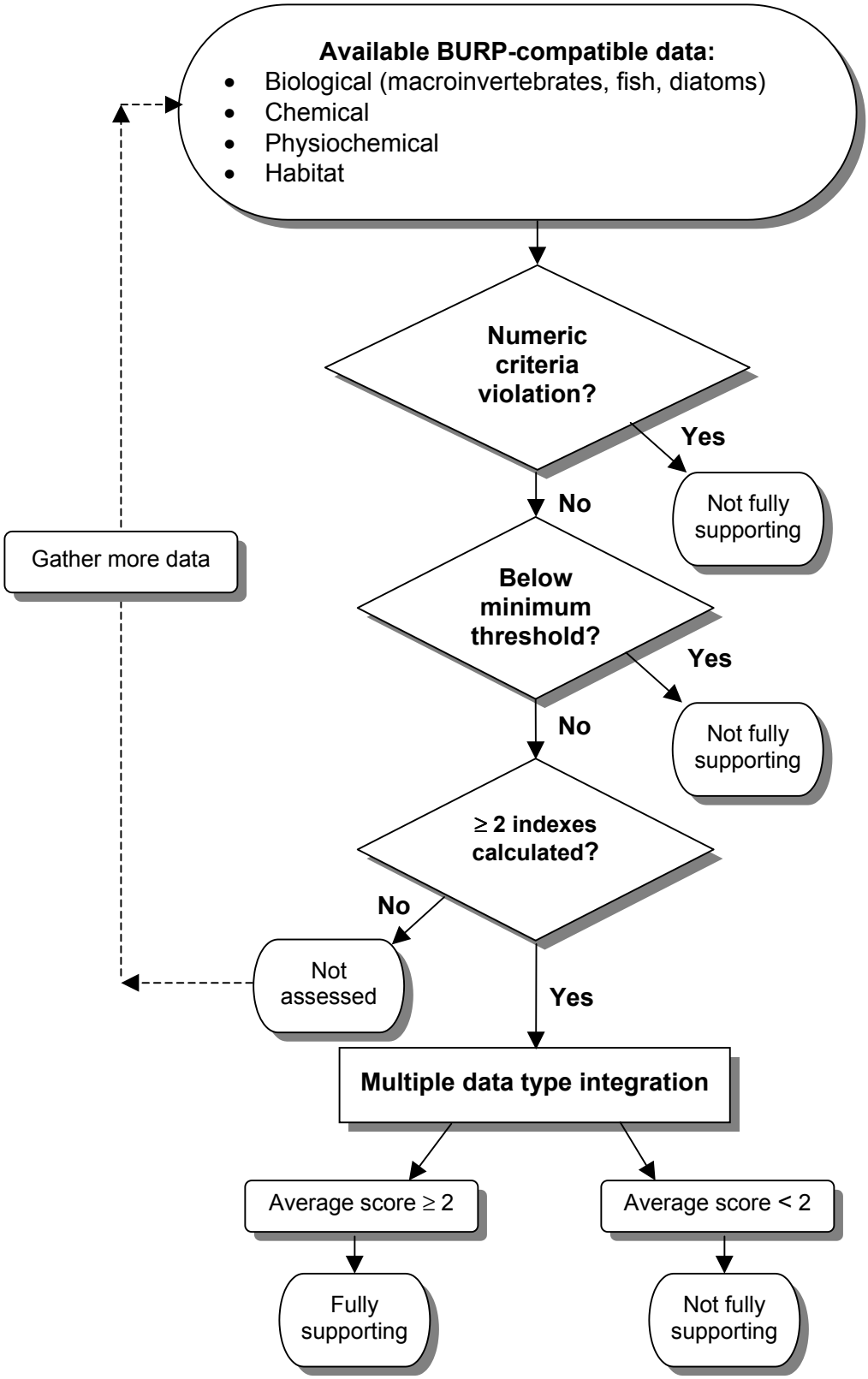


Figure 6-1. Stream cold water aquatic life use support determination.

Step 3
Identify any index scores below the minimum threshold levels.

> If there are any scores below minimum threshold levels, then DEQ automatically determines the water body is not fully supporting.

Step 4
Identify corresponding 1, 2, or 3 condition ratings for each index.

Step 5
Average the index ratings to determine the use support. To average the individual index ratings, sum the ratings and divide by the number of indexes used.

> An average score of greater than or equal to 2 is considered fully supporting.
> An average score of less than 2 is considered not fully supporting.

Step 6
Review these preliminary, quantitative results to ensure that they meet logical expectations and data requirements. If not, re-evaluate the data and provide sound justification for support status ratings/assignments different from the indication of the quantitative results (see Grafe et al. 2002).

Example of the stream assessment approach[16]

Big Cottonwood Creek[17]

Big Cottonwood Creek is approximately 21 miles long and a second order stream located in the Goose Creek HUC #17040211 (see Figures 6-2 and 6-3). The shrubland watershed has a road crossing at the BURP site and is used for both recreation and grazing purposes. USFS and IDFG have retired the grazing allotments along the lower portion of Big Cottonwood Creek. After Big Cottonwood Creek leaves BLM public lands it is diverted for agricultural uses and flows only occasionally in its natural channel.

[16] This example is intended to illustrate the assessment process only and is not intended as a DEQ finding of beneficial use support status for aquatic life.
[17] Example data provided by Sean Woodhead, DEQ Twin Falls Regional Office.

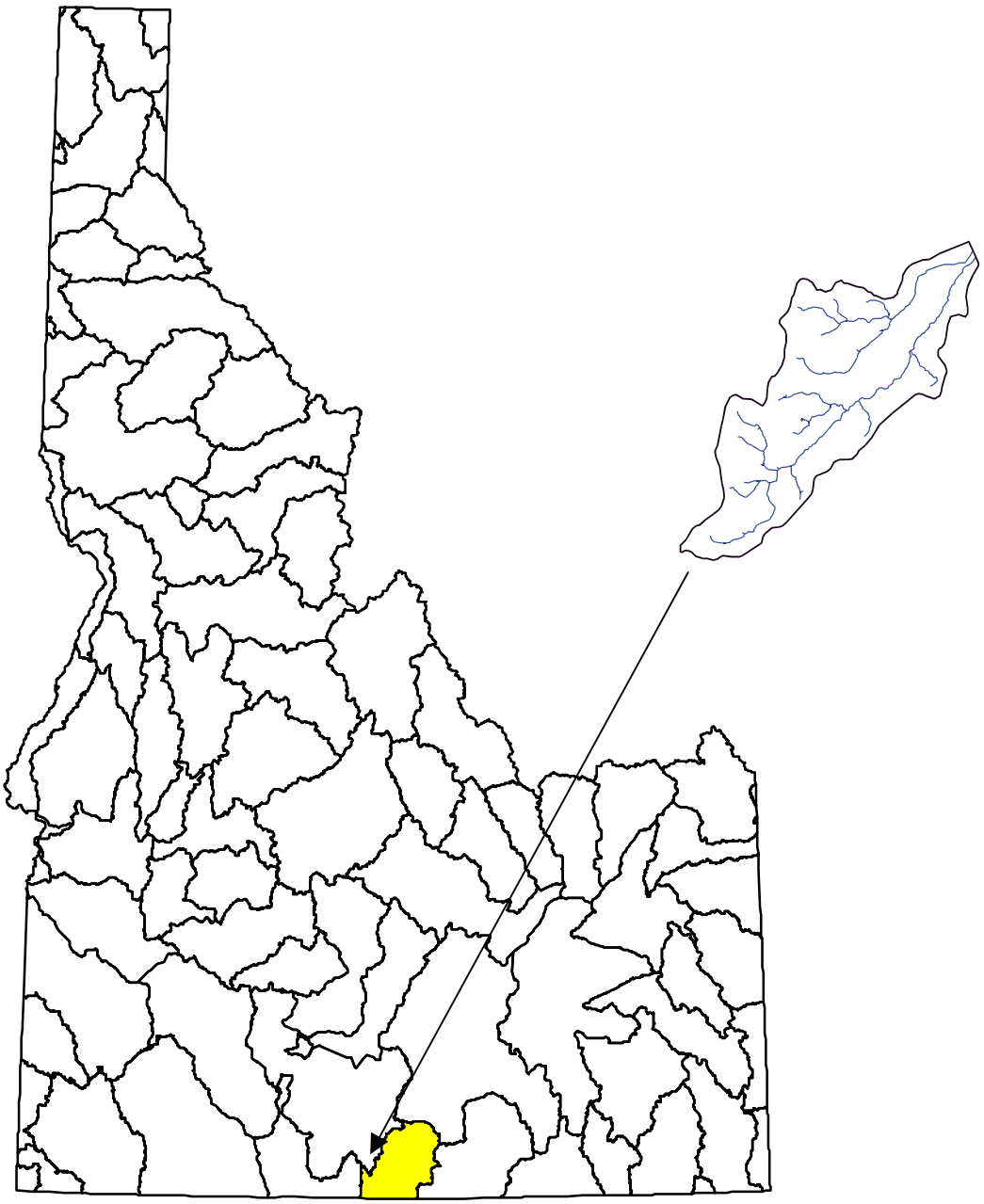


Figure 6-2. Big Cottonwood Creek located in Goose Creek HUC #17040211

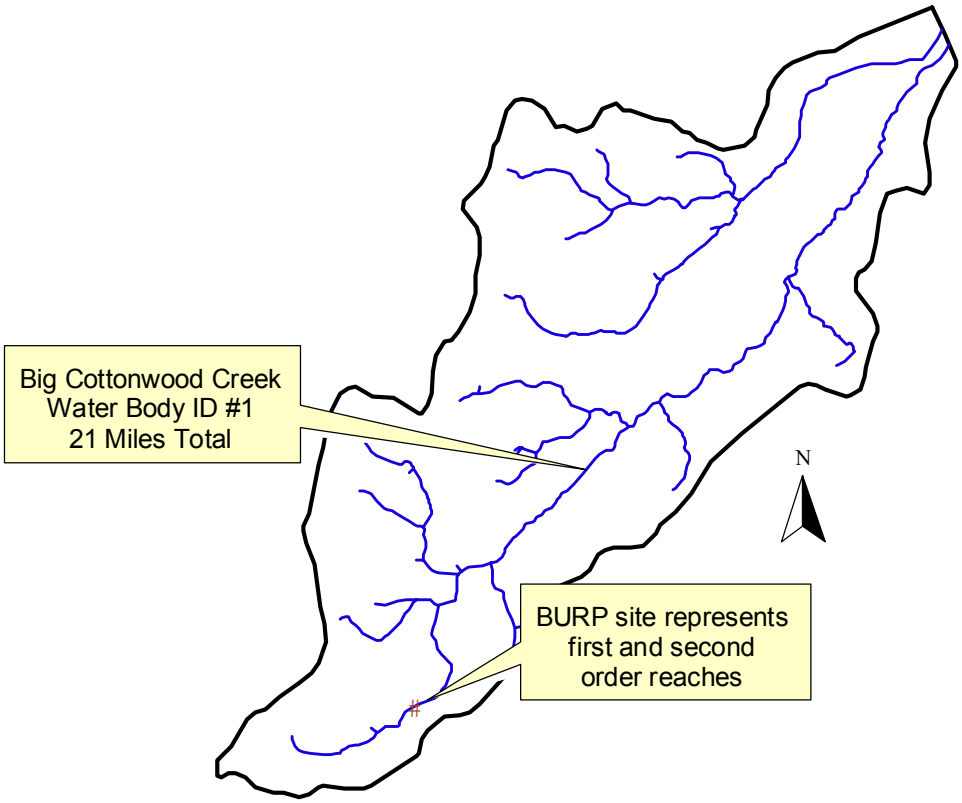


Figure 6.3. Big Cottonwood Creek in 6th Field HUC #170402111901. BURP site at upper portion of watershed

DEQ uses different bioassessment indexes to make this determination (see Chapter 2). After identifying values and an average criteria rating for the water body size criteria, the assessor determines the average rating is less than 1.7 and consequently, classifies Big Cottonwood Creek as a stream. Table 6-4 summarizes the results of the water body size determination.

Table 6-4. Summary of water body size criteria results

Criteria	Value	Rating
Stream order	3.00	1
Average width at base flow (m)	1.85	1
Average depth at base flow (m)	0.16	1
	Average Rating	1

After identifying the water body size and appropriate indexes to use, the assessor calculates the stream indexes for the macroinvertebrate, fish, and habitat BURP data. Table 6-5 summarizes the index calculations and condition rating assignments for data integration purposes. In assigning these ratings, the assessor uses the following classifications: basins (Table 6-1, SMI), range (Table 6-2 SFI), and Snake River Basin/High Desert (Table 6-3 SHI) classifications.

Table 6-5. Stream index scores and corresponding condition ratings for Big Cottonwood Creek

Monitoring Station	SMI Score	SMI Condition Rating	SFI Score	SFI Condition Rating	SHI Score	SHI Condition Rating	Condition Rating Average
Site	87	3	79	2	82	3	2.67

DEQ averages the condition ratings to integrate the different index scores. The result for Big Cottonwood Creek is 2.67. There are no numeric criteria exceedances or index scores below the minimum threshold breakpoints. The average condition rating for the stream index scores greater than 2.0 resulting in a fully supporting preliminary determination. If there had been two BURP sites, DEQ uses the lower average of the condition ratings. If there had been more than two monitoring sites, then DEQ takes an average of all the condition ratings.

REFERENCES

Bauer, S. B. and S. C. Ralph. 1999. Aquatic habitat indicators and their application to water quality objectives within the Clean Water Act. EPA-910-R-99-014. US Environmental Protection Agency, Region 10, Seattle, Washington.

Grafe, C.S., C.A. Mebane, M.J. McIntyre, D.A. Essig, D.H. Brandt, and D.T. Mosier. 2002. The Idaho Department of Environmental Quality Water Body Assessment Guidance, Second Edition-Final. Idaho Department of Environmental Quality; Boise, Idaho.

Appendix A.
Metric Discrimination

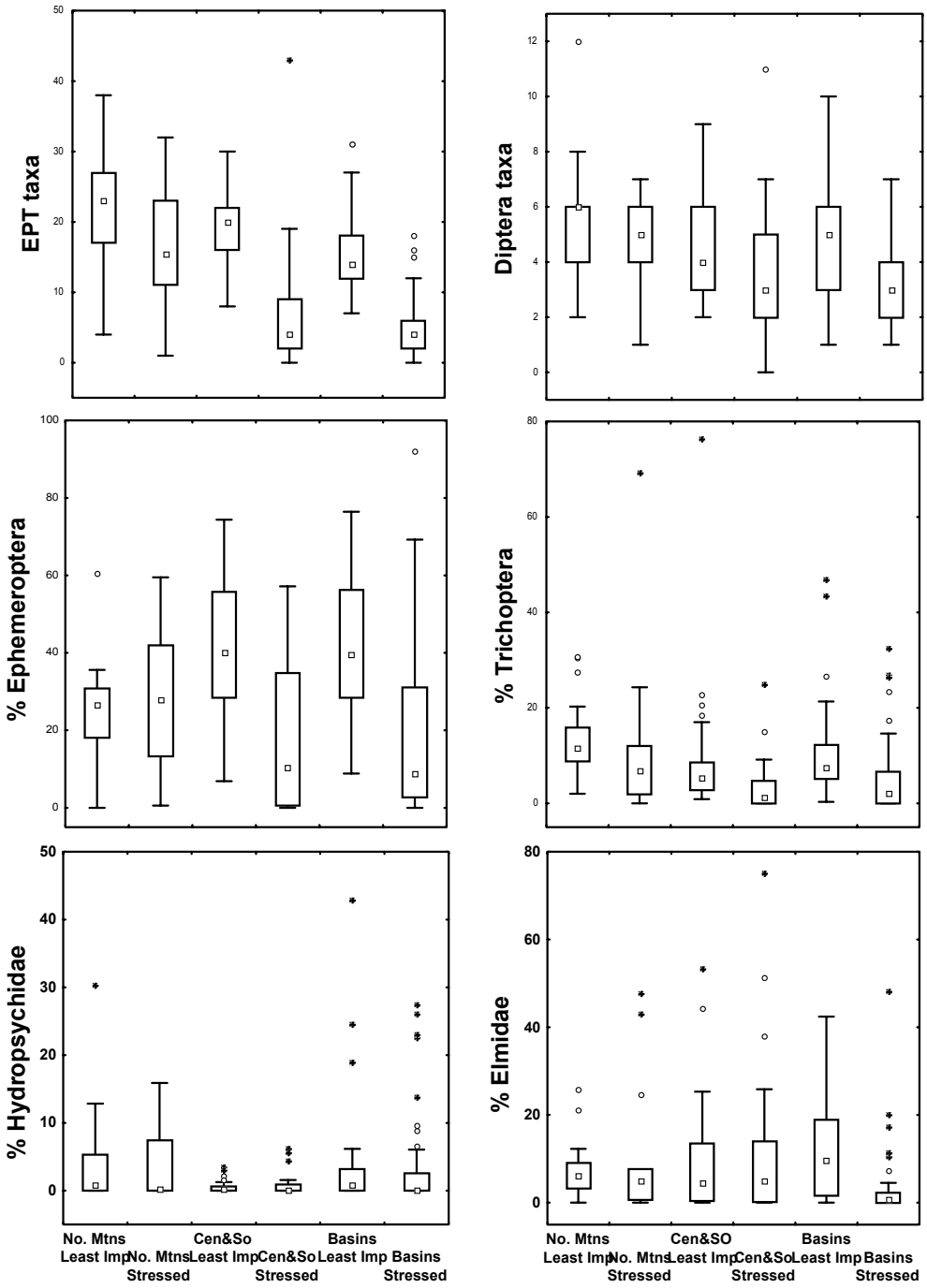


Figure A-1. Selected distributions of least impacted and stressed metrics in bioregions of Idaho; calibration samples only. Refer to legend in Figure 3-2.

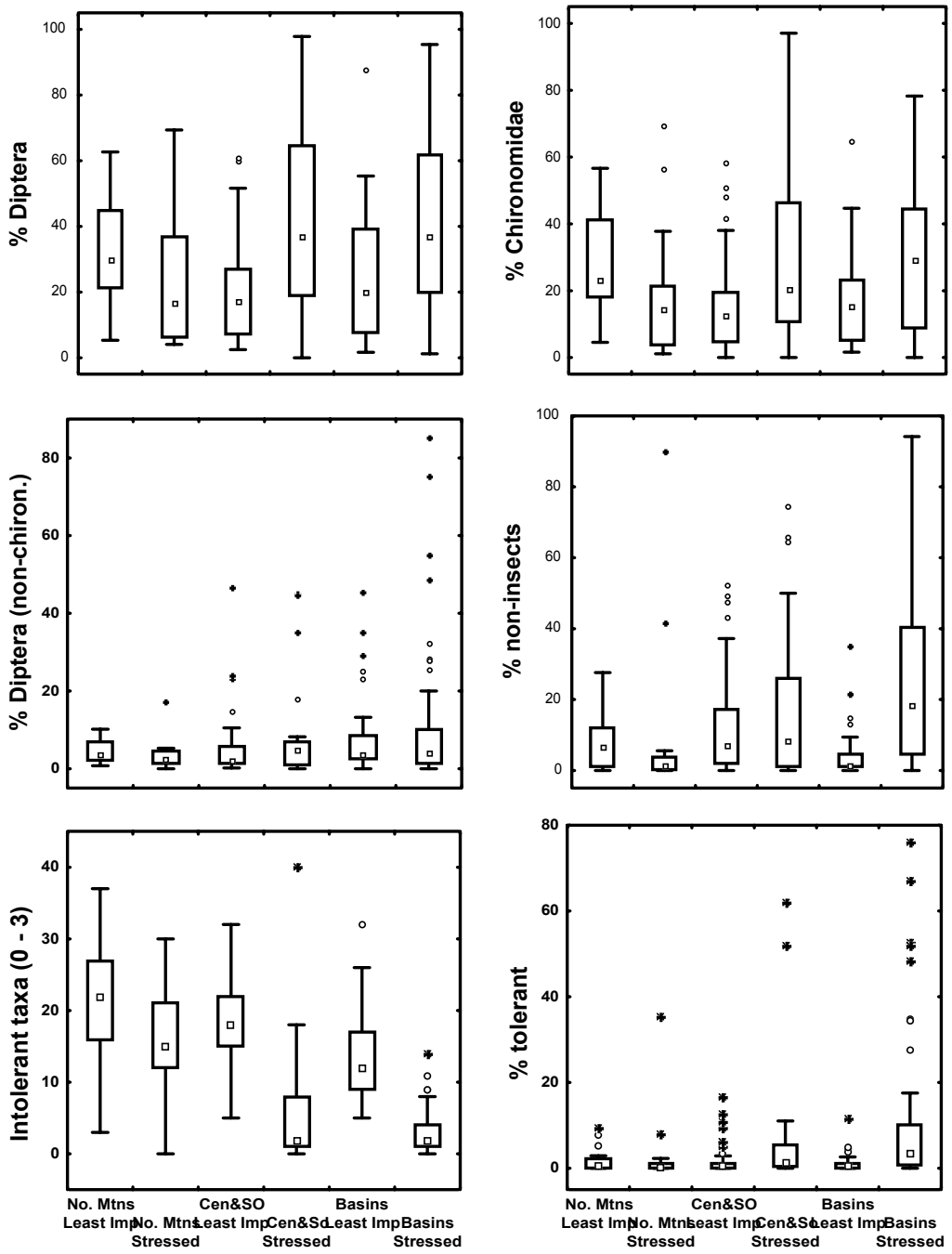


Figure A-1. *(continued)*

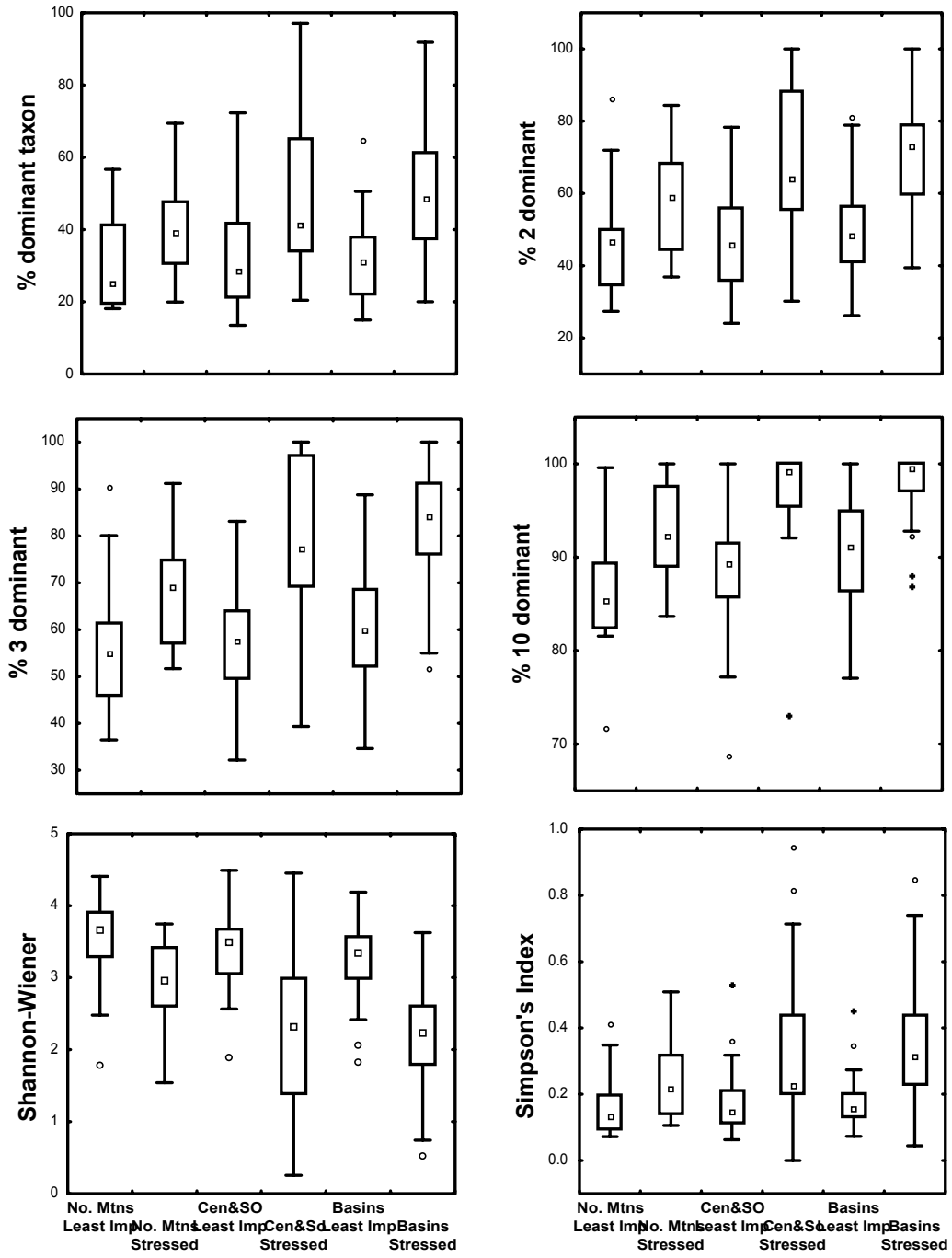


Figure A-1. *(continued)*

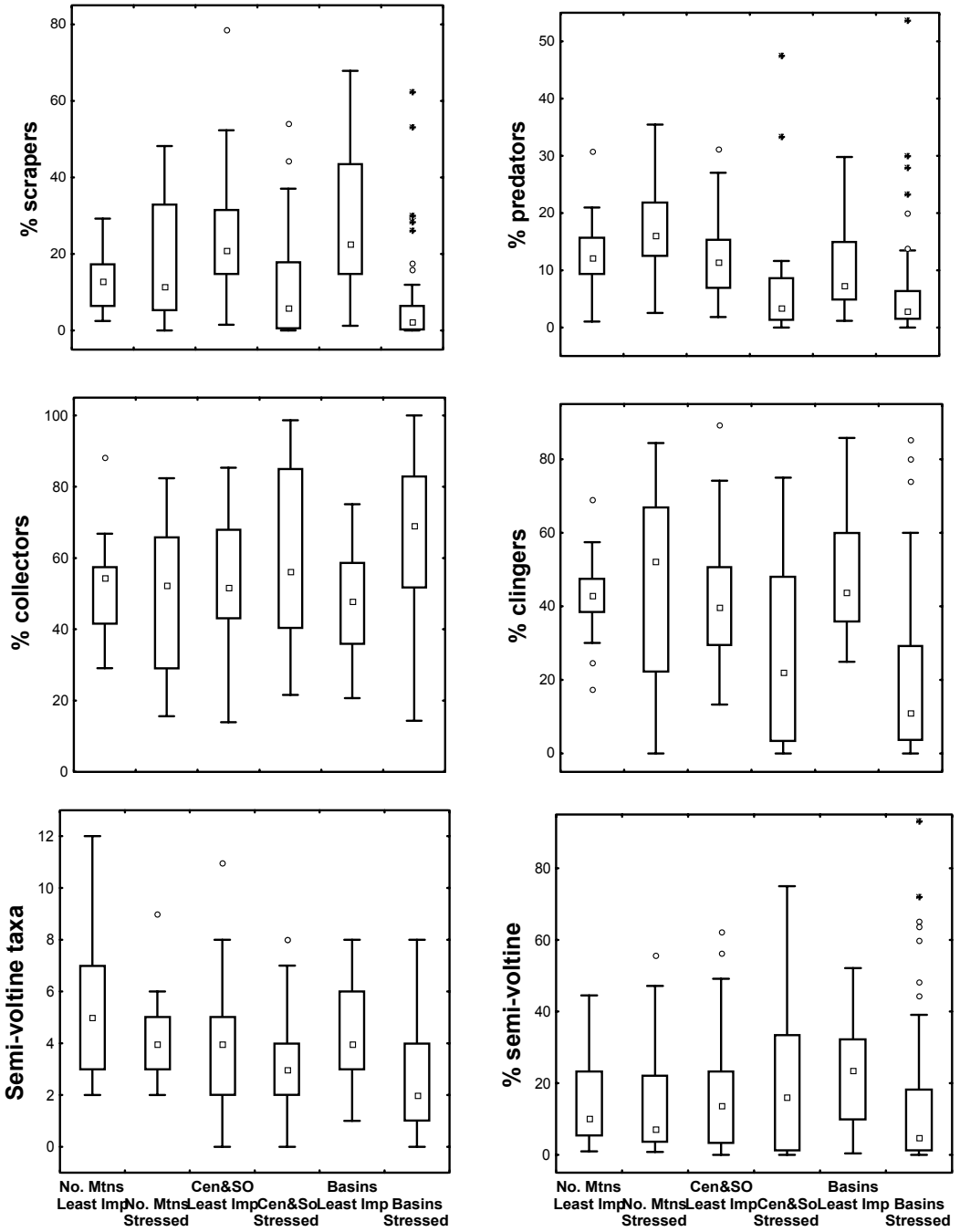


Figure A-1. *(continued)*

Appendix B.
Metric Scoring Formulas

Table B-1. Metric scoring formulas for SMI metrics. The 5th and 95th percentiles are based on all least impacted and stressed sites. Any scores that exceed 100 were reset to 100.

		5th or 95th Percentiles (as per formula)		
Metric	Metric Scoring Formula	No. Mtns.	C&S Mtns.	Basins
Total taxa	100 * "Total taxa" / 95th	39	37	34
Ephemeroptera taxa	100 * "Ephemeroptera taxa" / 95th	13	10	9
Plecoptera taxa	100 * "Plecoptera taxa" / 95th	10	8	6
Trichoptera taxa	100 * "Trichoptera taxa" / 95th	10	9	7
% Plecoptera	100 * "% Plecoptera" / 95th	40	25	20
HBI	100 * (10 - "HBI") / (10 - 5th)	1.6	2	2.7
% 5 dominant	100 * (100 - "% 5 dominant") / (100 - 5th)	52	53	64
Scraper taxa	100 * "Scraper taxa" / 95th	8	8	8
Clinger taxa	100 * "Clinger taxa" / 95th	23	19	17

Appendix C.
Least Impacted and Stressed Site *A Priori* Stream Condition and Index Score (Draft 2000 Data Set)

Table C-1. Least impacted and stressed streams with index scores and biological condition ratings. The thresholds between "good" and "fair" ratings are based on the 25th percentile of least impacted index scores in each bioregion.

Sample ID	Ecoregion	Stream Name	*a priori*	Index	Rating
Northern Mountains					
94NIRO0001	N. North. Rockies	Wolf Lodge Creek Lower	Stressed	60.4	Good
94NIRO0002	N. North. Rockies	Lower Cocolalla Creek	Stressed	48.9	Fair
94NIRO0003	N. North. Rockies	Lower Fish Creek	Stressed	69.0	Good
94NIRO0007	N. North. Rockies	Trestle Creek	Least Imp.	76.5	Very Good
94NIRO0015	N. North. Rockies	Gold Creek	Stressed	50.1	Fair
94NIRO0018	N. North. Rockies	Two Mouth (Reach 1)	Least Imp.	70.5	Good
94NIRO0019	N. North. Rockies	Trapper (Upper)	Least Imp.	80.5	Very Good
94NIRO0023	N. North. Rockies	Lighting (Lower R)	Stressed	61.2	Good
94NIRO0029	N. North. Rockies	Long Canyon Creek	Least Imp.	52.2	Fair
94NIRO0030	N. North. Rockies	Parker Creek	Least Imp.	64.2	Good
94NIRO0036	N. North. Rockies	Smith Creek	Least Imp.	68.9	Good
94NIRO0040	N. North. Rockies	E Fork Nine Mile Up	Stressed	74.1	Good
94NIRO0041	N. North. Rockies	Canyon Creek R2 Up	Stressed	20.0	Poor
94NIRO0043	N. North. Rockies	South Fork Coeur D Alene R	Least Imp.	84.0	Very Good
94NIRO0044	N. North. Rockies	Fly Creek Lower	Least Imp.	73.1	Good
94NIRO0051	N. North. Rockies	St Joe River Upper	Least Imp.	94.2	Very Good
94NIRO0052	N. North. Rockies	Beaver Creek (U)	Least Imp.	72.8	Good
94NIRO0054	N. North. Rockies	Copper Lower	Least Imp.	66.0	Good
94NIRO0059	N. North. Rockies	Deer Creek	Least Imp.	60.7	Good
95NCIROA26	N. North. Rockies	Sixmile Creek	Least Imp.	51.1	Fair
95NCIROB12	N. North. Rockies	Texas Creek	Stressed	8.7	Very Poor
95NCIROB13	N. North. Rockies	Schmidt Creek	Stressed	10.7	Very Poor
95NCIROB15	N. North. Rockies	Camp Creek	Least Imp.	74.3	Good
95NCIROB23	N. North. Rockies	Yakus Creek (Lower)	Stressed	54.2	Good
95NIRO0A10	N. North. Rockies	Hoodoo Creek (Lower)	Stressed	10.0	Very Poor
95NIRO0A14	N. North. Rockies	Hangman Creek (Upper)	Least Imp.	21.7	Poor
95NIRO0A37	N. North. Rockies	East River (Lower)	Stressed	64.3	Good
95NIRO0A45	N. North. Rockies	Cougar Creek (Lower)	Stressed	20.4	Poor
95NIRO0A53	N. North. Rockies	Mosquito Creek	Least Imp.	50.5	Fair
95NIRO0A70	N. North. Rockies	Blue Joe Creek	Stressed	45.9	Fair
95NIRO0A72	N. North. Rockies	Deep Creek (Lower)	Stressed	42.8	Fair
95NIRO0B42	N. North. Rockies	E Fork Meadow Creek	Least Imp.	67.2	Good
96NCIROA35	N. North. Rockies	Crooked River (Upper)	Stressed	74.9	Good
96NCIROA37	N. North. Rockies	Long Haul Creek	Stressed	18.6	Poor
96NCIROB31	N. North. Rockies	White Pine Creek (Potential Ref.)	Least Imp.	69.3	Good
96NCIROB37	N. North. Rockies	East Fork Meadow Creek	Least Imp.	72.7	Good

Sample ID	Ecoregion	Stream Name	*a priori*	Index	Rating
96NCIROC07	N. North. Rockies	Otterson Creek	Least Imp.	39.3	Fair
96NCIROC10	N. North. Rockies	Hamby Fork (Upper)	Least Imp.	86.0	Very Good
96NCIROC13	N. North. Rockies	Glover Creek	Least Imp.	62.7	Good
96NCIROC29	N. North. Rockies	Crooked Fork (Upper)	Least Imp.	79.7	Very Good
96NIRO0A01	N. North. Rockies	Fish Creek (Lower)	Stressed	44.2	Fair
96NIRO0A02	N. North. Rockies	Cub Creek	Least Imp.	35.8	Poor
96NIRO0A06	N. North. Rockies	Cinnamon Creek	Least Imp.	57.7	Good
96NIRO0A26	N. North. Rockies	Moon Creek (Lower)	Stressed	44.3	
96NIRO0B15	N. North. Rockies	Adair Creek (Lower)	Stressed	72.1	Good
96NIRO0A54	N. North. Rockies	Prospector Creek	Least Imp.	54.2	Good
96NIRO0A73	N. North. Rockies	Carlin Creek (Lower)	Stressed	53.0	Good
Central and Southern Mountains					
94EIRO0017	Middle Rockies	Brockman (U)	Stressed	16.5	Very Poor
94EIRO0027	S. North. Rockies	Twin Bridges (L)	Stressed	51.1	Fair
94EIRO0049	S. North. Rockies	Mill (U)	Least Imp.	77.6	Good
94EIRO0062	S. North. Rockies	Dump (U)	Stressed	53.7	Fair
94EIRO0071	S. North. Rockies	Warm Springs (U)	Stressed	23.3	Poor
94SWIROA17	S. North. Rockies	Round Valley Ck	Least Imp.	85.3	Very Good
94SWIROA27	S. North. Rockies	Upper Bear Creek 027	Least Imp.	80.9	Very Good
94SWIROA32	Blue Mountains	Crooked R (U)	Least Imp.	61.6	Good
94SWIROA48	Blue Mountains	Deep (U)	Least Imp.	92.3	Very Good
94SWIROA49	Blue Mountains	Deep (L)	Least Imp.	78.3	Good
94SWIROA52	S. North. Rockies	Deadhorse (U)	Least Imp.	76.3	Good
94SWIROA56	S. North. Rockies	Twentymile (L)	Least Imp.	71.1	Good
94SWIROA57	S. North. Rockies	Twentymile (U)	Least Imp.	76.3	Good
94SWIROB07	Blue Mountains	Deer	Least Imp.	56.2	Fair
94SWIROB13	Blue Mountains	Mud Creek 001	Stressed	24.5	Poor
94SWIROB14	Blue Mountains	Mud Creek 002	Stressed	10.0	Very Poor
95EIRO0A05	Middle Rockies	Antelope Creek (Lower)	Stressed	10.7	Very Poor
95EIRO0A27	S. North. Rockies	Road Creek (Upper)	Stressed	6.8	Very Poor
95EIRO0A41	Middle Rockies	Icehouse Creek (Middle)	Stressed	56.9	Fair
95EIRO0A47	S. North. Rockies	Big Deer Creek (Upper)	Least Imp.	69.3	Good
95EIRO0A49	S. North. Rockies	Blackbird Creek (Upper)	Stressed	6.6	Very Poor
95EIRO0A63	Middle Rockies	Sheridan Creek(Lower)	Stressed	52.7	Fair
95EIRO0A64	Middle Rockies	Sheridan Creek (Lower)	Stressed	26.7	Poor
95EIRO0A65	Middle Rockies	Sheridan Creek (Lower)	Stressed	29.0	Poor
95EIRO0A90	S. North. Rockies	Challis Creek (Lower)	Stressed	48.1	Fair
95EIRO0A92	S. North. Rockies	Yankee Fork(Lower)	Stressed	90.6	Very Good
95EIRO0A94	Middle Rockies	Fox Creek (Upper)	Least Imp.	60.1	Good
95EIRO0A98	Middle Rockies	Bitch Creek (Middle)	Least Imp.	52.6	Fair
95EIRO0B39	S. North. Rockies	Blackbird Creek (Lower)	Stressed	16.6	Poor
95EIRO0B40	S. North. Rockies	Panther Creek (Upper)	Least Imp.	82.9	Very Good
95EIRO0B48	S. North. Rockies	Van Horn Creek (Upper)	Least Imp.	77.4	Good
95EIRO0B52	Middle Rockies	Darby Creek (Upper)	Least Imp.	42.0	Fair
95EIRO0B77	S. North. Rockies	Big Deer Creek (Lower)	Stressed	14.4	Very Poor
95EIRO0B78	S. North. Rockies	Panther Creek (Lower)	Stressed	19.1	Very Poor
95EIRO0B79	S. North. Rockies	Panther Creek (Middle)	Stressed	22.5	Poor
95EIROA101	S. North. Rockies	Little Eightmile Creek (Middle)	Least Imp.	70.1	Good
95SCIROA74	S. North. Rockies	Paradise Creek	Least Imp.	49.1	Fair
95SCIROA77	S. North. Rockies	Salt Creek	Least Imp.	73.8	Good
95SCIROA86	S. North. Rockies	Red Warrior Creek	Least Imp.	54.9	Fair

Sample ID	Ecoregion	Stream Name	*a priori*	Index	Rating
95SCIROA87	S. North. Rockies	Warfield Creek	Least Imp.	60.2	Good
95SCIROB12	S. North. Rockies	Little Beaver Creek	Stressed	44.7	Fair
95SCIROB20	S. North. Rockies	Quigley Creek	Stressed	31.3	Poor
95SCIROB25	S. North. Rockies	Shoshone Creek (Upper)	Stressed	31.9	Poor
95SCIROB29	S. North. Rockies	Cove Creek	Stressed	16.9	Very Poor
95SCIROB52	S. North. Rockies	Senate Creek	Least Imp.	60.8	Good
95SCIROB53	S. North. Rockies	Big Wood River	Least Imp.	76.7	Good
95SCIROB55	S. North. Rockies	Owl Creek	Least Imp.	72.6	Good
95SCIROB56	S. North. Rockies	Westernhome Gulch	Least Imp.	68.0	Good
95SEIRO060	Wasatch & Uinta	Logan River	Least Imp.	33.5	Fair
95SEIRO061	Wasatch & Uinta	Beaver Creek	Least Imp.	31.1	Poor
95SWIROA14	Blue Mountains	Round Valley Creek (Lower)	Least Imp.	34.1	Fair
95SWIROA27	Blue Mountains	French Creek (Lower)	Least Imp.	71.0	Good
95SWIROA28	Blue Mountains	French Creek (Upper)	Least Imp.	79.7	Very Good
95SWIROA30	Blue Mountains	Silver Creek (Lower)	Least Imp.	64.2	Good
95SWIROA32	Blue Mountains	Silver Creek (Upper)	Least Imp.	50.0	Fair
95SWIROA37	Blue Mountains	Mud Creek (Upper)	Stressed	12.1	Very Poor
95SWIROA38	Blue Mountains	Mud Creek (Lower)	Stressed	12.9	Very Poor
95SWIROA39	Blue Mountains	Sloan Creek (Lower)	Stressed	34.3	Poor
95SWIROA41	S. North. Rockies	Kennally Creek (Upper)	Least Imp.	85.0	Very Good
95SWIROA46	S. North. Rockies	Deadhorse Creek	Least Imp.	62.6	Good
95SWIROB23	Blue Mountains	Fawn Creek (Lower)	Least Imp.	44.3	Fair
95SWIROB36	Blue Mountains	Johnson Creek	Least Imp.	63.2	Good
95SWIROB38	Blue Mountains	Fawn Creek (Upper)	Least Imp.	73.6	Good
95SWIROB39	Blue Mountains	Campbell Creek	Least Imp.	67.7	Good
95SWIROC09	S. North. Rockies	Fall Creek (Middle)	Least Imp.	58.8	Good
95SWIROC17	Blue Mountains	Weiser River (Middle)	Least Imp.	79.3	Good
95SWIROC18	S. North. Rockies	Twentymile Creek (Upper)	Least Imp.	66.7	Good
95SWIROC19	S. North. Rockies	Twentymile Creek (Middle)	Least Imp.	60.0	Good
95SWIROC22	Blue Mountains	Boulder Creek (Upper)	Least Imp.	85.4	Very Good
96EIROY026	Middle Rockies	Tie Canyon	Least Imp.	51.9	Fair
96EIROY033	Middle Rockies	Tygee Creek	Least Imp.	62.2	Good
96EIROY042	Middle Rockies	Yale Creek	Least Imp.	57.9	Good
96EIROY046	Middle Rockies	Snow Creek	Least Imp.	94.9	Very Good
96EIROY051	Middle Rockies	North Fork Fish Creek	Least Imp.	51.0	Fair
96EIROY071	S. North. Rockies	Bellas Canyon Creek	Least Imp.	66.3	Good
96EIROY072	S. North. Rockies	Ramey Creek	Least Imp.	69.0	Good
96EIROY073	S. North. Rockies	Ramey Creek	Least Imp.	65.3	Good
96EIROY075	S. North. Rockies	Bear Canyon Creek	Least Imp.	62.7	Good
96EIROY100	S. North. Rockies	Champion Creek	Least Imp.	49.1	Fair
96EIROY108	S. North. Rockies	Basin Creek	Least Imp.	65.3	Good
96EIROY109	S. North. Rockies	Rough Creek	Least Imp.	62.5	Good
96EIROY168	Middle Rockies	Yale Creek	Least Imp.	68.4	Good
96EIROZ005	Middle Rockies	Sheep Creek	Stressed	28.1	Poor
96EIROZ008	Middle Rockies	Sheep Creek	Stressed	29.2	Poor
96EIROZ020	Middle Rockies	Pine Creek	Least Imp.	57.9	Good
96EIROZ021	Middle Rockies	Pine Creek	Least Imp.	49.3	Fair
96EIROZ022	Middle Rockies	North Fork Rainey Creek	Least Imp.	49.8	Fair
96EIROZ044	Middle Rockies	West Camas Creek	Least Imp.	60.2	Good
96EIROZ064	Middle Rockies	Cow Creek	Stressed	18.6	Poor
96EIROZ117	Middle Rockies	Tyler Creek (1)	Least Imp.	66.9	Good

Sample ID	Ecoregion	Stream Name	*a priori*	Index	Rating
96EIROZ125	Middle Rockies	Palisades Creek (4)	Least Imp.	78.8	Very Good
96EIROZ131	Middle Rockies	Bitch Creek	Least Imp.	76.5	Good
96SCIROA16	S. North. Rockies	Skunk Creek (Lower)	Least Imp.	56.3	Fair
96SCIROA34	S. North. Rockies	Skeleton Creek (Middle)	Least Imp.	74.3	Good
96SCIROA39	S. North. Rockies	Ross Fork (Lower)	Least Imp.	61.8	Good
96SCIROA41	S. North. Rockies	Ross Fork (Upper)	Least Imp.	71.7	Good
96SCIROA44	S. North. Rockies	Fox Creek (Upper)	Least Imp.	50.1	Fair
96SCIROA45	S. North. Rockies	Prairie Creek (Upper)	Least Imp.	60.1	Good
96SCIROA53	S. North. Rockies	Paradise Creek (Upper)	Least Imp.	59.0	Good
96SCIROB07	S. North. Rockies	Deer Creek	Least Imp.	68.1	Good
96SCIROB27	S. North. Rockies	Camp Creek (Upper)	Stressed	44.7	Fair
96SCIROB28	S. North. Rockies	Hyndman Creek (Middle)	Least Imp.	60.3	Good
96SCIROB44	S. North. Rockies	Hyndman Creek (Upper)	Least Imp.	66.8	Good
96SEIROA32	Wasatch & Uinta	Sugar Creek	Least Imp.	73.2	Good
96SEIROA34	Wasatch & Uinta	Birch Creek	Least Imp.	70.8	Good
96SEIROA43	Middle Rockies	Sage Creek (Middle)	Least Imp.	69.8	Good
96SEIROA61	Middle Rockies	Tygee Creek (Lower)	Stressed	47.7	Fair
96SWIROB38	S. North. Rockies	Lime Creek (Lower)	Least Imp.	33.9	Fair
96SWIROB57	Blue Mountains	Mud Creek (Lower)	Stressed	17.6	Poor
96SWIROB58	Blue Mountains	Mud Creek (Upper)	Stressed	20.2	Poor
96SWIROB59	S. North. Rockies	Twentymile Creek (Lower)	Least Imp.	64.3	Good
96SWIROB60	S. North. Rockies	Twentymile Creek (Middle)	Least Imp.	88.0	Very Good
96SWIROB61	S. North. Rockies	Twentymile Creek (Upper)	Least Imp.	67.8	Good
Basins					
94EIRO0012	Snake River Plain	Birch (L)	Stressed	25.2	Poor
94EIRO0014	N. Basin & Range	Hell (U)	Stressed	30.6	Poor
94EIRO0018	N. Basin & Range	Brockman (L)	Stressed	37.0	Fair
94EIRO0048	Snake River Plain	Big Timber (U)	Least Imp.	74.4	Good
94EIRO0066	Snake River Plain	Medicine Ldg (L)	Least Imp.	82.2	Very Good
94EIRO0067	Snake River Plain	Medicine Ldg (M)	Least Imp.	48.9	Fair
94NCIRO016	Columbia Plateau	Paradise Creek	Stressed	15.4	Very Poor
94SCIRO001	N. Basin & Range	Sublett (U)	Least Imp.	43.1	Fair
94SCIRO003	N. Basin & Range	Raft R	Stressed	42.5	Fair
94SCIRO008	Snake River Plain	Salmon Falls	Least Imp.	65.4	Good
94SCIRO013	N. Basin & Range	Goose	Least Imp.	98.6	Very Good
94SCIRO017	N. Basin & Range	Little Cottonwood (L)	Stressed	14.3	Very Poor
94SCIRO023	Snake River Plain	Billingsley (M)	Stressed	17.7	Poor
94SCIRO024	Snake River Plain	Billingsley (L)	Stressed	21.2	Poor
94SCIRO025	Snake River Plain	Marsh (L)	Stressed	22.0	Poor
94SCIRO027	Snake River Plain	Shoshone (U)	Stressed	38.7	Fair
94SCIRO038	Snake River Plain	Shoshone (L)	Stressed	46.2	Fair
94SCIRO041	Snake River Plain	Billingsley (U)	Stressed	11.5	Very Poor
94SEIRO039	Wyoming Basin	North Creek (L)	Stressed	19.0	Poor
94SEIRO042	Wyoming Basin	Skinner Creek U	Least Imp.	94.4	Very Good
94SWIROA05	Snake River Plain	Succor Creek Upper Site	Stressed	52.4	Good
94SWIROA06	Snake River Plain	Succor Creek Lower Site	Stressed	41.6	Fair
94SWIROA07	Snake River Plain	Big Jacks Creek Lower Site	Least Imp.	67.0	Good
94SWIROA10	Snake River Plain	Bruneau River	Least Imp.	83.2	Very Good
94SWIROA14	Snake River Plain	Owyhee River Below Battle Creek	Least Imp.	65.4	Good
94SWIROA15	Snake River Plain	Owyhee River Lower Site	Least Imp.	62.0	Good
95EIRO0A01	N. Basin & Range	Hell Creek (Middle)	Stressed	22.2	Poor

Sample ID	Ecoregion	Stream Name	*a priori*	Index	Rating
95EIRO0A02	N. Basin & Range	Hell Creek (Lower)	Stressed	13.8	Very Poor
95EIRO0A04	N. Basin & Range	Meadow Creek (Upper)	Least Imp.	49.8	Fair
95EIRO0A08	Snake River Plain	Badger Creek (Lower)	Least Imp.	50.9	Good
95EIRO0A14	Snake River Plain	Dry Creek (Upper)	Stressed	38.9	Fair
95EIRO0A24	Snake River Plain	Morse Creek (Lower)	Stressed	25.7	Poor
95EIRO0A33	Snake River Plain	Warm Springs Creek (Upper)	Stressed	15.5	Very Poor
95EIRO0A57	Snake River Plain	Antelope Creek (Lower)	Stressed	52.5	Good
95EIRO0A99	Snake River Plain	Bitch Creek (Lower)	Least Imp.	66.6	Good
95EIRO0B02	N. Basin & Range	Meadow Creek (Lower)	Stressed	14.8	Very Poor
95EIRO0B06	Snake River Plain	Horseshoe Creek(Lower)	Stressed	21.3	Poor
95EIRO0B09	Snake River Plain	Warm Springs Creek (Lower)	Stressed	10.1	Very Poor
95EIRO0B12	Snake River Plain	Warm Springs Creek(Upper)	Stressed	25.5	Poor
95EIRO0B17	N. Basin & Range	Sellars Creek (Upper)	Least Imp.	41.4	Fair
95EIRO0B23	N. Basin & Range	Sellars Creek (Lower)	Least Imp.	33.9	Fair
95EIRO0B42	Snake River Plain	Hawley Creek (Middle)	Least Imp.	52.5	Good
95EIRO0B56	Snake River Plain	South Leigh Creek (Lower)	Stressed	28.2	Poor
95EIRO0B63	Snake River Plain	Beaver Creek (Upper)	Stressed	9.6	Very Poor
95EIRO0B69	N. Basin & Range	Grays Lake Outlet (Lower)	Least Imp.	48.9	Fair
95EIRO0B73	N. Basin & Range	Grays Lake Outlet (Upper)	Least Imp.	41.6	Fair
95EIROA116	Snake River Plain	Bohannon Creek (Middle)	Least Imp.	86.6	Very Good
95EIROA117	Snake River Plain	Canyon Creek (Middle)	Least Imp.	88.5	Very Good
95NCIROA06	Columbia Plateau	Cottonwood Creek (Upper)	Stressed	18.8	Poor
95NCIROB01	Columbia Plateau	Tammany Creek	Stressed	18.2	Poor
95NCIROB34	Columbia Plateau	Paradise Creek	Stressed	25.5	Poor
95SCIROA10	Snake River Plain	Clover Creek (Lower)	Stressed	26.7	Poor
95SCIROA11	Snake River Plain	Clover Creek (Upper)	Stressed	23.2	Poor
95SCIROA14	Snake River Plain	Camas Creek (Upper)	Stressed	21.3	Poor
95SCIROA15	Snake River Plain	Camas Creek	Stressed	15.6	Very Poor
95SCIROA16	Snake River Plain	Camas Creek	Stressed	26.3	Poor
95SCIROA17	Snake River Plain	Camas Creek	Stressed	7.1	Very Poor
95SCIROA22	Snake River Plain	E Fork Rock Creek	Stressed	16.9	Poor
95SCIROA26	Snake River Plain	Dry Creek (Upper)	Stressed	12.4	Very Poor
95SCIROA34	N. Basin & Range	Emery Creek	Stressed	17.8	Poor
95SCIROA35	N. Basin & Range	Blue Hill Creek (Lower)	Stressed	13.4	Very Poor
95SCIROA37	N. Basin & Range	Blue Hill Creek(Upper)	Stressed	13.6	Very Poor
95SCIROA40	Snake River Plain	Camas Creek (Lowest)	Stressed	34.5	Fair
95SCIROA59	Snake River Plain	Rock Creek (Middle)	Stressed	31.3	Poor
95SCIROA61	Snake River Plain	Rock Creek	Stressed	24.6	Poor
95SCIROB04	N. Basin & Range	Raft River (Upper)	Stressed	15.9	Very Poor
95SCIROB07	N. Basin & Range	Little Cottonwood Creek	Stressed	16.4	Very Poor
95SCIROB11	Snake River Plain	Beaver Creek	Stressed	19.6	Poor
95SCIROB14	Snake River Plain	Pole Camp Creek	Stressed	16.7	Poor
95SCIROB15	Snake River Plain	Hopper Gulch Spring	Stressed	30.7	Poor
95SCIROB24	Snake River Plain	Shoshone Creek (Lower)	Stressed	41.5	Fair
95SCIROB32	Snake River Plain	Mcmullen Creek	Stressed	22.8	Poor
95SCIROB34	N. Basin & Range	Beaverdam Creek	Stressed	11.2	Very Poor
95SCIROB38	Snake River Plain	Big Flat Creek (Upper)	Least Imp.	51.9	Good
95SEIRO003	N. Basin & Range	Bell Marsh Creek (Upper)	Least Imp.	54.4	Good
95SEIRO022	Wyoming Basin	Pearl Creek (Upper)	Least Imp.	68.0	Good
95SEIRO023	Wyoming Basin	Co-Op Creek (Lower)	Stressed	29.5	Poor
95SEIRO024	Wyoming Basin	Co-Op Creek (Upper)	Least Imp.	57.0	Good

Sample ID	Ecoregion	Stream Name	*a priori*	Index	Rating
95SEIRO033	Wyoming Basin	Thomas Fork (Lower)	Stressed	30.7	Poor
95SEIRO034	Wyoming Basin	Thomas Fork (Upper)	Stressed	46.4	Fair
95SEIRO062	N. Basin & Range	Map6 Creek (Upper)	Least Imp.	58.6	Good
95SEIRO065	N. Basin & Range	Battle Creek(Upper)	Stressed	23.0	Poor
95SEIRO066	N. Basin & Range	Battle Creek (Lower)	Stressed	31.2	Poor
95SEIRO071	N. Basin & Range	Malad River (Lower)	Stressed	9.8	Very Poor
95SEIRO072	N. Basin & Range	Twentyfour Mile Creek	Stressed	30.1	Poor
95SWIROA01	Snake River Plain	Crane Creek (Upper)	Stressed	14.8	Very Poor
95SWIROA06	Snake River Plain	Big Jacks Creek (Upper)	Least Imp.	54.7	Good
95SWIROA18	Snake River Plain	Squaw Creek (Upper)	Least Imp.	51.8	Good
95SWIROB05	Snake River Plain	Succor Creek (Lower)	Stressed	26.2	Poor
95SWIROB06	Snake River Plain	Succor Creek (Upper)	Stressed	24.2	Poor
95SWIROB07	Snake River Plain	Juniper Creek	Least Imp.	32.9	Poor
95SWIROB11	Snake River Plain	Nickel Creek (Upper)	Stressed	9.3	Very Poor
95SWIROB19	Snake River Plain	Minneha Creek (Lower)	Least Imp.	31.8	Poor
95SWIROC10	Snake River Plain	Succor Creek	Stressed	31.2	Poor
96EIROY164	Snake River Plain	Squaw Creek	Least Imp.	88.3	Very Good
96EIROY165	Snake River Plain	Squaw Creek	Least Imp.	94.5	Very Good
96EIROZ001	N. Basin & Range	Meadow Creek	Stressed	25.0	Poor
96EIROZ002	N. Basin & Range	South Fork Sellars Creek	Least Imp.	43.6	Fair
96EIROZ003	N. Basin & Range	Sellars Creek	Least Imp.	72.0	Good
96EIROZ112	Snake River Plain	Williams Creek	Least Imp.	71.4	Good
96EIROZ130	Snake River Plain	Bitch Creek	Least Imp.	83.5	Very Good
96NCIROA38	Columbia Plateau	Shebang Creek	Stressed	28.3	Poor
96NCIROB45	Columbia Plateau	Paradise Creek	Stressed	25.2	Poor
96NCIROZ05	Columbia Plateau	Mission Creek (Upper)	Least Imp.	83.6	Very Good
96NCIROZ06	Columbia Plateau	Mission Creek (Lower)	Least Imp.	53.3	Good
96NCIROZ08	Columbia Plateau	Mission Creek (Middle)	Least Imp.	71.8	Good
96SCIROA02	Snake River Plain	Pole Camp Creek	Stressed	43.4	Fair
96SCIROA05	Snake River Plain	Langford Flat Creek	Stressed	26.4	Poor
96SCIROA07	Snake River Plain	Shoshone Creek	Stressed	68.0	Good
96SCIROA08	Snake River Plain	Shoshone Creek	Stressed	38.7	Fair
96SCIROA09	Snake River Plain	Langford Flat Creek	Stressed	19.3	Poor
96SCIROA10	Snake River Plain	Hot Creek	Stressed	33.0	Poor
96SCIROA13	Snake River Plain	Hot Creek	Stressed	40.2	Fair
96SCIROB02	Snake River Plain	Hopper Gulch Creek	Stressed	16.1	Very Poor
96SCIROB18	Snake River Plain	Big Creek (Lower)	Stressed	57.0	Good
96SCIROB22	N. Basin & Range	Raft River	Stressed	14.7	Very Poor
96SCIROB30	Snake River Plain	East Fork Dry Creek (Lower)	Least Imp.	89.9	Very Good
96SCIROB33	N. Basin & Range	Goose Creek (Middle)	Stressed	33.7	Fair
96SCIROB39	N. Basin & Range	Goose Creek (Lower)	Stressed	19.2	Poor
96SCIROB61	Snake River Plain	Cottonwood Creek (Lower)	Stressed	27.9	Poor
96SCIROB68	Snake River Plain	Chimney Creek (Upper)	Stressed	73.8	Good
96SCIROB72	N. Basin & Range	Beaverdam Creek	Stressed	17.2	Poor
96SEIROA06	N. Basin & Range	Jackson Creek (Upper)	Least Imp.	64.9	Good
96SEIROA08	N. Basin & Range	Rattlesnake Creek (Lower)	Stressed	35.2	Fair
96SEIROA20	N. Basin & Range	Cherry Creek (Upper)	Least Imp.	77.8	Very Good
96SEIROA27	N. Basin & Range	Worm Creek (Lower)	Stressed	23.5	Poor
96SEIROA37	N. Basin & Range	Gravel Creek	Least Imp.	66.8	Good
96SEIROA54	Wyoming Basin	Ovid Creek	Stressed	8.7	Very Poor
96SWIROA01	Snake River Plain	Ryegrass Creek (Upper)	Stressed	39.4	Fair

Sample ID	Ecoregion	Stream Name	*a priori*	Index	Rating
96SWIROA02	Snake River Plain	Alkali Creek (Upper)	Stressed	37.3	Fair
96SWIROA03	Snake River Plain	Alkali Creek (Middle)	Stressed	23.2	Poor
96SWIROA65	Snake River Plain	Lost Creek (Lower)	Least Imp.	62.0	Good
96SWIROB02	Snake River Plain	Ryegrass Creek (Lower)	Stressed	17.6	Poor
96SWIROB13	Snake River Plain	Pleasant Valley Creek (Upper)	Stressed	35.9	Fair
96SWIROB14	Snake River Plain	Pleasant Valley Creek (Lower)	Stressed	26.0	Poor

Appendix D.
Least Impacted and Stressed Site *A Priori* Stream Condition and Index Score (Refined Data Set for Northern Mountains and Corrections for Ambiguous Taxa)

Table D-1. Least impacted and stressed streams with SMI scores.

Sample ID	Ecoregion	Stream Name	*a priori*	Index
Northern Mountains				
1994SCDAA007	N. North. Rockies	Trestle Creek	Least Imp.	73.3
1994SCDAA008	N. North. Rockies	Pack River (Reach 2)	Stressed	47.9
1994SCDAA009	N. North. Rockies	Pack River (Lower)	Stressed	48.8
1994SCDAA021	N. North. Rockies	Upper Priest R Lower R	Least Imp.	69.5
1994SCDAA022	N. North. Rockies	Upper Priest R Upper R2	Least Imp.	62.7
1994SCDAA023	N. North. Rockies	Lighting (Lower R)	Stressed	57.5
1994SCDAA026	N. North. Rockies	Grouse (Lower R)	Stressed	62.5
1994SCDAA029	N. North. Rockies	Long Canyon Creek	Least Imp.	55.9
1994SCDAA030	N. North. Rockies	Parker Creek	Least Imp.	65.2
1994SCDAA040	N. North. Rockies	E Fork Nine Mile Up	Stressed	72.0
1994SCDAA041	N. North. Rockies	Canyon Creek R2 Up	Stressed	19.4
1994SCDAA042	N. North. Rockies	Canyon Creek R1 Up	Stressed	68.5
1994SCDAA044	N. North. Rockies	Fly Creek Lower	Least Imp.	69.8
1994SCDAA045	N. North. Rockies	Fly Creek Upper	Least Imp.	88.2
1994SCDAA046	N. North. Rockies	Mosquito Creek (L)	Least Imp.	66.2
1994SCDAA047	N. North. Rockies	Mosquito Creek (U)	Least Imp.	63.8
1994SCDAA050	N. North. Rockies	St Joe River	Least Imp.	78.7
1994SCDAA051	N. North. Rockies	St Joe River Upper	Least Imp.	90.6
1994SCDAA054	N. North. Rockies	Copper Lower	Least Imp.	70.2
1994SCDAA055	N. North. Rockies	Copper Upper	Least Imp.	79.2
1995SCDAA007	N. North. Rockies	Hangman Creek (Lower)	Stressed	31.5
1995SCDAA010	N. North. Rockies	Hoodoo Creek (Lower)	Stressed	10.9
1995SCDAA012	N. North. Rockies	Hoodoo Creek (Upper)	Stressed	8.4
1995SCDAA028	N. North. Rockies	Sisters Creek (Upper)	Stressed	56.5
1995SCDAA045	N. North. Rockies	Cougar Creek (Lower)	Stressed	22.1
1995SCDAA051	N. North. Rockies	Pack River	Stressed	52.9
1995SCDAA057	N. North. Rockies	Schweitzer Creek (Lower)	Stressed	58.9
1995SCDAA070	N. North. Rockies	Blue Joe Creek	Stressed	47.0
1995SCDAB008	N. North. Rockies	Emerald Creek (Lower)	Stressed	40.5
1995SCDAB046	N. North. Rockies	Brown Creek	Stressed	38.5
1996SCDAA010	N. North. Rockies	Bruin Creek	Least Imp.	76.9
1996SCDAA032	N. North. Rockies	Government Gulch	Stressed	37.8
1996SCDAA051	N. North. Rockies	West Fork Bluff Creek	Stressed	71.2
1996SCDAA063	N. North. Rockies	East Fork Eagle Creek	Stressed	54.3
1996SCDAA070	N. North. Rockies	Steamboat Creek (Lower)	Stressed	42.1
1996SCDAB006	N. North. Rockies	Fernan Creek (Lower)	Stressed	19.4

Sample ID	Ecoregion	Stream Name	*a priori*	Index
1996SCDAB029	N. North. Rockies	East Fork Pine Creek (Lower)	Stressed	50.4
1996SCDAB031	N. North. Rockies	Pine Creek (Upper)	Stressed	54.7
1996SCDAB032	N. North. Rockies	Prichard Creek (Lower Reach)	Stressed	33.4
1996SCDAB038	N. North. Rockies	Canyon Creek (Lower)	Stressed	17.3
1997SCDAA004	N. North. Rockies	Kid Creek(Lower)	Stressed	21.8
1997SCDAA006	N. North. Rockies	East Fork Pine Creek	Stressed	39.0
1997SCDAA028	N. North. Rockies	Loop Creek(Lower)	Stressed	84.6
1997SCDAA034	N. North. Rockies	Trestle Creek(Upper)	Least Imp.	78.8
1997SCDAA040	N. North. Rockies	Olson Creek	Least Imp.	84.4
1997SCDAA046	N. North. Rockies	Lower W. Branch Priest Riv.(Lower1)	Stressed	46.0
1997SCDAA047	N. North. Rockies	Lower W. Branch Priest Riv.(Middle2)	Stressed	54.7
1998SCDAA005	N. North. Rockies	Denver Creek	Stressed	46.1
1998SCDAA015	N. North. Rockies	Long Canyon Creek	Stressed	52.8
1998SCDAA023	N. North. Rockies	Gold Creek (Upper)	Least Imp.	81.9
1998SCDAA025	N. North. Rockies	Binarch Creek	Stressed	23.4
1998SCDAB005	N. North. Rockies	West Fork Eagle Creek (Upper)	Least Imp.	78.4
1998SCDAB011	N. North. Rockies	Graham Creek	Least Imp.	60.0
1998SCDAB014	N. North. Rockies	Hoodoo Creek	Stressed	6.5
1998SCDAB032	N. North. Rockies	Gold Creek (Upper)	Stressed	46.8
1998SCDAB034	N. North. Rockies	Gold Creek (Lower)	Least Imp.	78.6
1998SCDAB040	N. North. Rockies	South Fork Granite Creek (Upper)	Least Imp.	73.1
1998SCDAB045	N. North. Rockies	Blacktail Creek	Least Imp.	65.2
1998SCDAB046	N. North. Rockies	Whitetail Creek	Least Imp.	58.4
1998SCDAB048	N. North. Rockies	Lower W. Branch Priest Riv. (Lower3)	Stressed	37.8
1998SCDAB061	N. North. Rockies	Lower W. Branch Priest Riv. (Upper4)	Stressed	49.6
1999SCDAA005	N. North. Rockies	Jordan Creek	Least Imp.	68.1
1999SCDAA006	N. North. Rockies	Deer Creek	Least Imp.	79.1
1999SCDAA007	N. North. Rockies	Emerson Creek (Independence Creek)	Least Imp.	78.6
1999SCDAA008	N. North. Rockies	Savage Creek (E. Fork E. Fork Creek)	Least Imp.	56.7
1999SCDAA009	N. North. Rockies	Lightning Creek (Above Quartz Creek)	Least Imp.	54.4
1999SCDAA018	N. North. Rockies	Hobo Creek	Least Imp.	75.4
1999SCDAA019	N. North. Rockies	Mosquito Creek	Least Imp.	65.8
1999SCDAA020	N. North. Rockies	Timber Creek	Least Imp.	55.5
Central and Southern Mountains				
94EIRO0017	Middle Rockies	Brockman (U)	Stressed	17.4
94EIRO0027	S. North. Rockies	Twin Bridges (L)	Stressed	49.5
94EIRO0049	S. North. Rockies	Mill (U)	Least Imp.	81.0
94EIRO0062	S. North. Rockies	Dump (U)	Stressed	56.4
94EIRO0071	S. North. Rockies	Warm Springs (U)	Stressed	24.6
94SWIROA17	S. North. Rockies	Round Valley Ck	Least Imp.	87.7
94SWIROA27	S. North. Rockies	Upper Bear Creek 027	Least Imp.	75.7
94SWIROA32	Blue Mountains	Crooked R (U)	Least Imp.	61.1
94SWIROA48	Blue Mountains	Deep (U)	Least Imp.	94.7
94SWIROA49	Blue Mountains	Deep (L)	Least Imp.	79.5
94SWIROA52	S. North. Rockies	Deadhorse (U)	Least Imp.	72.3
94SWIROA56	S. North. Rockies	Twentymile (L)	Least Imp.	66.4
94SWIROA57	S. North. Rockies	Twentymile (U)	Least Imp.	68.2
94SWIROB07	Blue Mountains	Deer	Least Imp.	57.7
94SWIROB13	Blue Mountains	Mud Creek 001	Stressed	25.8
94SWIROB14	Blue Mountains	Mud Creek 002	Stressed	10.4
95EIRO0A05	Middle Rockies	Antelope Creek (Lower)	Stressed	11.2

Sample ID	Ecoregion	Stream Name	*a priori*	Index
95EIRO0A27	S. North. Rockies	Road Creek (Upper)	Stressed	6.9
95EIRO0A41	Middle Rockies	Icehouse Creek (Middle)	Stressed	58.8
95EIRO0A47	S. North. Rockies	Big Deer Creek (Upper)	Least Imp.	71.4
95EIRO0A49	S. North. Rockies	Blackbird Creek (Upper)	Stressed	6.6
95EIRO0A63	Middle Rockies	Sheridan Creek(Lower)	Stressed	47.3
95EIRO0A64	Middle Rockies	Sheridan Creek (Lower)	Stressed	28.7
95EIRO0A65	Middle Rockies	Sheridan Creek (Lower)	Stressed	28.9
95EIRO0A90	S. North. Rockies	Challis Creek (Lower)	Stressed	46.4
95EIRO0A92	S. North. Rockies	Yankee Fork(Lower)	Stressed	90.6
95EIRO0A94	Middle Rockies	Fox Creek (Upper)	Least Imp.	57.3
95EIRO0A98	Middle Rockies	Bitch Creek (Middle)	Least Imp.	57.1
95EIRO0B39	S. North. Rockies	Blackbird Creek (Lower)	Stressed	17.4
95EIRO0B40	S. North. Rockies	Panther Creek (Upper)	Least Imp.	79.9
95EIRO0B48	S. North. Rockies	Van Horn Creek (Upper)	Least Imp.	80.9
95EIRO0B52	Middle Rockies	Darby Creek (Upper)	Least Imp.	41.6
95EIRO0B77	S. North. Rockies	Big Deer Creek (Lower)	Stressed	14.1
95EIRO0B78	S. North. Rockies	Panther Creek (Lower)	Stressed	19.1
95EIRO0B79	S. North. Rockies	Panther Creek (Middle)	Stressed	24.0
95EIROA101	S. North. Rockies	Little Eightmile Creek (Middle)	Least Imp.	74.1
95SCIROA74	S. North. Rockies	Paradise Creek	Least Imp.	51.9
95SCIROA77	S. North. Rockies	Salt Creek	Least Imp.	74.3
95SCIROA86	S. North. Rockies	Red Warrior Creek	Least Imp.	58.4
95SCIROA87	S. North. Rockies	Warfield Creek	Least Imp.	61.7
95SCIROB12	S. North. Rockies	Little Beaver Creek	Stressed	43.0
95SCIROB20	S. North. Rockies	Quigley Creek	Stressed	32.2
95SCIROB25	S. North. Rockies	Shoshone Creek (Upper)	Stressed	32.7
95SCIROB29	S. North. Rockies	Cove Creek	Stressed	18.0
95SCIROB52	S. North. Rockies	Senate Creek	Least Imp.	64.7
95SCIROB53	S. North. Rockies	Big Wood River	Least Imp.	82.0
95SCIROB55	S. North. Rockies	Owl Creek	Least Imp.	77.1
95SCIROB56	S. North. Rockies	Westernhome Gulch	Least Imp.	68.8
95SEIRO060	Wasatch & Uinta	Logan River	Least Imp.	35.4
95SEIRO061	Wasatch & Uinta	Beaver Creek	Least Imp.	33.2
95SWIROA14	Blue Mountains	Round Valley Creek (Lower)	Least Imp.	36.4
95SWIROA27	Blue Mountains	French Creek (Lower)	Least Imp.	70.7
95SWIROA28	Blue Mountains	French Creek (Upper)	Least Imp.	78.9
95SWIROA30	Blue Mountains	Silver Creek (Lower)	Least Imp.	63.3
95SWIROA32	Blue Mountains	Silver Creek (Upper)	Least Imp.	52.8
95SWIROA37	Blue Mountains	Mud Creek (Upper)	Stressed	12.5
95SWIROA38	Blue Mountains	Mud Creek (Lower)	Stressed	13.5
95SWIROA39	Blue Mountains	Sloan Creek (Lower)	Stressed	36.5
95SWIROA41	S. North. Rockies	Kennally Creek (Upper)	Least Imp.	85.7
95SWIROA46	S. North. Rockies	Deadhorse Creek	Least Imp.	67.3
95SWIROB23	Blue Mountains	Fawn Creek (Lower)	Least Imp.	46.9
95SWIROB36	Blue Mountains	Johnson Creek	Least Imp.	62.2
95SWIROB38	Blue Mountains	Fawn Creek (Upper)	Least Imp.	73.3
95SWIROB39	Blue Mountains	Campbell Creek	Least Imp.	70.6
95SWIROC09	S. North. Rockies	Fall Creek (Middle)	Least Imp.	62.8
95SWIROC17	Blue Mountains	Weiser River (Middle)	Least Imp.	84.1
95SWIROC18	S. North. Rockies	Twentymile Creek (Upper)	Least Imp.	68.8
95SWIROC19	S. North. Rockies	Twentymile Creek (Middle)	Least Imp.	64.7

Sample ID	Ecoregion	Stream Name	*a priori*	Index
95SWIROC22	Blue Mountains	Boulder Creek (Upper)	Least Imp.	88.3
96EIROY026	Middle Rockies	Tie Canyon	Least Imp.	51.1
96EIROY033	Middle Rockies	Tygee Creek	Least Imp.	64.8
96EIROY042	Middle Rockies	Yale Creek	Least Imp.	61.2
96EIROY046	Middle Rockies	Snow Creek	Least Imp.	95.7
96EIROY051	Middle Rockies	North Fork Fish Creek	Least Imp.	51.2
96EIROY071	S. North. Rockies	Bellas Canyon Creek	Least Imp.	64.3
96EIROY072	S. North. Rockies	Ramey Creek	Least Imp.	61.4
96EIROY073	S. North. Rockies	Ramey Creek	Least Imp.	65.7
96EIROY075	S. North. Rockies	Bear Canyon Creek	Least Imp.	57.3
96EIROY100	S. North. Rockies	Champion Creek	Least Imp.	50.5
96EIROY108	S. North. Rockies	Basin Creek	Least Imp.	68.2
96EIROY109	S. North. Rockies	Rough Creek	Least Imp.	62.7
96EIROY168	Middle Rockies	Yale Creek	Least Imp.	66.1
96EIROZ005	Middle Rockies	Sheep Creek	Stressed	29.9
96EIROZ008	Middle Rockies	Sheep Creek	Stressed	29.0
96EIROZ020	Middle Rockies	Pine Creek	Least Imp.	56.4
96EIROZ021	Middle Rockies	Pine Creek	Least Imp.	49.8
96EIROZ022	Middle Rockies	North Fork Rainey Creek	Least Imp.	53.2
96EIROZ044	Middle Rockies	West Camas Creek	Least Imp.	62.2
96EIROZ064	Middle Rockies	Cow Creek	Stressed	19.6
96EIROZ117	Middle Rockies	Tyler Creek (1)	Least Imp.	65.5
96EIROZ125	Middle Rockies	Palisades Creek (4)	Least Imp.	75.8
96EIROZ131	Middle Rockies	Bitch Creek	Least Imp.	74.3
96SCIROA16	S. North. Rockies	Skunk Creek (Lower)	Least Imp.	54.1
96SCIROA34	S. North. Rockies	Skeleton Creek (Middle)	Least Imp.	69.7
96SCIROA39	S. North. Rockies	Ross Fork (Lower)	Least Imp.	62.9
96SCIROA41	S. North. Rockies	Ross Fork (Upper)	Least Imp.	74.0
96SCIROA44	S. North. Rockies	Fox Creek (Upper)	Least Imp.	52.1
96SCIROA45	S. North. Rockies	Prairie Creek (Upper)	Least Imp.	61.2
96SCIROA53	S. North. Rockies	Paradise Creek (Upper)	Least Imp.	60.4
96SCIROB07	S. North. Rockies	Deer Creek	Least Imp.	66.9
96SCIROB27	S. North. Rockies	Camp Creek (Upper)	Stressed	42.0
96SCIROB28	S. North. Rockies	Hyndman Creek (Middle)	Least Imp.	65.1
96SCIROB44	S. North. Rockies	Hyndman Creek (Upper)	Least Imp.	67.7
96SEIROA32	Wasatch & Uinta	Sugar Creek	Least Imp.	70.2
96SEIROA34	Wasatch & Uinta	Birch Creek	Least Imp.	68.6
96SEIROA43	Middle Rockies	Sage Creek (Middle)	Least Imp.	64.8
96SEIROA61	Middle Rockies	Tygee Creek (Lower)	Stressed	49.1
96SWIROB38	S. North. Rockies	Lime Creek (Lower)	Least Imp.	35.9
96SWIROB57	Blue Mountains	Mud Creek (Lower)	Stressed	18.6
96SWIROB58	Blue Mountains	Mud Creek (Upper)	Stressed	21.2
96SWIROB59	S. North. Rockies	Twentymile Creek (Lower)	Least Imp.	63.1
96SWIROB60	S. North. Rockies	Twentymile Creek (Middle)	Least Imp.	89.2
96SWIROB61	S. North. Rockies	Twentymile Creek (Upper)	Least Imp.	71.9
Basins				
94EIRO0012	Snake River Plain	Birch (L)	Stressed	25.7
94EIRO0014	N. Basin & Range	Hell (U)	Stressed	30.0
94EIRO0018	N. Basin & Range	Brockman (L)	Stressed	38.8
94EIRO0048	Snake River Plain	Big Timber (U)	Least Imp.	76.4
94EIRO0066	Snake River Plain	Medicine Ldg (L)	Least Imp.	82.6

Sample ID	Ecoregion	Stream Name	*a priori*	Index
94EIRO0067	Snake River Plain	Medicine Ldg (M)	Least Imp.	51.7
94NCIRO016	Columbia Plateau	Paradise Creek	Stressed	15.7
94SCIRO001	N. Basin & Range	Sublett (U)	Least Imp.	42.5
94SCIRO003	N. Basin & Range	Raft R	Stressed	41.4
94SCIRO008	Snake River Plain	Salmon Falls	Least Imp.	66.4
94SCIRO013	N. Basin & Range	Goose	Least Imp.	97.8
94SCIRO017	N. Basin & Range	Little Cottonwood (L)	Stressed	14.8
94SCIRO023	Snake River Plain	Billingsley (M)	Stressed	18.1
94SCIRO024	Snake River Plain	Billingsley (L)	Stressed	22.2
94SCIRO025	Snake River Plain	Marsh (L)	Stressed	22.7
94SCIRO027	Snake River Plain	Shoshone (U)	Stressed	40.2
94SCIRO038	Snake River Plain	Shoshone (L)	Stressed	48.5
94SCIRO041	Snake River Plain	Billingsley (U)	Stressed	11.6
94SEIRO039	Wyoming Basin	North Creek (L)	Stressed	19.8
94SEIRO042	Wyoming Basin	Skinner Creek U	Least Imp.	93.0
94SWIROA05	Snake River Plain	Succor Creek Upper Site	Stressed	54.3
94SWIROA06	Snake River Plain	Succor Creek Lower Site	Stressed	42.5
94SWIROA07	Snake River Plain	Big Jacks Creek Lower Site	Least Imp.	64.0
94SWIROA10	Snake River Plain	Bruneau River	Least Imp.	83.7
94SWIROA14	Snake River Plain	Owyhee River Below Battle Creek	Least Imp.	67.5
94SWIROA15	Snake River Plain	Owyhee River Lower Site	Least Imp.	61.7
95EIRO0A01	N. Basin & Range	Hell Creek (Middle)	Stressed	23.7
95EIRO0A02	N. Basin & Range	Hell Creek (Lower)	Stressed	14.2
95EIRO0A04	N. Basin & Range	Meadow Creek (Upper)	Least Imp.	50.1
95EIRO0A08	Snake River Plain	Badger Creek (Lower)	Least Imp.	50.1
95EIRO0A14	Snake River Plain	Dry Creek (Upper)	Stressed	40.5
95EIRO0A24	Snake River Plain	Morse Creek (Lower)	Stressed	26.3
95EIRO0A33	Snake River Plain	Warm Springs Creek (Upper)	Stressed	16.1
95EIRO0A57	Snake River Plain	Antelope Creek (Lower)	Stressed	46.5
95EIRO0A99	Snake River Plain	Bitch Creek (Lower)	Least Imp.	70.7
95EIRO0B02	N. Basin & Range	Meadow Creek (Lower)	Stressed	15.2
95EIRO0B06	Snake River Plain	Horseshoe Creek(Lower)	Stressed	22.4
95EIRO0B09	Snake River Plain	Warm Springs Creek (Lower)	Stressed	10.3
95EIRO0B12	Snake River Plain	Warm Springs Creek(Upper)	Stressed	26.6
95EIRO0B17	N. Basin & Range	Sellars Creek (Upper)	Least Imp.	41.4
95EIRO0B23	N. Basin & Range	Sellars Creek (Lower)	Least Imp.	33.4
95EIRO0B42	Snake River Plain	Hawley Creek (Middle)	Least Imp.	50.5
95EIRO0B56	Snake River Plain	South Leigh Creek (Lower)	Stressed	29.7
95EIRO0B63	Snake River Plain	Beaver Creek (Upper)	Stressed	9.8
95EIRO0B69	N. Basin & Range	Grays Lake Outlet (Lower)	Least Imp.	50.8
95EIRO0B73	N. Basin & Range	Grays Lake Outlet (Upper)	Least Imp.	41.9
95EIROA116	Snake River Plain	Bohannon Creek (Middle)	Least Imp.	88.0
95EIROA117	Snake River Plain	Canyon Creek (Middle)	Least Imp.	87.7
95NCIROA06	Columbia Plateau	Cottonwood Creek (Upper)	Stressed	19.7
95NCIROB01	Columbia Plateau	Tammany Creek	Stressed	18.8
95NCIROB34	Columbia Plateau	Paradise Creek	Stressed	25.9
95SCIROA10	Snake River Plain	Clover Creek (Lower)	Stressed	27.9
95SCIROA11	Snake River Plain	Clover Creek (Upper)	Stressed	23.0
95SCIROA14	Snake River Plain	Camas Creek (Upper)	Stressed	22.2
95SCIROA15	Snake River Plain	Camas Creek	Stressed	16.3
95SCIROA16	Snake River Plain	Camas Creek	Stressed	25.6

Sample ID	Ecoregion	Stream Name	*a priori*	Index
95SCIROA17	Snake River Plain	Camas Creek	Stressed	7.1
95SCIROA22	Snake River Plain	E Fork Rock Creek	Stressed	15.4
95SCIROA26	Snake River Plain	Dry Creek (Upper)	Stressed	11.8
95SCIROA34	N. Basin & Range	Emery Creek	Stressed	18.7
95SCIROA35	N. Basin & Range	Blue Hill Creek (Lower)	Stressed	13.7
95SCIROA37	N. Basin & Range	Blue Hill Creek(Upper)	Stressed	13.6
95SCIROA40	Snake River Plain	Camas Creek (Lowest)	Stressed	36.7
95SCIROA59	Snake River Plain	Rock Creek (Middle)	Stressed	32.8
95SCIROA61	Snake River Plain	Rock Creek	Stressed	25.6
95SCIROB04	N. Basin & Range	Raft River (Upper)	Stressed	16.5
95SCIROB07	N. Basin & Range	Little Cottonwood Creek	Stressed	17.0
95SCIROB11	Snake River Plain	Beaver Creek	Stressed	20.2
95SCIROB14	Snake River Plain	Pole Camp Creek	Stressed	17.4
95SCIROB15	Snake River Plain	Hopper Gulch Spring	Stressed	32.0
95SCIROB24	Snake River Plain	Shoshone Creek (Lower)	Stressed	41.1
95SCIROB32	Snake River Plain	Mcmullen Creek	Stressed	23.9
95SCIROB34	N. Basin & Range	Beaverdam Creek	Stressed	11.4
95SCIROB38	Snake River Plain	Big Flat Creek (Upper)	Least Imp.	52.0
95SEIRO003	N. Basin & Range	Bell Marsh Creek (Upper)	Least Imp.	50.3
95SEIRO022	Wyoming Basin	Pearl Creek (Upper)	Least Imp.	66.9
95SEIRO023	Wyoming Basin	Co-Op Creek (Lower)	Stressed	31.4
95SEIRO024	Wyoming Basin	Co-Op Creek (Upper)	Least Imp.	56.2
95SEIRO033	Wyoming Basin	Thomas Fork (Lower)	Stressed	30.6
95SEIRO034	Wyoming Basin	Thomas Fork (Upper)	Stressed	46.4
95SEIRO062	N. Basin & Range	Map6 Creek (Upper)	Least Imp.	58.4
95SEIRO065	N. Basin & Range	Battle Creek(Upper)	Stressed	23.9
95SEIRO066	N. Basin & Range	Battle Creek (Lower)	Stressed	29.9
95SEIRO071	N. Basin & Range	Malad River (Lower)	Stressed	10.1
95SEIRO072	N. Basin & Range	Twentyfour Mile Creek	Stressed	29.1
95SWIROA01	Snake River Plain	Crane Creek (Upper)	Stressed	15.3
95SWIROA06	Snake River Plain	Big Jacks Creek (Upper)	Least Imp.	57.3
95SWIROA18	Snake River Plain	Squaw Creek (Upper)	Least Imp.	50.1
95SWIROB05	Snake River Plain	Succor Creek (Lower)	Stressed	26.5
95SWIROB06	Snake River Plain	Succor Creek (Upper)	Stressed	24.4
95SWIROB07	Snake River Plain	Juniper Creek	Least Imp.	33.6
95SWIROB11	Snake River Plain	Nickel Creek (Upper)	Stressed	9.5
95SWIROB19	Snake River Plain	Minneha Creek (Lower)	Least Imp.	33.8
95SWIROC10	Snake River Plain	Succor Creek	Stressed	32.7
96EIROY164	Snake River Plain	Squaw Creek	Least Imp.	85.4
96EIROY165	Snake River Plain	Squaw Creek	Least Imp.	93.2
96EIROZ001	N. Basin & Range	Meadow Creek	Stressed	26.1
96EIROZ002	N. Basin & Range	South Fork Sellars Creek	Least Imp.	44.4
96EIROZ003	N. Basin & Range	Sellars Creek	Least Imp.	71.2
96EIROZ112	Snake River Plain	Williams Creek	Least Imp.	73.0
96EIROZ130	Snake River Plain	Bitch Creek	Least Imp.	80.5
96NCIROA38	Columbia Plateau	Shebang Creek	Stressed	27.1
96NCIROB45	Columbia Plateau	Paradise Creek	Stressed	25.8
96NCIROZ05	Columbia Plateau	Mission Creek (Upper)	Least Imp.	83.6
96NCIROZ06	Columbia Plateau	Mission Creek (Lower)	Least Imp.	54.1
96NCIROZ08	Columbia Plateau	Mission Creek (Middle)	Least Imp.	72.3
96SCIROA02	Snake River Plain	Pole Camp Creek	Stressed	45.9

Sample ID	Ecoregion	Stream Name	*a priori*	Index
96SCIROA05	Snake River Plain	Langford Flat Creek	Stressed	25.5
96SCIROA07	Snake River Plain	Shoshone Creek	Stressed	69.3
96SCIROA08	Snake River Plain	Shoshone Creek	Stressed	40.7
96SCIROA09	Snake River Plain	Langford Flat Creek	Stressed	19.9
96SCIROA10	Snake River Plain	Hot Creek	Stressed	34.6
96SCIROA13	Snake River Plain	Hot Creek	Stressed	42.4
96SCIROB02	Snake River Plain	Hopper Gulch Creek	Stressed	16.9
96SCIROB18	Snake River Plain	Big Creek (Lower)	Stressed	57.9
96SCIROB22	N. Basin & Range	Raft River	Stressed	14.9
96SCIROB30	Snake River Plain	East Fork Dry Creek (Lower)	Least Imp.	91.5
96SCIROB33	N. Basin & Range	Goose Creek (Middle)	Stressed	33.2
96SCIROB39	N. Basin & Range	Goose Creek (Lower)	Stressed	20.1
96SCIROB61	Snake River Plain	Cottonwood Creek (Lower)	Stressed	29.2
96SCIROB68	Snake River Plain	Chimney Creek (Upper)	Stressed	71.7
96SCIROB72	N. Basin & Range	Beaverdam Creek	Stressed	17.6
96SEIROA06	N. Basin & Range	Jackson Creek (Upper)	Least Imp.	68.5
96SEIROA08	N. Basin & Range	Rattlesnake Creek (Lower)	Stressed	34.4
96SEIROA20	N. Basin & Range	Cherry Creek (Upper)	Least Imp.	77.3
96SEIROA27	N. Basin & Range	Worm Creek (Lower)	Stressed	24.3
96SEIROA37	N. Basin & Range	Gravel Creek	Least Imp.	67.5
96SEIROA54	Wyoming Basin	Ovid Creek	Stressed	8.9
96SWIROA01	Snake River Plain	Ryegrass Creek (Upper)	Stressed	41.8
96SWIROA02	Snake River Plain	Alkali Creek (Upper)	Stressed	38.7
96SWIROA03	Snake River Plain	Alkali Creek (Middle)	Stressed	23.6
96SWIROA65	Snake River Plain	Lost Creek (Lower)	Least Imp.	59.1
96SWIROB02	Snake River Plain	Ryegrass Creek (Lower)	Stressed	16.4
96SWIROB13	Snake River Plain	Pleasant Valley Creek (Upper)	Stressed	37.1
96SWIROB14	Snake River Plain	Pleasant Valley Creek (Lower)	Stressed	26.3

Appendix E.
Cumulative Distribution of Candidate Metrics, All Rangeland Sites

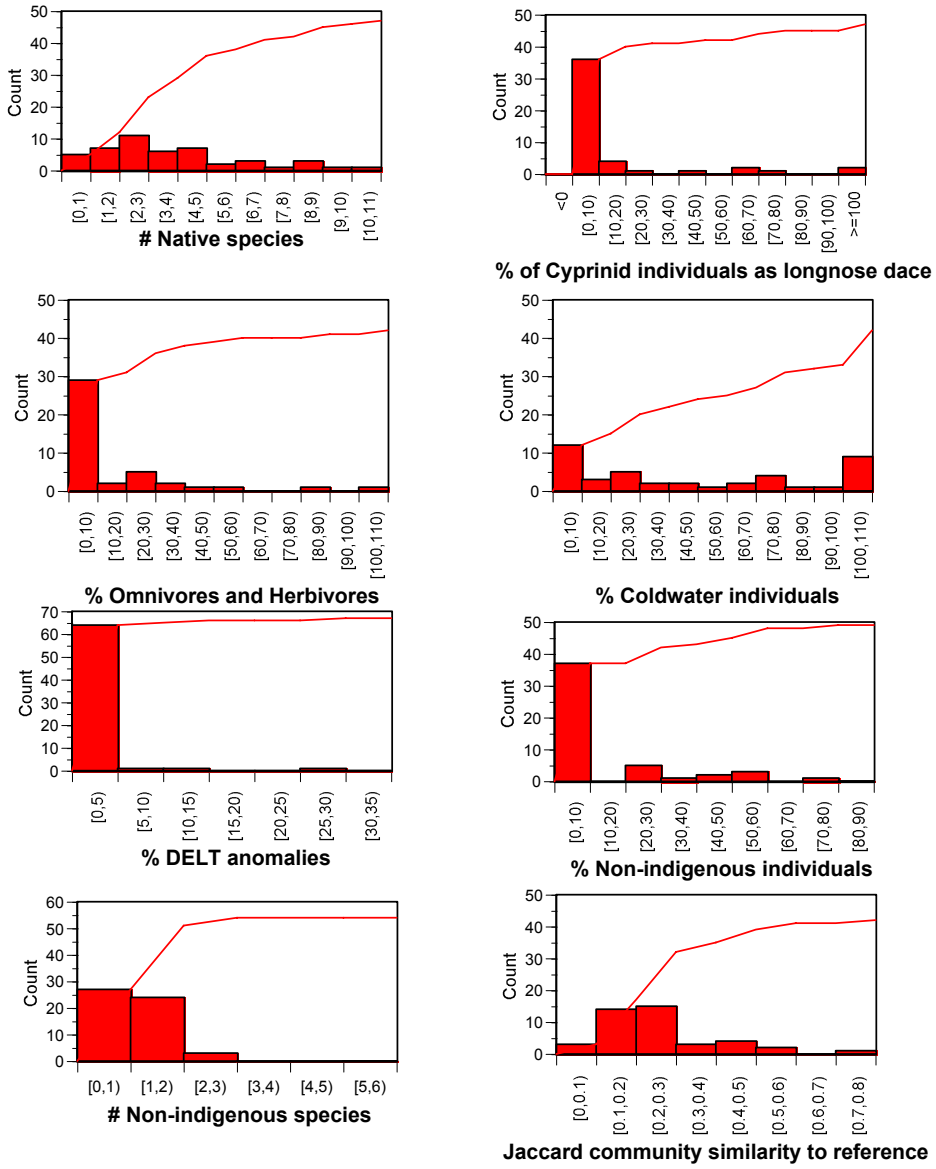


Figure E-1. Cumulative distribution of candidate metrics, all rangeland sites. “Rangeland" sites are those located in the Northern Basin and Range ecoregion below 1750m, Snake River Basin/High Desert ecoregion below 1600m, and the Columbia Basin ecoregion below 1200m.

Appendix F.
Cumulative Distribution of Selected Metrics, Small Forest Streams

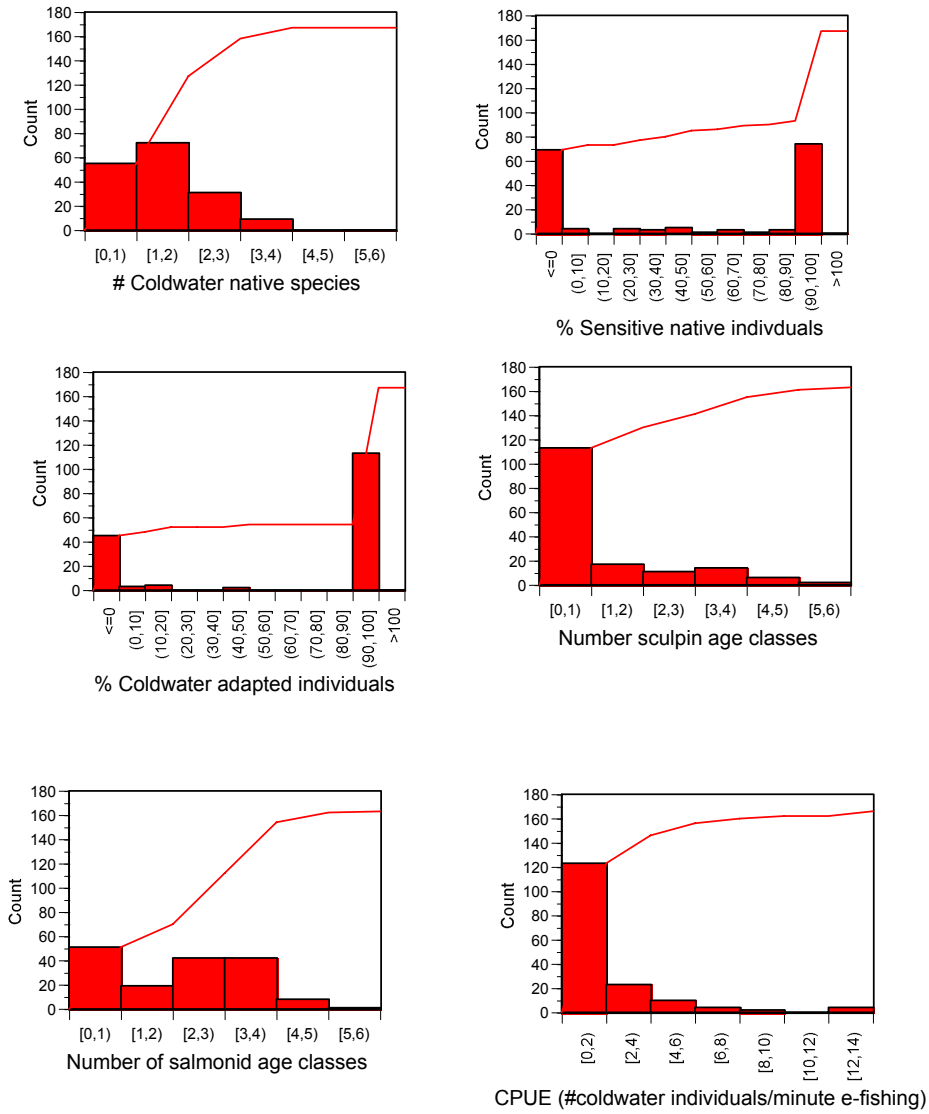


Figure F-1. Cumulative distribution of selected metrics, small forest streams. "Forest" stream sites include those located in the Northern Rockies, Middle Rockies, or Blue Mountains ecoregions. 1st and 2nd order streams were considered small, if stream order information was missing, streams with average reach wetted width of less than 2.5 m were considered small.

Appendix G.
Cumulative Distribution of Selected Metrics, Large Forest Streams

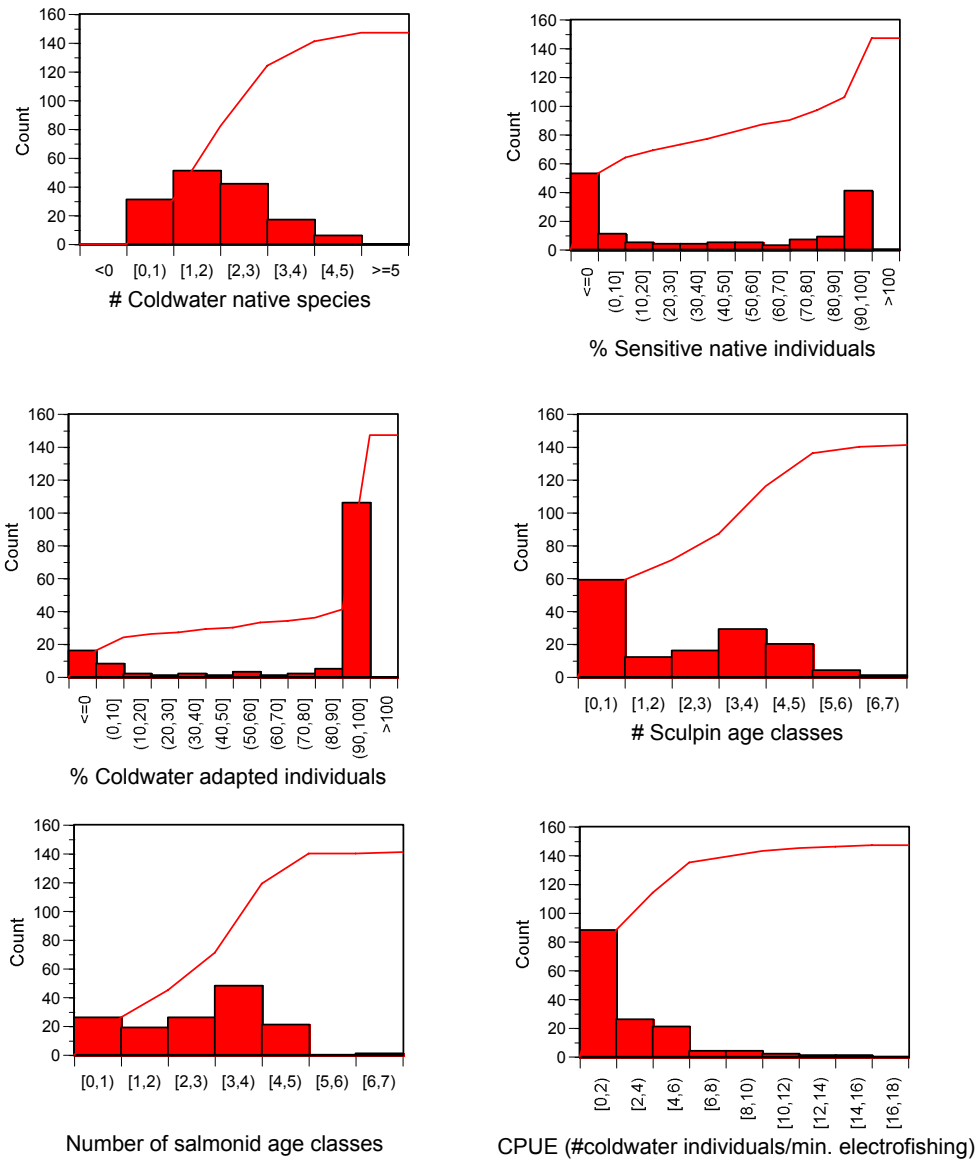


Figure G-1. Cumulative distribution of selected metrics, larger forest streams. 3rd and 4th order streams were considered larger streams, if stream order information was missing, streams with average reach wetted width of greater than 2.5 m were considered small.

Appendix H.
Data Summary

RANGELAND INDEX

Table H-1. Rangeland Index

RANGELAND INDEX						
Water Body	**Site ID**	**Stream Basin**	**Bio-region**	**R,T,O**	**SFI Range**	**Recommended Index to Apply**
Grass Cr	1994SCDAA034	KOOT	F	O	90	Forest
Grass Cr	1998SCDAA016	KOOT	F	O	69	Forest
Cedar Draw Cr	1997STWFA028	LSNK	R	T	68	Rangeland
Florence Spring	USNK-25	LSNK	R	S	87	Rangeland
Rock Cr@Twin Falls	USNK-18-96	LSNK	R	T	57	Rangeland
Rock@Rock93	USNK-17	LSNK	F	R	37	Forest
Rock@US30 93	USNK-18-93	LSNK	R	O	53	Rangeland
Rock@US30 94	USNK-18-94b	LSNK	R	O	81	Rangeland
Rock@US30 95	USNK-18-95	LSNK	R	O	78	Rangeland
Rock@US30 96	USNK-18-96	LSNK	R	O	57	Rangeland
Rock@US30 97a	USNK-18-97a	LSNK	R	O	75	Rangeland
Rock@US30 97b	USNK-18-97b	LSNK	R	O	57	Rangeland
Rock+US30 94	USNK-18-94a	LSNK	R	O	50	Rangeland
Rock-US30 94	USNK-18-94c	LSNK	R	O	63	Rangeland
Jarbidge River, EF	1997S	LSNK	R	R	89	Rangeland
Willow Cr	1997SbBOIA017	LSNK	F	O	47	Forest
Wilson Cr	2000SBOIW003	LSNK	F	R	84	Forest
Bear Cr	1998SIDFC110	LSNK	F	R	96	Forest
Birch Creek	1998SIDFC107	LSNK	F	R	72	Forest
Boundary Cr	1998SIDFC061	LSNK	F	R	89	Forest
Champion Cr	1998SIDFC135	LSNK	F	R	69	Forest
East Basin Cr	1996SIDFY105	LSNK	F	R	96	Forest
Jordan (L)	1995SIDFA039	LSNK	F	O	98	Forest
Jordan (U)	1995SIDFA038	LSNK	F	R	76	Forest
Pettit Lake Cr	1995SIDFA087	LSNK	F	R	74	Forest
Pettit Lake Creek	1995SIDFB086	LSNK	F	R	67	Forest
Pettit Lake Creek	1995SIDFB087	LSNK	F	R	74	Forest
Road Cr	1995SIDFA027	LSNK	F	T	68	Forest
Road Cr	1995SIDFA028	LSNK	F	T	74	Forest
Squaw Cr	SQ2-1980	LSNK	F	R	91	Forest
Squaw Cr	SQ2-1981	LSNK	F	R	91	Forest
Squaw Cr	SQ2-1982	LSNK	F	R	91	Forest
Squaw Cr	SQ2-1986	LSNK	F	R	89	Forest
Squaw Cr	SQ2-1989	LSNK	F	R	91	Forest
Squaw Cr	SQ2-1990	LSNK	F	R	91	Forest
Squaw Cr	SQ2-1991	LSNK	F	R	91	Forest
Squaw Cr	SQ2-1996	LSNK	F	R	91	Forest
Squaw Cr	SQ3-1997	LSNK	F	R	91	Forest
Squaw Cr	SQ2-1998	LSNK	F	R	91	Forest

RANGELAND INDEX						
Water Body	**Site ID**	**Stream Basin**	**Bio-region**	**R,T,O**	**SFI Range**	**Recommended Index to Apply**
Squaw Cr	SQ2-1999	LSNK	F	R	91	Forest
Squaw Cr	SQ3-1986	LSNK	F	R	0	Forest
Squaw Cr	SQ2-1980	LSNK	F	R	91	Forest
Squaw Cr	SQ2-1981	LSNK	F	R	91	Forest
Squaw Cr	SQ2-1982	LSNK	F	R	91	Forest
Squaw Cr	SQ2-1986	LSNK	F	R	89	Forest
Squaw Cr	SQ2-1989	LSNK	F	R	94	Forest
Squaw Cr	SQ2-1990	LSNK	F	R	94	Forest
Squaw Cr	SQ2-1991	LSNK	F	R	94	Forest
Squaw Cr	SQ2-1996	LSNK	F	R	94	Forest
Squaw Cr	SQ2-1997	LSNK	F	R	94	Forest
Squaw Cr	SQ2-1998	LSNK	F	R	94	Forest
Squaw Cr	SQ3-1986	LSNK	F	R	85	Forest
Squaw Cr	SQ3-1989	LSNK	F	R	94	Forest
Squaw Cr	SQ3-1990	LSNK	F	R	94	Forest
Squaw Cr	SQ3-1991	LSNK	F	R	94	Forest
Squaw Cr	SQ3-1996	LSNK	F	R	94	Forest
Squaw Cr	SQ3-1997	LSNK	F	R	94	Forest
Squaw Cr	SQ3-1998	LSNK	F	R	95	Forest
Stanley Lake Cr	1995SIDFA37	LSNK	F	R	100	Forest
Thompson Cr	1995SIDFA104	LSNK	F	R	75	Forest
Thompson Cr	1995SIDFA105	LSNK	F	R	96	Forest
Thompson Cr	1995SIDFA104	LSNK	F	R	75	Forest
Thompson Cr	1995SIDFA105	LSNK	F	R	96	Forest
Thompson Cr	TC1-1986	LSNK	F	R	79	Forest
Thompson Cr	TC1-1989	LSNK	F	R	95	Forest
Thompson Cr	TC1-1990	LSNK	F	R	95	Forest
Thompson Cr	TC1-1996	LSNK	F	R	95	Forest
Thompson Cr	TC1-1997	LSNK	F	R	95	Forest
Thompson Cr	TC1-1998	LSNK	F	R	95	Forest
Thompson Cr	TC4-1986	LSNK	F	R	92	Forest
Thompson Cr	TC4-1989	LSNK	F	R	89	Forest
Thompson Cr	TC4-1990	LSNK	F	R	95	Forest
Thompson Cr	TC4-1996	LSNK	F	R	95	Forest
Thompson Cr	TC4-1997	LSNK	F	R	95	Forest
Thompson Cr	TC4-1998	LSNK	F	R	95	Forest
Valley Cr	1995SIDFA071	LSNK	F	R	85	Forest
Valley Cr	1995SIDFA073	LSNK	F	R	98	Forest
Warm Springs Cr	1998SIDFC134	LSNK	F	R	72	Forest
West Pass Creek	1998SIDFC127	LSNK	F	R	96	Forest
Yankee Fork	1995SIDFA092	LSNK	F	R	76	Forest
Yankee Fork	1995SIDFA093	LSNK	F	T	68	Forest
Pahsimeroi R., EF	1998SIDFD124	LSNK	F	R	75	Forest
Pahsimeroi R., WF	1998SIDFD123	LSNK	F	R	74	Forest
Patterson Cr.	1995SIDFA083	LSNK	F	R	92	Forest
Patterson Cr.	1995SIDFM128	LSNK	F	R	77	Forest
Patterson Cr.	1995SIDFA084	LSNK	F	R	82	Forest
4th of July Cr	1997EIROM123	LSNK	F	R	88	Forest
Allan Cr	1999SIDFM063	LSNK	F	O	74	Forest
Allison Cr	1997SIDFM041	LSNK	F	R	78	Forest

RANGELAND INDEX						
Water Body	**Site ID**	**Stream Basin**	**Bio-region**	**R,T,O**	**SFI Range**	**Recommended Index to Apply**
Anderson Cr	1997SIDFM054	LSNK	F	R	94	Forest
Arnett Cr	1998SIDF091	LSNK	F	O	77	Forest
Beaver Cr	1998SIDF095	LSNK	F	R	76	Forest
Blackbird Cr + WF	1995SIDF0B39	LSNK	F	T	0	Forest
Blackbird Cr nr mouth	1995SIDF0B39	LSNK	F	T	0	Forest
Boulder Cr	1998SIDF076	LSNK	R	R	90	Rangeland
Cabin Cr	1997SIDFM102	LSNK	F	R	84	Forest
Camp Cr	1998SIDFD107	LSNK	F	R	73	Forest
Clear Cr	1998SIDFD137	LSNK	F	R	89	Forest
Copper Cr	1998SIDF091	LSNK	F	O	78	Forest
Deep Cr	1998SIDF091	LSNK	F	R	76	Forest
Deep Cr	1998SIDF091	LSNK	F	R	78	Forest
Deer Cr	1997SIDFL96	LSNK	R	R	69	Rangeland
Ditch Cr	1997SIDFM058	LSNK	F	R	96	Forest
E. Boulder Cr	1998SIDFD119	LSNK	F	R	72	Forest
E. Boulder Cr	1998SIDFD118	LSNK	F	R	77	Forest
Freeman Cr	1997SIDFM132	LSNK	R	R	96	Rangeland
Hammerean Cr	1997SIDFM056	LSNK	F	R	88	Forest
Hat Cr	1997SIDFL094	LSNK	F	O	76	Forest
Hughes Cr.	1997SIDFM060	LSNK	F	R	96	Forest
Hughes Cr., WF	1997SIDFM061	LSNK	F	R	91	Forest
Iron Cr	1998SIDFD100	LSNK	F	R	77	Forest
Iron Cr	1997SIDFL093	LSNK	F	R	96	Forest
Iron Cr., NF	1997SIDFD103	LSNK	F	R	67	Forest
Iron Cr., SF	1997SIDFD99	LSNK	F	R	79	Forest
Iron Cr., WF	1998SIDFD101	LSNK	F	R	72	Forest
Lake Cr.	1997SIDFL102	LSNK	F	O	78	Forest
Little Deer Cr.	1998SIDFD089	LSNK	F	R	88	Forest
McKim Cr.	1998SIDFD97	LSNK	F	R	72	Forest
Moose Cr	1997SIDFM106	LSNK	F	R	90	Forest
Moose Cr	1997SIDFB113	LSNK	F	R	92	Forest
Moyer Cr	1997SIDFM106	LSNK	F	R	79	Forest
Moyer Cr., SF	1997SIDFM105	LSNK	F	R	86	Forest
Musgrove Cr.	1997SIDF0M122	LSNK	F	R	87	Forest
N. Fork Salmon R.	1997SIDFM045	LSNK	F	R	96	Forest
N. Fork Salmon R., WF	1997SIDFM07	LSNK	F	R	96	Forest
Opal Cr	1997SIDFM96	LSNK	F	R	68	Forest
Otter Cr	1997SIDFM099	LSNK	F	R	92	Forest
Owl Cr	1998SIDFD077	LSNK	F	R	86	Forest
Panther Cr+Blackbird Cr	1997SIDF	LSNK	F	R	85	Forest
Panther Cr+Musgrove Cr	1998SIDFD141	LSNK	F	R	89	Forest
Panther Cr-Blackbird Cr	1995SIDF0B79	LSNK	F	T	68	Forest
Panther Cr-Opal Cr	1995SIDF0B40	LSNK	F	R	85	Forest
Porphyry Cr	1997SIDFM121	LSNK	F	R	68	Forest
Porphyry Cr	1997SIDFM120	LSNK	F	R	69	Forest
Rapps Cr	1998SIDFD106	LSNK	F	O	81	Forest
Rattlesnake Cr	1997SIDFL072	LSNK	R	R	92	Rangeland
Salt Cr	1997SIDFM104	LSNK	F	R	68	Forest
Sharkey Cr	1998SIDFD120	LSNK	F	O	83	Forest
Smithy Cr	1998SIDFM53	LSNK	R	O	82	Rangeland

RANGELAND INDEX						
Water Body	**Site ID**	**Stream Basin**	**Bio-region**	**R,T,O**	**SFI Range**	**Recommended Index to Apply**
Spring Cr	1996SIDFZ106	LSNK	R	R	60	Rangeland
Spring Cr	1997SIDFM65	LSNK	R	R	82	Rangeland
Spring Cr., EF	1997SIDFM066	LSNK	R	R	78	Rangeland
Threemile Cr	1997SIDF0M52	LSNK	R	O	94	Rangeland
Weasel Cr	1997SIDFM98	LSNK	F	R	64	Forest
Woodtick Cr	1998SIDFD93	LSNK	F	R	66	Forest
Basin	1997SIDFL090	LSNK	F	R	96	Forest
Basin	1997SIDFL088	LSNK	F	T	80	Forest
Big Eightmile	1995SIDFA078	LSNK	F	R	81	Forest
Big Eightmile	1995SIDFB074	LSNK	F	T	70	Forest
Bohannon	1995SIDFA116	LSNK	R	O	84	Rangeland
Clear	1997SIDFL081	LSNK	F	T	0	Forest
Cow	1996SIDFZ073	LSNK	F	O	91	Forest
Deer	1996SIDFZ016	LSNK	F	O	0	Forest
Ferry	1997SIDFM087	LSNK	F	T	0	Forest
Ford	1996SIDFZ011	LSNK	F	R	89	Forest
Geertson	1995SIDFB045	LSNK	R	O	88	Rangeland
Hawley	1995SIDFB042	LSNK	F	R	96	Forest
Hayden	1997SIDFM083	LSNK	F	R	90	Forest
Hayden, EF	1997SIDFM086	LSNK	F	R	68	Forest
Little Eightmile	1995SIDFA101	LSNK	F	R	93	Forest
Little Timber	1997SIDFL089	LSNK	F	R	92	Forest
Little Timber, MF	1997SIDFL078	LSNK	F	R	96	Forest
Little Timber, NF	1997SIDFL079	LSNK	F	R	96	Forest
McDevitt	1995SIDFA053	LSNK	R	T	80	Rangeland
Mill	1994SIDFA049	LSNK	F	R	65	Forest
Mill	1995SIDFA080	LSNK	F	T	0	Forest
Pattee	1996SIDFZ076	LSNK	F	O	96	Forest
Pratt	1997SIDFL086	LSNK	R	O	87	Rangeland
Sandy	1994SIDFA045	LSNK	F	R	83	Forest
Sandy	1995SIDFA081	LSNK	R	T	70	Rangeland
Shroud	1997SIDFM078	LSNK	F	R	66	Forest
Tenmile	1997SIDFL080	LSNK	F	T	0	Forest
Texas	1997SIDFM081	LSNK	F	T	77	Forest
Tobias	1996SIDFZ015	LSNK	F	R	71	Forest
Walter	1997SIDFM079	LSNK	R	T	0	Rangeland
Wildcat	1997SIDFM080	LSNK	F	R	85	Forest
Withington	1997SIDFL098	LSNK	F	O	74	Forest
Banner Cr	1997SIDFM143	LSNK	F	R	92	Forest
Bear Cr	1997SIDFL108	LSNK	F	R	73	Forest
Beaver Cr	1997SIDFL123	LSNK	F	R	74	Forest
Camp Cr	1997SIDFL110	LSNK	F	R	91	Forest
Cape Horn Cr	1997SIDFM144	LSNK	F	R	91	Forest
Cliff Cr	1997SIDFL124	LSNK	F	R	94	Forest
Indian Cr.	2000SBOIW001	LSNK	F	R	94	Forest
Knapp Cr	1997SIDFL112	LSNK	F	R	82	Forest
Marble Cr	2000SBOIW002	LSNK	F	R	86	Forest
Marsh Cr	1997SIDFM145	LSNK	F	R	91	Forest
Marsh Cr	1997SIDFM146	LSNK	F	R	89	Forest
Marsh Cr	1997SIDFM147	LSNK	F	R	79	Forest

RANGELAND INDEX						
Water Body	**Site ID**	**Stream Basin**	**Bio-region**	**R,T,O**	**SFI Range**	**Recommended Index to Apply**
Camas Cr	1997SIDFM090	LSNK	F	R	92	Forest
Hoodo Cr	1997SIDFM118	LSNK	F	R	0	Forest
Hoodo Cr	1997SIDFM115	LSNK	F	R	84	Forest
Papoose Cr	2000SBOIW004	LSNK	F	R	89	Forest
Ship Island Cr	2000SIDFW	LSNK	F	R	85	Forest
Shovel Cr	1997SIDFM113	LSNK	F	R	70	Forest
Shovel Cr	1998SIDFD146	LSNK	F	R	80	Forest
Silver Cr	1997SIDFM095	LSNK	F	R	87	Forest
Silver Cr	1997SIDFM101	LSNK	F	R	92	Forest
Silver Cr	1997SIDFM094	LSNK	F	R	75	Forest
Yellowjacket Cr	1997SIDFM112	LSNK	F	R	87	Forest
Yellowjacket Cr., NF	1997SIDFM119	LSNK	F	R	0	Forest
Bear Cr	2000SLEWW002	LSNK	F	R	80	Forest
Bitch Cr	2000SLEWW003	LSNK	F	R	100	Forest
Three Mile Cr. (Lower)	2000SLEWW003	LSNK	F	R		Forest
Three Mile Cr. (Upper)	2000SLEWW003	LSNK	F	R	0	Forest
Pinchot Cr	1998SLEWA034	LSNK	F	O	89	Forest
Long Meadow Cr	1997SLEWB012	LSNK	F	O	62	Forest
Hypothetical	1 bk	LSNK	F	O	58	Forest
Hypothetical	5 bk	LSNK	F	O	61	Forest
Hypothetical	5 bk, 5 msc	LSNK	F	O	68	Forest
Hypothetical	1 bk 1 msc	LSNK	F	O	62	Forest
Hypothetical	2 bk, 3 sc	LSNK	F	O	65	Forest
Hypothetical	4 bk, 6 sc	LSNK	F	O	67	Forest
Hypothetical	8 bk, 12 sc	LSNK	F	O	76	Forest
Hypothetical	16 bk, 24 msc	LSNK	F	O	88	Forest
Hypothetical	1 ct, 1 sh sc	LSNK	F	O	68	Forest
Hypothetical	" 2,2	LSNK	F	O	69	Forest
Hypothetical	" " 4,4	LSNK	F	O	72	Forest
Hypothetical	" " 8,8	LSNK	F	O	78	Forest
Hypothetical	16 ct, 16 shsc	LSNK	F	O	89	Forest
Hypothetical	32 ct, 32 shsc	LSNK	F	O	95	Forest
Little Boulder Cr	1997SLEWA019	LSNK	F	R	68	Forest
Noble Cr	1997SLEWC013	LSNK	F	R	94	Forest
Dog Cr	1997SLEWC31	LSNK	F	R	79	Forest
Hem Cr	1997SLEWA028	LSNK	F	R	77	Forest
Isabella Cr (upper)	1997SLEWC33	LSNK	F	R	80	Forest
Camas Creek	L	LSNK	F	R	28	Forest
Camas Creek	M	LSNK	F	T	39	Forest
Corral Creek	L	LSNK	F	R	78	Forest
Corral Creek	U	LSNK	F	R	78	Forest
Corral Creek	M	LSNK	F	T	78	Forest
Deep Creek	0	LSNK	R	R	53	Rangeland
Hurry Back Creek	L	LSNK	R	T	48	Rangeland
Hurry Back Creek	M	LSNK	R	T	49	Rangeland
Hurry Back Creek	U	LSNK	R	T	43	Rangeland
Juniper Creek	L	LSNK	R	O	83	Rangeland
Nip & Tuck Creek	L	LSNK	F	R	83	Forest
Nip & Tuck Creek	M	LSNK	F	R	87	Forest
Nip & Tuck Creek	U	LSNK	F	R	87	Forest

RANGELAND INDEX						
Water Body	**Site ID**	**Stream Basin**	**Bio-region**	**R,T,O**	**SFI Range**	**Recommended Index to Apply**
Owyhee River NF	L	LSNK	R	R	52	Rangeland
Owyhee River NF	M	LSNK	F	R	87	Forest
Owyhee River NF	U	LSNK	F	R	93	Forest
Owyhee River NF	UU	LSNK	F	R	87	Forest
Pete's Creek	L	LSNK	R	R	87	Rangeland
Pete's Creek	M	LSNK	R	R	45	Rangeland
Rail Creek	L	LSNK	R	R	50	Rangeland
Rail Creek	U	LSNK	R	T	27	Rangeland
Red Canyon WF	L	LSNK	R	R	87	Rangeland
Red Canyon WF	M	LSNK	R	R	87	Rangeland
Red Canyon WF	U	LSNK	F	R	87	Forest
S Boulder Creek	U	LSNK	F	R	87	Forest
Squaw Creek	L	LSNK	R	R	78	Rangeland
Squaw Creek	M	LSNK	R	R	83	Rangeland
Squaw Creek	U	LSNK	F	R	87	Forest
Running Cr	1997SLEWC039	LSNK	F	R	96	Forest
Tenmile Cr	1997SLEWC38	LSNK	F	R	93	Forest
Anderson Creek	M	LSNK	F	O	85	Forest
Anderson Creek	U	LSNK	F	R	85	Forest
Grizzly Creek	U	LSNK	R	T	87	Rangeland
Little Weiser River	0	LSNK	F	R	87	Forest
Weiser River WF	L	LSNK	R	R	96	Rangeland
Weiser River WF	M	LSNK	R	R	98	Rangeland
Weiser River WF	U	LSNK	F	T	80	Forest
Big Flat Cr	1995STWFB38	LSNK	F	R	49	Forest
Big Jack	ISU-27	LSNK	R	R	29	Rangeland
Big Jack Cr	ISU-16	LSNK	R	R	68	Rangeland
Big Smokey Cr	1995TWFA075	LSNK	F	R	93	Forest
Blue Lakes Spring	USNK-16	LSNK	R	S	60	Rangeland
Box Canyon Spring	USNK-21	LSNK	R	S	88	Rangeland
Briggs Spring, nr Buhl	USNK-20	LSNK	R	S	95	Rangeland
Bruneau R.	1997STWFA035	LSNK	R	T	57	Rangeland
Camp Cr	1995LEWB015	LSNK	F	R	88	Forest
Clover Cr	1997STWFA034	LSNK	R	O	27	Rangeland
Clover Cr	1997STWFA042	LSNK	R	O	16	Rangeland
Cottonwood Cr	ISU-17	LSNK	R	R	87	Rangeland
Cove Creek Spring	USNK-29	LSNK	R	S	68	Rangeland
CROOKED FORK, LOCHSA R	1996LEWC029	LSNK	F	R	94	Forest
Current Cr	ISU-46	LSNK	F	R	78	Forest
Deep	1995SBOIA058	LSNK	F	R	76	Forest
Deep Cr	ISU-52	LSNK	F	R	47	Forest
Deer Cr	1999TWFA012	LSNK	F	O	0	Forest
Deer Cr, NF	1999STWFA009	LSNK	F	O	0	Forest
Duncan Cr	ISU-47	LSNK	F	R	87	Forest
Glover	1996SLEWC013	LSNK	F	R	89	Forest
Hamby	1996LEWC010	LSNK	F	R	83	Forest
Hypo Jaccard cr	0	LSNK	R	0	70	Rangeland
Hypo Jaccard cr	0	LSNK	R	0	74	Rangeland
Hypo Jaccard cr	0	LSNK	R	0	68	Rangeland

RANGELAND INDEX						
Water Body	**Site ID**	**Stream Basin**	**Bio-region**	**R,T,O**	**SFI Range**	**Recommended Index to Apply**
Jacks Cr (lower)	1997SBOIB03	LSNK	R	O	43	Rangeland
Jacks Cr (upper)	1997SBOIB04	LSNK	R	O	23	Rangeland
Jarbidge River	1997STWFA032	LSNK	R	R	82	Rangeland
Lind Coulee	USGS-LIN016 11/04/93	LSNK	R	T	97	Rangeland
Lind Coulee	USGS-LIN016 11/02/95	LSNK	R	T	100	Rangeland
Lind Coulee	USGS-LIN016 11/02/94	LSNK	R	T	65	Rangeland
Little Jack Cr	ISU-15	LSNK	R	R	93	Rangeland
Lost Cr (lower)	1996BOIA065	LSNK	R	T	92	Rangeland
Mary's Cr	ISU-29	LSNK	F	R	59	Forest
Meadow Cr, EF	1996LEWB037	LSNK	F	R	79	Forest
Mission	1996SLEWZ005	LSNK	R	R	52	Rangeland
Otterson	1996LEWC007	LSNK	F	R	79	Forest
Pine, Cr. WF	1995SBOIA030	LSNK	F	R	82	Forest
Pleasant Valley Cr	1996SBOIB013	LSNK	F	T	37	Forest
Rock Cr @Rock Cr, ID	USNK-17	LSNK	R	R	37	Rangeland
Salmon Falls + reservoir	1994STWF008	LSNK	R	R	69	Rangeland
Satus Cr nr Toppenish, WA	YAKI NAWQA-18	LSNK	R	R	52	Rangeland
Sheep Cr	ISU-26	LSNK	R	R	44	Rangeland
Shoshone	1994STWFA027	LSNK	F	T	58	Forest
Shoshone	1994STWFA038	LSNK	R	T	48	Rangeland
Shoshone Cr	ISU-32	LSNK	F	R	27	Forest
Spring Cr	ISU-48	LSNK	R	R	82	Rangeland
Umtanum Cr, Umtanum, WA	YAKI NAWQA-13	LSNK	R	R	82	Rangeland
Van Buren Cr, NF	1999SLEWA024	LSNK	F	O	0	Forest
White Pine	1996LEWB031	LSNK	F	R	42	Forest
Wildhorse R -L	1994SBOIA034	LSNK	F	R		Forest
Wildhorse R -U	1994SBOIA033	LSNK	F	R		Forest
Willow Cr	1999SBOIA004	LSNK	F	O	0	Forest
Yakus	1995SLEWB023	LSNK	F	T	89	Forest
Long Canyon Creek	1998SCDAA015	PAN	F	O		Forest
LOWER COCOLALLA CREEK	1994SCDAA002	PAN	F	T	87	Forest
LOWER COCOLALLA CREEK	1994SCDAA002	PAN	F	T	87	Forest
Big Cr (upper)	1995SCDA0A39	PAN	F	O	94	Forest
Binarch Cr	1996SCDAA017	PAN	F	O	70	Forest
Caribou Cr (lower)	1995SCDA0A15	PAN	F	O	74	Forest
Caribou Cr (upper)	1995SCDA0A16	PAN	F	O	90	Forest
E River MF (Lower)	1996SCDA0A16	PAN	F	O	94	Forest
E River MF (Lower)	1995SCDA0A35	PAN	F	O	94	Forest
E River NF (Lower)	1998SCDAA026	PAN	F	O	88	Forest
Gold Cr.	1998SCDAA023	PAN	F	O	80	Forest
Granite Cr	1995SCDA0053	PAN	F	O	86	Forest
Granite Cr, SF	1998SCDAA024	PAN	F	O	81	Forest
Hunt Cr	1995NIRO0B22	PAN	F	O	78	Forest
Kalispell Cr (lower)	1995NIRO0B35	PAN	F	O	84	Forest

RANGELAND INDEX						
Water Body	**Site ID**	**Stream Basin**	**Bio-region**	**R,T,O**	**SFI Range**	**Recommended Index to Apply**
Kalispell Cr (middle)	1997NIRO0A22	PAN	F	O	76	Forest
Lamb Cr	1997SCDAA024	PAN	F	O	80	Forest
Lamb Cr (lower)	1997SCDA0A25	PAN	F	O	91	Forest
Lamb Cr (upper)	1995NIRO0B38	PAN	F	O	79	Forest
Lion Cr (lower)	1995SCDA0002	PAN	F	O	84	Forest
Lion Cr (upper)	1995SCDA0001	PAN	F	O	84	Forest
Lower W. Branch Priest R (lower)	1997SCDAA046	PAN	F	O	55	Forest
Lower W. Branch Priest R. (Middle)	1997SCDAA047	PAN	F	O	90	Forest
Quartz Cr (lower)	2000SCDA0002	PAN	F	O	76	Forest
Quartz Cr (upper)	2000SCDA0003	PAN	F	O	90	Forest
Reeder Cr (Middle)	2000SCDA0001	PAN	F	O	57	Forest
Reeder Cr (Upper)	1995SCDA0018	PAN	F	O	87	Forest
Soldier Cr (middle)	1998SCDAA027	PAN	F	O	80	Forest
Two Mouth Cr	1994SCDA0018	PAN	F	O	73	Forest
Two Mouth Cr (lower)	1994SCDA0017	PAN	F	O	91	Forest
Upper W. Branch Priest R (lower)	1999SCDA0015	PAN	F	O	83	Forest
Upper W. Branch Priest R (middle)	1999SCDA0014	PAN	F	O	77	Forest
Graham Creek	1998SCDAB011	PAN	F	O	96	Forest
East Fork Pine Creek	1998SCDAA008	PAN	F	O	93	Forest
East Fork Pine Creek	1996SCDAB028	PAN	F	O	63	Forest
Highland Creek	1998SCDAA003	PAN	F	O	89	Forest
Mica Cr (lower)	1996SCDAB011	PAN	F	O	86	Forest
Mosquito Cr	1994SCDAA046	PAN	F	O	92	Forest
Beaver Ck nr Mouth	USGS 473705/1155733	PAN	F	T		Forest
Canyon Ck nr Burke 00	USGS 12413118	PAN	F	R	100	Forest
Canyon Ck nr Woodland Park 00	USGS 12413123	PAN	F	T	0	Forest
Crab Cr, Ritzville, WA	USGS-UCC096-9/29/93	PAN	R	R	85	Rangeland
Crab Cr, Ritzville, WA	USGS-UCC096 9/14/94	PAN	R	R	69	Rangeland
DEER CREEK	1994SCDAA059	PAN	F	R	94	Forest
E Fk Eagle nr mouth	USGS 473925/1155302	PAN	F	T	88	Forest
E Fk Pine Ck abv Highland Mine 00	USGS 12413370	PAN	F	T	63	Forest
GOLD CREEK	1994SCDAA015	PAN	F	T	96	Forest
Hangman Ck@ Spokane, WA	nrok-22	PAN	R	T	22	Rangeland
Lightning Ck@Clark Fk, ID	nrok-11	PAN	F	T	74	Forest
LONG CANYON CREEK	1994SCDAA029	PAN	F	R		Forest
N Fk CdA nr Enaville	USGS 12413000	PAN	F	R	63	Forest
N Fk CdA nr Prichard	USGS 12411000	PAN	F	R	83	Forest
Palouse R., at Hooper, WA	USGS PAL018	PAN	R	T	9	Rangeland

RANGELAND INDEX						
Water Body	**Site ID**	**Stream Basin**	**Bio-region**	**R,T,O**	**SFI Range**	**Recommended Index to Apply**
PARKER CREEK	1994SCDAA030	PAN	F	R	87	Forest
Pine Ck nr Pinehurst 00	USGS 12413445	PAN	F	T	79	Forest
Pine Cr, Pine City, Wa	USGS-PIN008	PAN	R	T	53	Rangeland
Prichard Ck at Prichard	USGS 12411935	PAN	F	R	90	Forest
Prichard Ck nr Murray	USGS 473733/1155130	PAN	F	T	91	Forest
Prospector Cr	1996SCDAA054	PAN	F	R	89	Forest
S Fk CdA at Silverton 00	USGS 12413150	PAN	F	T	71	Forest
S Fk CdA nr Mullan 00	USGS 12413020	PAN	F	R	99	Forest
S Fk CdA nr Mullan 98	USGS 12413020	PAN	F	R	92	Forest
S Fk CdA nr Pinehurst 00b	USGS 12413470	PAN	F	T	57	Forest
S Fk CdA nr Pinehurst 98	USGS 12413470	PAN	F	T	63	Forest
S Fk CdA nr Pinehurst 99a	USGS 12413470	PAN	F	T	77	Forest
S Fk CdA nr Pinehurst 99b	USGS 12413470	PAN	F	T	70	Forest
S Fk CdA nr Pinehurst 99c	USGS 12413470	PAN	F	T	81	Forest
SF Palouse R. at Colfax, WA	USGS SFP002 9/27/93	PAN	R	T	37	Rangeland
SF Palouse R. at Colfax, WA	USGS SFP002 8/31/94	PAN	R	T	32	Rangeland
SF Palouse R. at Colfax, WA	USGS SFP002 9/01/94	PAN	R	T	47	Rangeland
St Joe at Calder	USGS 12414500	PAN	F	R	49	Forest
St Joe at Red Ives Work Station 00b	USGS 12413875	PAN	F	R	100	Forest
St Joe at Red Ives Work Station 98a	USGS 12413875	PAN	F	R	88	Forest
St Joe at Red Ives Work Station 99a	USGS 12413875	PAN	F	R	96	Forest
St Joe at Red Ives Work Station 99b	USGS 12413875	PAN	F	R	98	Forest
St Joe at Red Ives Work Station 99c	USGS 12413875	PAN	F	R	94	Forest
St Regis abv Rainy Ck 00	USGS 472510/1153608	PAN	F	R	99	Forest
St Regis nr Haugen 00	USGS 472304/1152359	PAN	F	R	96	Forest
St Regis nr St Regis 00	USGS 12354000	PAN	F	R	100	Forest
TWO MOUTH	1994SCDAA018	PAN	F	R	73	Forest
W Fk Eagle Ck blw Settlers Grove	USGS 474206/1155134	PAN	F	R	94	Forest
Bear	1996SIDFY031	USNK	F	R	84	Forest
Elk	1996SIDFY013	USNK	F	R	96	Forest
Fall	1996SIDFY017	USNK	F	O	88	Forest
Fall , S Fork	1996SIDFY018	USNK	F	O	88	Forest
Gibson	1996SIDFY024	USNK	F	R	79	Forest
Indian	1996SIDFY008	USNK	F	R	78	Forest
Pine	1996SIDFZ020	USNK	F	R	92	Forest
Pine	1996SIDFY026	USNK	F	R	77	Forest
Pine Cr, N Fork	1996SIDFZ122	USNK	F	R	95	Forest

RANGELAND INDEX						
Water Body	**Site ID**	**Stream Basin**	**Bio-region**	**R,T,O**	**SFI Range**	**Recommended Index to Apply**
Rainey	1996SIDFZ123	USNK	F	R	76	Forest
Rainey , N. Fork	1996SIDFZ022	USNK	F	R	94	Forest
Sheep	1996SIDFZ005	USNK	F	T	0	Forest
Tie Canyon	1996SIDFY027	USNK	F	R	82	Forest
West Pine	1996SIDFY028	USNK	F	R	78	Forest
Chick	1997SIDFM070	USNK	F	O	79	Forest
Fish	1997SIDFM076	USNK	F	R	47	Forest
Henry's Fork	1997SIDFM068	USNK	F	O	76	Forest
Hotel	1997SIDFM073	USNK	F	O	85	Forest
Icehouse	1995SIDFa041	USNK	F	R	80	Forest
Icehouse	1997SIDFM072	USNK	F	T	76	Forest
Jesse	1994SIDFA004	USNK	F	T	94	Forest
Porcupine	1997SIDFL072	USNK	F	R	56	Forest
Reas Pass	1996SIDFY040	USNK	F	O	0	Forest
Robinson Cr + Rock Cr	1996SIDFY055	USNK	F	R	94	Forest
Robinson Cr nr Warm R	USNK-6	USNK	F	R	93	Forest
Rock Cr	1996SIDFY053	USNK	F	R	84	Forest
Rock Cr	1996SIDFY052	USNK	F	T	64	Forest
Sheridan	1995SIDFA062	USNK	F	R	89	Forest
Sheridan	1995SIDFA065	USNK	F	T	37	Forest
Sheridan	1995SIDFA063	USNK	F	T	0	Forest
Sheridan	1995SIDFA064	USNK	F	T	41	Forest
Snow Cr	1996SIDFY046	USNK	F	R	91	Forest
Thirsty	1996SIDFz120	USNK	F	O	83	Forest
Twin	1997SIDFM067	USNK	F	T	93	Forest
Warm River	1997SIDFM071	USNK	F	R	88	Forest
Warm River	1997SIDFM075	USNK	F	R	88	Forest
Yale	1996SIDFY041	USNK	F	O	83	Forest
Conant	1997SIDFL068	USNK	F	O	100	Forest
Conant	1996SIDFz127	USNK	F	O	81	Forest
Conant	1997SIDFL061	USNK	F	O	88	Forest
Conant	1997SIDFL067	USNK	F	O	86	Forest
Dry	1997SIDFL062	USNK	F	O	0	Forest
Squirrel	1997SIDFL069	USNK	F	O	83	Forest
Bitch Cr	1996SIDFZ131	USNK	F	R	87	Forest
Bitch Cr	USNK-8	USNK	F	R	94	Forest
Calamity	1997SIDFL016	USNK	F	O	89	Forest
Canyon	1995SIDFA117	USNK	F	R	88	Forest
Darby	1997SIDFL073	USNK	F	O	88	Forest
Darby	1995SIDFB052	USNK	F	R	71	Forest
Drake	1996SIDFZ017	USNK	F	R	71	Forest
Fish	1997SIDFM015	USNK	F	R	93	Forest
Fox	1995SIDFA094	USNK	F	R	71	Forest
Fox	1995SIDFB050	USNK	F	T	0	Forest
Game	1997SIDFL058	USNK	F	R	83	Forest
Henderson	1996SIDFZ024	USNK	F	R	0	Forest
Horseshoe	1995SIDFB004	USNK	F	R	96	Forest
Horseshoe, NF	1997SIDFL057	USNK	F	R	89	Forest
Little Pine	1996SIDFZ025	USNK	F	R	72	Forest
Mahogany	1996SIDFZ121	USNK	F	R	85	Forest

RANGELAND INDEX						
Water Body	**Site ID**	**Stream Basin**	**Bio-region**	**R,T,O**	**SFI Range**	**Recommended Index to Apply**
Middle Twin	1997SIDFL065	USNK	F	O	0	Forest
Mike Harris	1996SIDFZ029	USNK	F	R	68	Forest
Moody	1995SIDFB082	USNK	R	O	95	Rangeland
Moody, N	1997SIDFL015	USNK	F	R	83	Forest
Moody, S	1997SIDFL014	USNK	F	R	88	Forest
Murphy	1996SIDFZ027	USNK	F	R	84	Forest
N. Leigh	1995SIDFB058	USNK	F	R	82	Forest
North Twin	1996SIDFZ023	USNK	F	R	73	Forest
Packsaddle	1995SIDFB003	USNK	F	R	80	Forest
Packsaddle , N Fork	1996SIDFZ032	USNK	F	R	71	Forest
Sheep	1997SIDFL013	USNK	F	R	83	Forest
South Leigh	1995SIDFB054	USNK	F	R	79	Forest
South Twin	1997SIDFL064	USNK	F	T	0	Forest
Spring	1995SIDFB024	USNK	F	O	92	Forest
Spring	1997SIDFM152	USNK	F	O	0	Forest
State	1997SIDFM014	USNK	F	R	93	Forest
Teton	1995SIDFA112	USNK	F	R	100	Forest
Teton	1997SIDFL076	USNK	F	T	0	Forest
Warm	1997SIDFL063	USNK	F	O	79	Forest
Warm	1997SIDFL018	USNK	F	T	17	Forest
Woods	1997SIDFL071	USNK	F	O	82	Forest
Wright	1997SIDFL019	USNK	F	T	0	Forest
Birch	1996SIDFZ037	USNK	R	T	67	Rangeland
Birch	1996SIDFZ041	USNK	F	T	67	Forest
Birch	1996SIDFZ038	USNK	F	T	86	Forest
Bridge Cr	1998SIDFD001	USNK	R	O	73	Rangeland
Brockman	1994SIDFA017	USNK	F	T	62	Forest
Brockman Cr	1998SIDFC002	USNK	F	T	0	Forest
Buck	1996SIDFY002	USNK	F	T	41	Forest
Bulls Fork	1997SIDFL001	USNK	F	T	0	Forest
Bulls Fork	1997SIDFM001	USNK	F	T	0	Forest
Bulls Fork Cr	1997SIDFL001	USNK	F	T	0	Forest
Bulls Fork Cr	1997SIDFM001	USNK	F	T	0	Forest
Canyon Cr	1997SIDFL010	USNK	F	T	0	Forest
Corral	1994SIDFA084	USNK	F	T	69	Forest
Crane Cr	1998SIDFD009	USNK	F	T	0	Forest
Crane Cr	1997SIDFM005	USNK	F	T	41	Forest
Crane Cr	1997SIDFM006	USNK	F	T	0	Forest
Dan	1996SIDFY126	USNK	F	T	17	Forest
Dan Cr	1998SIDFC001	USNK	F	T	0	Forest
Deep Cr	1997SIDFL004	USNK	R	T	0	Rangeland
Eagle Cr, North Fork	1998SIDFD002	USNK	F	T	0	Forest
Gravel Cr	1998SIDFD007	USNK	F	R	71	Forest
Gravel Cr	1998SIDFD008	USNK	F	R	71	Forest
Grays Lake Outlet	1997SIDFM141	USNK	F	R	45	Forest
Grays Lake Outlet	1995SIDFB073	USNK	R	R	79	Rangeland
Grays Lake Outlet	1995SIDFB069	USNK	R	R	71	Rangeland
Grays Lake Outlet	1997SIDFM141	USNK	F	T	52	Forest
Hancock	1995SIDFA017	USNK	F	T	62	Forest
Hell	1994SIDFA014	USNK	F	T	67	Forest

RANGELAND INDEX						
Water Body	**Site ID**	**Stream Basin**	**Bio-region**	**R,T,O**	**SFI Range**	**Recommended Index to Apply**
Hell	1995SIDFA001	USNK	F	T	37	Forest
Homer	1995SIDFA018	USNK	F	R	40	Forest
Indian Fork Cr	1997SIDFM002	USNK	F	T	0	Forest
Lava	1994SIDFA081	USNK	F	T	66	Forest
Lava	1994SIDFA082	USNK	F	T	50	Forest
Lava, WF	1996SIDFY134	USNK	F	T	69	Forest
Long Valley	1997SIDFL007	USNK	F	T	41	Forest
Long Valley Cr	1997SIDFL008	USNK	F	T	0	Forest
Meadow	1996SIDFZ001	USNK	F	O	0	Forest
Meadow	1995SIDFA004	USNK	F	R	92	Forest
Meadow	1996SIDFY001	USNK	R	T	69	Rangeland
Meadow Cr	1998SIDFD010	USNK	F	R	0	Forest
Meadow Cr	1998SIDFD005	USNK	F	R	86	Forest
Mill	1996SIDFY003	USNK	F	O	69	Forest
Mud Cr	1997SIDFL009	USNK	F	T	51	Forest
Mud Spring Cr	1997SIDFL003	USNK	R	T	0	Rangeland
Mud Spring Cr	1998SIDFC003	USNK	R	T	0	Rangeland
North Fork Meadow Cr	1998SIDFC004	USNK	F	R	70	Forest
Peterson Cr	1998SIDFD011	USNK	F	T	0	Forest
Right Cr	1998SIDFD012	USNK	F	T	0	Forest
Sawmill	1994SIDFA015	USNK	F	O	78	Forest
Sawmill	1994SIDFA016	USNK	F	T	46	Forest
Sellars	1996SIDFZ003	USNK	F	R	0	Forest
Sellars , S. Fork	1995SIDFB017	USNK	F	R	96	Forest
Seventy	1995SIDFB015	USNK	F	T	44	Forest
Shirley Cr	1998SIDFD004	USNK	F	T	44	Forest
Tex	1995SIDFA106	USNK	R	T	17	Rangeland
Twin Cr	1997SIDFL011	USNK	F	T	0	Forest
Willow	1997SIDFM003	USNK	F	O	75	Forest
Willow	1994SIDFA079	USNK	R	O	47	Rangeland
Willow Cr	1998SIDFD003	USNK	F	R	74	Forest
Willow Cr	1995SIDFB72	USNK	F	R	68	Forest
Webb Cr	1997SPOCA066	USNK	R	O	96	Rangeland
Crooked	1997SIDFM139	USNK	F	T	0	Forest
Divide	1997SIDFM136	USNK	F	R	0	Forest
Edie	1995SIDFB029	USNK	F	R	88	Forest
Fritz	1995SIDFB028	USNK	F	O	0	Forest
Horse	1997SIDFM135	USNK	F	R	96	Forest
Irving	1995SIDFB059	USNK	F	R	94	Forest
Medicine Lodge	1997SIDFM151	USNK	F	R	94	Forest
Medicine Lodge	1994SIDFA067	USNK	F	R	94	Forest
Medicine Lodge	1994SIDFA085	USNK	F	R	94	Forest
Medicine Lodge Cr	1994SIDF066	USNK	R	T	0	Rangeland
Middle	1997SIDFM137	USNK	F	O	94	Forest
Myers	1997SIDFM138	USNK	F	O	0	Forest
Myers Cr	1997SIDF138	USNK	F	T	0	Forest
Warm	1995SIDFB025	USNK	F	R	94	Forest
Warm Cr	1994SIDF077	USNK	F	R	96	Forest
Webber	1997SIDFM134	USNK	F	R	93	Forest
Iron Cr	1997SIDF0L36	USNK	F	R	71	Forest

RANGELAND INDEX						
Water Body	**Site ID**	**Stream Basin**	**Bio-region**	**R,T,O**	**SFI Range**	**Recommended Index to Apply**
Iron Cr	1997SIDF0L35	USNK	F	R	79	Forest
Main Fork Cr	1997SIDF0L28	USNK	F	R	85	Forest
Main Fork Cr	1998SIDFD024	USNK	F	R	70	Forest
Medicine Lodge Cr nr Small	USNK-23	USNK	F	R	96	Forest
Smithie Cr, Right Fork	1998SIDFD030	USNK	F	R	0	Forest
Smithie Cr.	1997SIDFL027	USNK	F	R	84	Forest
South Cr	1998SIDFD014	USNK	F	R	77	Forest
Timber Cr	1997SIDFL24	USNK	F	R	87	Forest
Timber Cr	1997SIDFL026	USNK	F	R	78	Forest
Timber Cr	1998IDFSD021	USNK	F	R	0	Forest
Wet Cr	1995IDFA034	USNK	F	R	86	Forest
Wet Cr	1995IDFA011	USNK	F	R	81	Forest
Boone Cr	1998SIDFD073	USNK	F	T	0	Forest
3rd Fork Creek	ISU-8	USNK	R	R	87	Rangeland
Angus, lower	ISU-60	USNK	F	R	78	Forest
Angus, upper	ISU-61	USNK	F	R	30	Forest
Bell Marsh	1995POC003	USNK	R	R	78	Rangeland
Big	1996STWFB018	USNK	F	T	42	Forest
Big Willow Cr	ISU-44	USNK	R	R	77	Rangeland
Camas Cr	ISU-51	USNK	F	R	50	Forest
Cassia	ISU-28	USNK	R	R	100	Rangeland
Cherry Cr	1996SPOCA020	USNK	F	R	66	Forest
Chippy	ISU-62	USNK	R	R	89	Rangeland
Clyde Cr	ISU-64	USNK	F	R	85	Forest
Cold Springs Cr	ISU-45	USNK	R	R	87	Rangeland
Cottonwood	1996STWFB061	USNK	R	T	25	Rangeland
Crow	ISU-65	USNK	F	R	51	Forest
Devils Washbowl Spring	USNK-15	USNK	R	S	66	Rangeland
Dry Cr, EF	1996TWFB030	USNK	R	R	93	Rangeland
Goose Cr	1994STWFA013	USNK	R	R	83	Rangeland
Goose Cr	1997STWFA072	USNK	R	R	94	Rangeland
Hot	1996STWFA013	USNK	F	T	52	Forest
Lake Fork Cr	ISU-18	USNK	R	R	83	Rangeland
Lanes	ISU-67	USNK	F	R	55	Forest
Little Beaver	1995STWFB012	USNK	F	T	89	Forest
Little Granite Cr, nr Bondurant, WY	USNK-2	USNK	F	R	83	Forest
Maple	1995SPOCA062	USNK	F	R	92	Forest
Marsh Cr	1994STWFA025	USNK	R	T	85	Rangeland
Marsh Cr@McCammon	usgs-130075000-97	USNK	R	T	60	Rangeland
Mink, SF	ISU-49	USNK	F	R	0	Forest
Paradise	1995STWFA074	USNK	F	T	88	Forest
Pearl	ISU-68	USNK	F	R	85	Forest
Pebble	ISU-85	USNK	F	R	87	Forest
Raft R. (narrows)	1999STWFA01	USNK	R	O	0	Rangeland
Rock (Holbrook)	ISU-86	USNK	R	R	55	Rangeland
Sage Creek	1996SPOCA43	USNK	R	R	68	Rangeland
Salt R near Smoot, WY	USNK-4	USNK	F	R	96	Forest
Sheep Cr	1996SIDFZ005	USNK	F	T	0	Forest

RANGELAND INDEX						
Water Body	**Site ID**	**Stream Basin**	**Bio-region**	**R,T,O**	**SFI Range**	**Recommended Index to Apply**
Slug Cr	ISU-71	USNK	F	R	0	Forest
Spring Cr nr Ft. Hall	USNK-13	USNK	R	R	55	Rangeland
Station Cr	ISU-19	USNK	R	R	91	Rangeland
Sublett Cr U	1994STWF001	USNK	F	R	93	Forest
Trapper	ISU-31	USNK	R	R	94	Rangeland
Upper Portneuf	ISU-69	USNK	R	R	57	Rangeland
Wolverine	ISU-50	USNK	F	R	87	Forest
Wright Cr	ISU-73	USNK	R	R	0	Rangeland

FOREST INDEX

Table H-2. Forest Index

FOREST INDEX						
Stream	**Site ID**	**Stream Basin**	**Bio-region**	**Class**	**SFI-Forest**	**Recommended Index to Apply**
Grass Cr	1994SCDAA034	KOOT	F	O	74	Forest
Grass Cr	1998SCDAA016	KOOT	F	O	55	Forest
Cedar Draw Cr	1997STWFA028	LSNK	R	T	35	Rangeland
Florence Spring	USNK-25	LSNK	R	S	88	Rangeland
Rock Cr@Twin Falls	USNK-18-96	LSNK	R	T	66	Rangeland
Rock@Rock93	USNK-17	LSNK	F	R	45	Forest
Rock@US30 93	USNK-18-93	LSNK	R	O	60	Rangeland
Rock@US30 94	USNK-18-94b	LSNK	R	O	82	Rangeland
Rock@US30 95	USNK-18-95	LSNK	R	O	76	Rangeland
Rock@US30 96	USNK-18-96	LSNK	R	O	60	Rangeland
Rock@US30 97a	USNK-18-97a	LSNK	R	O	76	Rangeland
Rock@US30 97b	USNK-18-97b	LSNK	R	O	46	Rangeland
Rock+US30 94	USNK-18-94a	LSNK	R	O	38	Rangeland
Rock-US30 94	USNK-18-94c	LSNK	R	O	78	Rangeland
Jarbidge River, EF	1997S	LSNK	R	R	85	Rangeland
Willow Cr	1997SbBOIA017	LSNK	F	O	49	Forest
Wilson Cr	2000SBOIW003	LSNK	F	R	89	Forest
Bear Cr	1998SIDFC110	LSNK	F	R	98	Forest
Birch Creek	1998SIDFC107	LSNK	F	R	68	Forest
Boundary Cr	1998SIDFC061	LSNK	F	R	93	Forest
Champion Cr	1998SIDFC135	LSNK	F	R	34	Forest
East Basin Cr	1996SIDFY105	LSNK	F	R	95	Forest
Jordan (L)	1995SIDFA039	LSNK	F	O	93	Forest
Jordan (U)	1995SIDFA038	LSNK	F	R	71	Forest
Pettit Lake Cr	1995SIDFA087	LSNK	F	R	29	Forest
Pettit Lake Creek	1995SIDFB086	LSNK	F	R	72	Forest
Pettit Lake Creek	1995SIDFB087	LSNK	F	R	44	Forest
Road Cr	1995SIDFA027	LSNK	F	T	55	Forest
Road Cr	1995SIDFA028	LSNK	F	T	67	Forest
Squaw Cr	SQ2-1980	LSNK	F	R	99	Forest
Squaw Cr	SQ2-1981	LSNK	F	R	99	Forest
Squaw Cr	SQ2-1982	LSNK	F	R	99	Forest
Squaw Cr	SQ2-1986	LSNK	F	R	81	Forest
Squaw Cr	SQ2-1989	LSNK	F	R	98	Forest
Squaw Cr	SQ2-1990	LSNK	F	R	98	Forest
Squaw Cr	SQ2-1991	LSNK	F	R	87	Forest
Squaw Cr	SQ2-1996	LSNK	F	R	100	Forest
Squaw Cr	SQ3-1997	LSNK	F	R	98	Forest
Squaw Cr	SQ2-1998	LSNK	F	R	90	Forest
Squaw Cr	SQ2-1999	LSNK	F	R	98	Forest
Squaw Cr	SQ3-1986	LSNK	F	R	0	Forest
Squaw Cr	SQ2-1980	LSNK	F	R	99	Forest
Squaw Cr	SQ2-1981	LSNK	F	R	99	Forest
Squaw Cr	SQ2-1982	LSNK	F	R	99	Forest

FOREST INDEX						
Stream	Site ID	Stream Basin	Bio-region	Class	SFI-Forest	Recommended Index to Apply
Squaw Cr	SQ2-1986	LSNK	F	R	91	Forest
Squaw Cr	SQ2-1989	LSNK	F	R	98	Forest
Squaw Cr	SQ2-1990	LSNK	F	R	99	Forest
Squaw Cr	SQ2-1991	LSNK	F	R	98	Forest
Squaw Cr	SQ2-1996	LSNK	F	R	99	Forest
Squaw Cr	SQ2-1997	LSNK	F	R	98	Forest
Squaw Cr	SQ2-1998	LSNK	F	R	98	Forest
Squaw Cr	SQ3-1986	LSNK	F	R	86	Forest
Squaw Cr	SQ3-1989	LSNK	F	R	100	Forest
Squaw Cr	SQ3-1990	LSNK	F	R	99	Forest
Squaw Cr	SQ3-1991	LSNK	F	R	98	Forest
Squaw Cr	SQ3-1996	LSNK	F	R	90	Forest
Squaw Cr	SQ3-1997	LSNK	F	R	90	Forest
Squaw Cr	SQ3-1998	LSNK	F	R	100	Forest
Stanley Lake Cr	1995SIDFA37	LSNK	F	R	85	Forest
Thompson Cr	1995SIDFA104	LSNK	F	R	75	Forest
Thompson Cr	1995SIDFA105	LSNK	F	R	90	Forest
Thompson Cr	1995SIDFA104	LSNK	F	R	75	Forest
Thompson Cr	1995SIDFA105	LSNK	F	R	90	Forest
Thompson Cr	TC1-1986	LSNK	F	R	89	Forest
Thompson Cr	TC1-1989	LSNK	F	R	99	Forest
Thompson Cr	TC1-1990	LSNK	F	R	100	Forest
Thompson Cr	TC1-1996	LSNK	F	R	99	Forest
Thompson Cr	TC1-1997	LSNK	F	R	100	Forest
Thompson Cr	TC1-1998	LSNK	F	R	99	Forest
Thompson Cr	TC4-1986	LSNK	F	R	97	Forest
Thompson Cr	TC4-1989	LSNK	F	R	81	Forest
Thompson Cr	TC4-1990	LSNK	F	R	99	Forest
Thompson Cr	TC4-1996	LSNK	F	R	99	Forest
Thompson Cr	TC4-1997	LSNK	F	R	99	Forest
Thompson Cr	TC4-1998	LSNK	F	R	100	Forest
Valley Cr	1995SIDFA071	LSNK	F	R	72	Forest
Valley Cr	1995SIDFA073	LSNK	F	R	96	Forest
Warm Springs Cr	1998SIDFC134	LSNK	F	R	59	Forest
West Pass Creek	1998SIDFC127	LSNK	F	R	96	Forest
Yankee Fork	1995SIDFA092	LSNK	F	R	64	Forest
Yankee Fork	1995SIDFA093	LSNK	F	T	62	Forest
Pahsimeroi R., EF	1998SIDFD124	LSNK	F	R	80	Forest
Pahsimeroi R., WF	1998SIDFD123	LSNK	F	R	72	Forest
Patterson Cr.	1995SIDFA083	LSNK	F	R	94	Forest
Patterson Cr.	1995SIDFM128	LSNK	F	R	73	Forest
Patterson Cr.	1995SIDFA084	LSNK	F	R	60	Forest
4th of July Cr	1997EIROM123	LSNK	F	R	99	Forest
Allan Cr	1999SIDFM063	LSNK	F	O	81	Forest
Allison Cr	1997SIDFM041	LSNK	F	R	85	Forest
Anderson Cr	1997SIDFM054	LSNK	F	R	95	Forest
Arnett Cr	1998SIDF091	LSNK	F	O	60	Forest
Beaver Cr	1998SIDF095	LSNK	F	R	83	Forest
Blackbird Cr + WF	1995SIDF0B39	LSNK	F	T	Barren	Forest
Blackbird Cr nr mouth	1995SIDF0B39	LSNK	F	T	0	Forest

FOREST INDEX						
Stream	**Site ID**	**Stream Basin**	**Bio-region**	**Class**	**SFI-Forest**	**Recommended Index to Apply**
Boulder Cr	1998SIDF076	LSNK	R	R	94	Rangeland
Cabin Cr	1997SIDFM102	LSNK	F	R	63	Forest
Camp Cr	1998SIDFD107	LSNK	F	R	83	Forest
Clear Cr	1998SIDFD137	LSNK	F	R	71	Forest
Copper Cr	1998SIDF091	LSNK	F	O	84	Forest
Deep Cr	1998SIDF091	LSNK	F	R	82	Forest
Deep Cr	1998SIDF091	LSNK	F	R	57	Forest
Deer Cr	1997SIDFL96	LSNK	R	R	66	Rangeland
Ditch Cr	1997SIDFM058	LSNK	F	R	99	Forest
E. Boulder Cr	1998SIDFD119	LSNK	F	R	70	Forest
E. Boulder Cr	1998SIDFD118	LSNK	F	R	69	Forest
Freeman Cr	1997SIDFM132	LSNK	R	R	99	Rangeland
Hammerean Cr	1997SIDFM056	LSNK	F	R	97	Forest
Hat Cr	1997SIDFL094	LSNK	F	O	87	Forest
Hughes Cr.	1997SIDFM060	LSNK	F	R	90	Forest
Hughes Cr., WF	1997SIDFM061	LSNK	F	R	82	Forest
Iron Cr	1998SIDFD100	LSNK	F	R	91	Forest
Iron Cr	1997SIDFL093	LSNK	F	R	95	Forest
Iron Cr., NF	1997SIDFD103	LSNK	F	R	79	Forest
Iron Cr., SF	1997SIDFD99	LSNK	F	R	89	Forest
Iron Cr., WF	1998SIDFD101	LSNK	F	R	82	Forest
Lake Cr.	1997SIDFL102	LSNK	F	O	74	Forest
Little Deer Cr.	1998SIDFD089	LSNK	F	R	92	Forest
McKim Cr.	1998SIDFD97	LSNK	F	R	79	Forest
Moose Cr	1997SIDFM106	LSNK	F	R	82	Forest
Moose Cr	1997SIDFB113	LSNK	F	R	88	Forest
Moyer Cr	1997SIDFM106	LSNK	F	R	65	Forest
Moyer Cr., SF	1997SIDFM105	LSNK	F	R	73	Forest
Musgrove Cr.	1997SIDF0M122	LSNK	F	R	79	Forest
N. Fork Salmon R.	1997SIDFM045	LSNK	F	R	98	Forest
N. Fork Salmon R., WF	1997SIDFM07	LSNK	F	R	98	Forest
Opal Cr	1997SIDFM96	LSNK	F	R	40	Forest
Otter Cr	1997SIDFM099	LSNK	F	R	99	Forest
Owl Cr	1998SIDFD077	LSNK	F	R	59	Forest
Panther Cr+Blackbird Cr	1997SIDF	LSNK	F	R	68	Forest
Panther Cr+Musgrove Cr	1998SIDFD141	LSNK	F	R	70	Forest
Panther Cr-Blackbird Cr	1995SIDF0B79	LSNK	F	T	51	Forest
Panther Cr-Opal Cr	1995SIDF0B40	LSNK	F	R	68	Forest
Porphyry Cr	1997SIDFM121	LSNK	F	R	66	Forest
Porphyry Cr	1997SIDFM120	LSNK	F	R	71	Forest
Rapps Cr	1998SIDFD106	LSNK	F	O	74	Forest
Rattlesnake Cr	1997SIDFL072	LSNK	R	R	83	Rangeland
Salt Cr	1997SIDFM104	LSNK	F	R	80	Forest
Sharkey Cr	1998SIDFD120	LSNK	F	O	81	Forest
Smithy Cr	1998SIDFM53	LSNK	R	O	92	Rangeland
Spring Cr	1996SIDFZ106	LSNK	R	R	69	Rangeland
Spring Cr	1997SIDFM65	LSNK	R	R	77	Rangeland
Spring Cr., EF	1997SIDFM066	LSNK	R	R	70	Rangeland
Threemile Cr	1997SIDF0M52	LSNK	R	O	99	Rangeland
Weasel Cr	1997SIDFM98	LSNK	F	R	76	Forest

FOREST INDEX						
Stream	**Site ID**	**Stream Basin**	**Bio-region**	**Class**	**SFI-Forest**	**Recommended Index to Apply**
Woodtick Cr	1998SIDFD93	LSNK	F	R	78	Forest
Basin	1997SIDFL090	LSNK	F	R	88	Forest
Basin	1997SIDFL088	LSNK	F	T	66	Forest
Big Eightmile	1995SIDFA078	LSNK	F	R	66	Forest
Big Eightmile	1995SIDFB074	LSNK	F	T	41	Forest
Bohannon	1995SIDFA116	LSNK	R	O	76	Rangeland
Clear	1997SIDFL081	LSNK	F	T	Barren	Forest
Cow	1996SIDFZ073	LSNK	F	O	83	Forest
Deer	1996SIDFZ016	LSNK	F	O	Barren	Forest
Ferry	1997SIDFM087	LSNK	F	T	Barren	Forest
Ford	1996SIDFZ011	LSNK	F	R	82	Forest
Geertson	1995SIDFB045	LSNK	R	O	87	Rangeland
Hawley	1995SIDFB042	LSNK	F	R	98	Forest
Hayden	1997SIDFM083	LSNK	F	R	80	Forest
Hayden, EF	1997SIDFM086	LSNK	F	R	84	Forest
Little Eightmile	1995SIDFA101	LSNK	F	R	97	Forest
Little Timber	1997SIDFL089	LSNK	F	R	83	Forest
Little Timber, MF	1997SIDFL078	LSNK	F	R	96	Forest
Little Timber, NF	1997SIDFL079	LSNK	F	R	92	Forest
McDevitt	1995SIDFA053	LSNK	R	T	65	Rangeland
Mill	1994SIDFA049	LSNK	F	R	64	Forest
Mill	1995SIDFA080	LSNK	F	T	Barren	Forest
Pattee	1996SIDFZ076	LSNK	F	O	86	Forest
Pratt	1997SIDFL086	LSNK	R	O	82	Rangeland
Sandy	1994SIDFA045	LSNK	F	R	88	Forest
Sandy	1995SIDFA081	LSNK	R	T	53	Rangeland
Shroud	1997SIDFM078	LSNK	F	R	65	Forest
Tenmile	1997SIDFL080	LSNK	F	T	Barren	Forest
Texas	1997SIDFM081	LSNK	F	T	50	Forest
Tobias	1996SIDFZ015	LSNK	F	R	78	Forest
Walter	1997SIDFM079	LSNK	R	T	Barren	Rangeland
Wildcat	1997SIDFM080	LSNK	F	R	78	Forest
Withington	1997SIDFL098	LSNK	F	O	52	Forest
Banner Cr	1997SIDFM143	LSNK	F	R	78	Forest
Bear Cr	1997SIDFL108	LSNK	F	R	83	Forest
Beaver Cr	1997SIDFL123	LSNK	F	R	59	Forest
Camp Cr	1997SIDFL110	LSNK	F	R	90	Forest
Cape Horn Cr	1997SIDFM144	LSNK	F	R	91	Forest
Cliff Cr	1997SIDFL124	LSNK	F	R	93	Forest
Indian Cr.	2000SBOIW001	LSNK	F	R	92	Forest
Knapp Cr	1997SIDFL112	LSNK	F	R	76	Forest
Marble Cr	2000SBOIW002	LSNK	F	R	87	Forest
Marsh Cr	1997SIDFM145	LSNK	F	R	72	Forest
Marsh Cr	1997SIDFM146	LSNK	F	R	96	Forest
Marsh Cr	1997SIDFM147	LSNK	F	R	75	Forest
Camas Cr	1997SIDFM090	LSNK	F	R	73	Forest
Hoodo Cr	1997SIDFM118	LSNK	F	R	Barren	Forest
Hoodo Cr	1997SIDFM115	LSNK	F	R	73	Forest
Papoose Cr	2000SBOIW004	LSNK	F	R	75	Forest
Ship Island Cr	2000SIDFW___	LSNK	F	R	94	Forest

FOREST INDEX						
Stream	**Site ID**	**Stream Basin**	**Bio-region**	**Class**	**SFI-Forest**	**Recommended Index to Apply**
Shovel Cr	1997SIDFM113	LSNK	F	R	67	Forest
Shovel Cr	1998SIDFD146	LSNK	F	R	60	Forest
Silver Cr	1997SIDFM095	LSNK	F	R	80	Forest
Silver Cr	1997SIDFM101	LSNK	F	R	83	Forest
Silver Cr	1997SIDFM094	LSNK	F	R	59	Forest
Yellowjacket Cr	1997SIDFM112	LSNK	F	R	77	Forest
Yellowjacket Cr., NF	1997SIDFM119	LSNK	F	R	Barren	Forest
Bear Cr	2000SLEWW002	LSNK	F	R	70	Forest
Bitch Cr	2000SLEWW003	LSNK	F	R	96	Forest
Three Mile Cr. (Lower)	2000SLEWW003	LSNK	F	R	44	Forest
Three Mile Cr. (upper)	2000SLEWW003	LSNK	F	R	Barren	Forest
Pinchot Cr	1998SLEWA034	LSNK	F	O	93	Forest
Long Meadow Cr	1997SLEWB012	LSNK	F	O	26	Forest
Hypothetical	1 bk	LSNK	F	O	21	Forest
Hypothetical	5 bk	LSNK	F	O	31	Forest
Hypothetical	5 bk, 5 msc	LSNK	F	O	55	Forest
Hypothetical	1 bk 1 msc	LSNK	F	O	38	Forest
Hypothetical	2 bk, 3 sc	LSNK	F	O	44	Forest
Hypothetical	4 bk, 6 sc	LSNK	F	O	62	Forest
Hypothetical	8 bk, 12 sc	LSNK	F	O	73	Forest
Hypothetical	16 bk, 24 msc	LSNK	F	O	80	Forest
Hypothetical	1 ct, 1 sh sc	LSNK	F	O	55	Forest
Hypothetical	" 2,2	LSNK	F	O	60	Forest
Hypothetical	" " 4,4	LSNK	F	O	78	Forest
Hypothetical	" " 8,8	LSNK	F	O	88	Forest
Hypothetical	16 ct, 16 shsc	LSNK	F	O	95	Forest
Hypothetical	32 ct, 32 shsc	LSNK	F	O	98	Forest
Little Boulder Cr	1997SLEWA019	LSNK	F	R	65	Forest
Noble Cr	1997SLEWC013	LSNK	F	R	100	Forest
Dog Cr	1997SLEWC31	LSNK	F	R	68	Forest
Hem Cr	1997SLEWA028	LSNK	F	R	88	Forest
Isabella Cr (upper)	1997SLEWC33	LSNK	F	R	78	Forest
Camas Creek	L	LSNK	F	R	15	Forest
Camas Creek	M	LSNK	F	T	0	Forest
Corral Creek	L	LSNK	F	R	70	Forest
Corral Creek	U	LSNK	F	R	80	Forest
Corral Creek	M	LSNK	F	T	69	Forest
Deep Creek	0	LSNK	R	R	10	Rangeland
Hurry Back Creek	L	LSNK	R	T	32	Rangeland
Hurry Back Creek	M	LSNK	R	T	0	Rangeland
Hurry Back Creek	U	LSNK	R	T	0	Rangeland
Juniper Creek	L	LSNK	R	O	45	Rangeland
Nip & Tuck Creek	L	LSNK	F	R	64	Forest
Nip & Tuck Creek	M	LSNK	F	R	100	Forest
Nip & Tuck Creek	U	LSNK	F	R	100	Forest
Owyhee River NF	L	LSNK	R	R	25	Rangeland
Owyhee River NF	M	LSNK	F	R	80	Forest
Owyhee River NF	U	LSNK	F	R	80	Forest
Owyhee River NF	UU	LSNK	F	R	80	Forest
Pete's Creek	L	LSNK	R	R	70	Rangeland

FOREST INDEX						
Stream	**Site ID**	**Stream Basin**	**Bio-region**	**Class**	**SFI-Forest**	**Recommended Index to Apply**
Pete's Creek	M	LSNK	R	R	53	Rangeland
Rail Creek	L	LSNK	R	R	36	Rangeland
Rail Creek	U	LSNK	R	T	0	Rangeland
Red Canyon WF	L	LSNK	R	R	69	Rangeland
Red Canyon WF	M	LSNK	R	R	69	Rangeland
Red Canyon WF	U	LSNK	F	R	80	Forest
S Boulder Creek	U	LSNK	F	R	70	Forest
Squaw Creek	L	LSNK	R	R	62	Rangeland
Squaw Creek	M	LSNK	R	R	69	Rangeland
Squaw Creek	U	LSNK	F	R	81	Forest
Running Cr	1997SLEWC039	LSNK	F	R	100	Forest
Tenmile Cr	1997SLEWC38	LSNK	F	R	96	Forest
Anderson Creek	M	LSNK	F	O	74	Forest
Anderson Creek	U	LSNK	F	R	74	Forest
Grizzly Creek	U	LSNK	R	T	51	Rangeland
Little Weiser River	0	LSNK	F	R	80	Forest
Weiser River WF	L	LSNK	R	R	89	Rangeland
Weiser River WF	M	LSNK	R	R	98	Rangeland
Weiser River WF	U	LSNK	F	T	40	Forest
Big Flat Cr	1995STWFB38	LSNK	F	R	18	Forest
Big Jack	ISU-27	LSNK	R	R	14	Rangeland
Big Jack Cr	ISU-16	LSNK	R	R	12	Rangeland
Big Smokey Cr	1995TWFA075	LSNK	F	R	83	Forest
Blue Lakes Spring	USNK-16	LSNK	R	S	52	Rangeland
Box Canyon Spring	USNK-21	LSNK	R	S	92	Rangeland
Briggs Spring, nr Buhl	USNK-20	LSNK	R	S	85	Rangeland
Bruneau R.	1997STWFA035	LSNK	R	T	8	Rangeland
Camp Cr	1995LEWB015	LSNK	F	R	68	Forest
Clover Cr	1997STWFA034	LSNK	R	O	0	Rangeland
Clover Cr	1997STWFA042	LSNK	R	O	0	Rangeland
Cottonwood Cr	ISU-17	LSNK	R	R	50	Rangeland
Cove Creek Spring	USNK-29	LSNK	R	S	68	Rangeland
CROOKED FORK, LOCHSA R	1996LEWC029	LSNK	F	R	81	Forest
Current Cr	ISU-46	LSNK	F	R	40	Forest
Deep	1995SBOIA058	LSNK	F	R	85	Forest
Deep Cr	ISU-52	LSNK	F	R	22	Forest
Deer Cr	1999TWFA012	LSNK	F	O	0	Forest
Deer Cr, NF	1999STWFA009	LSNK	F	O	0	Forest
Duncan Cr	ISU-47	LSNK	F	R	100	Forest
Glover	1996SLEWC013	LSNK	F	R	86	Forest
Hamby	1996LEWC010	LSNK	F	R	39	Forest
Hypo Jaccard cr	0	LSNK	R	0	52	Rangeland
Hypo Jaccard cr	0	LSNK	R	0	75	Rangeland
Hypo Jaccard cr	0	LSNK	R	0	62	Rangeland
Jacks Cr (lower)	1997SBOIB03	LSNK	R	O	0	Rangeland
Jacks Cr (upper)	1997SBOIB04	LSNK	R	O	0	Rangeland
Jarbidge River	1997STWFA032	LSNK	R	R	80	Rangeland
Lind Coulee	USGS-LIN016 11/04/93	LSNK	R	T	61	Rangeland

FOREST INDEX						
Stream	**Site ID**	**Stream Basin**	**Bio-region**	**Class**	**SFI-Forest**	**Recommended Index to Apply**
Lind Coulee	USGS-LIN016 11/02/95	LSNK	R	T	93	Rangeland
Lind Coulee	USGS-LIN016 11/02/94	LSNK	R	T	24	Rangeland
Little Jack Cr	ISU-15	LSNK	R	R	97	Rangeland
Lost Cr (lower)	1996BOIA065	LSNK	R	T	89	Rangeland
Mary's Cr	ISU-29	LSNK	F	R	0	Forest
Meadow Cr, EF	1996LEWB037	LSNK	F	R	65	Forest
Mission	1996SLEWZ005	LSNK	R	R	30	Rangeland
Otterson	1996LEWC007	LSNK	F	R	66	Forest
Pine, Cr. WF	1995SBOIA030	LSNK	F	R	91	Forest
Pleasant Valley Cr	1996SBOIB013	LSNK	F	T	0	Forest
Rock Cr @Rock Cr, ID	USNK-17	LSNK	R	R	32	Rangeland
Salmon Falls + reservoir	1994STWF008	LSNK	R	R	39	Rangeland
Satus Cr nr Toppenish, WA	YAKI NAWQA-18	LSNK	R	R	34	Rangeland
Sheep Cr	ISU-26	LSNK	R	R	0	Rangeland
Shoshone	1994STWFA027	LSNK	F	T	41	Forest
Shoshone	1994STWFA038	LSNK	R	T	10	Rangeland
Shoshone Cr	ISU-32	LSNK	F	R	17	Forest
Spring Cr	ISU-48	LSNK	R	R	59	Rangeland
Umtanum Cr, Umtanum, WA	YAKI NAWQA-13	LSNK	R	R	99	Rangeland
Van Buren Cr, NF	1999SLEWA024	LSNK	F	O	0	Forest
White Pine	1996LEWB031	LSNK	F	R	29	Forest
Wildhorse R -L	1994SBOIA034	LSNK	F	R	94	Forest
Wildhorse R -U	1994SBOIA033	LSNK	F	R	58	Forest
Willow Cr	1999SBOIA004	LSNK	F	O	0	Forest
Yakus	1995SLEWB023	LSNK	F	T	94	Forest
Long Canyon Creek	1998SCDAA015	PAN	F	O	55	Forest
LOWER COCOLALLA CREEK	1994SCDAA002	PAN	F	T	82	Forest
LOWER COCOLALLA CREEK	1994SCDAA002	PAN	F	T	82	Forest
Big Cr (upper)	1995SCDA0A39	PAN	F	O	79	Forest
Binarch Cr	1996SCDAA017	PAN	F	O	77	Forest
Caribou Cr (lower)	1995SCDA0A15	PAN	F	O	43	Forest
Caribou Cr (upper)	1995SCDA0A16	PAN	F	O	62	Forest
E River MF (Lower)	1996SCDA0A16	PAN	F	O	83	Forest
E River MF (Lower)	1995SCDA0A35	PAN	F	O	84	Forest
E River NF (Lower)	1998SCDAA026	PAN	F	O	61	Forest
Gold Cr.	1998SCDAA023	PAN	F	O	84	Forest
Granite Cr	1995SCDA0053	PAN	F	O	73	Forest
Granite Cr, SF	1998SCDAA024	PAN	F	O	72	Forest
Hunt Cr	1995NIRO0B22	PAN	F	O	53	Forest
Kalispell Cr (lower)	1995NIRO0B35	PAN	F	O	68	Forest
Kalispell Cr (middle)	1997NIRO0A22	PAN	F	O	55	Forest
Lamb Cr	1997SCDAA024	PAN	F	O	51	Forest
Lamb Cr (lower)	1997SCDA0A25	PAN	F	O	70	Forest
Lamb Cr (upper)	1995NIRO0B38	PAN	F	O	40	Forest
Lion Cr (lower)	1995SCDA0002	PAN	F	O	57	Forest

FOREST INDEX						
Stream	**Site ID**	**Stream Basin**	**Bio-region**	**Class**	**SFI-Forest**	**Recommended Index to Apply**
Lion Cr (upper)	1995SCDA0001	PAN	F	O	59	Forest
Lower W. Branch Priest R (lower)	1997SCDAA046	PAN	F	O	20	Forest
Lower W. Branch Priest R. (Middle)	1997SCDAA047	PAN	F	O	54	Forest
Quartz Cr (lower)	2000SCDA0002	PAN	F	O	65	Forest
Quartz Cr (upper)	2000SCDA0003	PAN	F	O	74	Forest
Reeder Cr (Middle)	2000SCDA0001	PAN	F	O	39	Forest
Reeder Cr (Upper)	1995SCDA0018	PAN	F	O	50	Forest
Soldier Cr (middle)	1998SCDAA027	PAN	F	O	54	Forest
Two Mouth Cr	1994SCDA0018	PAN	F	O	70	Forest
Two Mouth Cr (lower)	1994SCDA0017	PAN	F	O	91	Forest
Upper W. Branch Priest R (lower)	1999SCDA0015	PAN	F	O	55	Forest
Upper W. Branch Priest R (middle)	1999SCDA0014	PAN	F	O	68	Forest
Graham Creek	1998SCDAB011	PAN	F	O	95	Forest
East Fork Pine Creek	1998SCDAA008	PAN	F	O	94	Forest
East Fork Pine Creek	1996SCDAB028	PAN	F	O	41	Forest
Highland Creek	1998SCDAA003	PAN	F	O	94	Forest
Mica Cr (lower)	1996SCDAB011	PAN	F	O	90	Forest
Mosquito Cr	1994SCDAA046	PAN	F	O	86	Forest
Beaver Ck nr Mouth	USGS 473705/1155733	PAN	F	T	99	Forest
Canyon Ck nr Burke 00	USGS 12413118	PAN	F	R	100	Forest
Canyon Ck nr Woodland Park 00	USGS 12413123	PAN	F	T	0	Forest
Crab Cr, Ritzville, WA	USGS-UCC096-9/29/93	PAN	R	R	48	Rangeland
Crab Cr, Ritzville, WA	USGS-UCC096 9/14/94	PAN	R	R	47	Rangeland
DEER CREEK	1994SCDAA059	PAN	F	R	85	Forest
E Fk Eagle nr mouth	USGS 473925/1155302	PAN	F	T	69	Forest
E Fk Pine Ck abv Highland Mine 00	USGS 12413370	PAN	F	T	52	Forest
GOLD CREEK	1994SCDAA015	PAN	F	T	90	Forest
Hangman Ck@ Spokane, WA	nrok-22	PAN	R	T	25	Rangeland
Lightning Ck@Clark Fk, ID	nrok-11	PAN	F	T	36	Forest
LONG CANYON CREEK	1994SCDAA029	PAN	F	R	73	Forest
N Fk CdA nr Enaville	USGS 12413000	PAN	F	R	52	Forest
N Fk CdA nr Prichard	USGS 12411000	PAN	F	R	52	Forest
Palouse R., at Hooper, WA	USGS PAL018	PAN	R	T	1	Rangeland
PARKER CREEK	1994SCDAA030	PAN	F	R	79	Forest
Pine Ck nr Pinehurst 00	USGS 12413445	PAN	F	T	65	Forest
Pine Cr, Pine City, Wa	USGS-PIN008	PAN	R	T	0	Rangeland
Prichard Ck at Prichard	USGS 12411935	PAN	F	R	89	Forest
Prichard Ck nr Murray	USGS	PAN	F	T	73	Forest

FOREST INDEX						
Stream	**Site ID**	**Stream Basin**	**Bio-region**	**Class**	**SFI-Forest**	**Recommended Index to Apply**
	473733/1155130					
Prospector Cr	1996SCDAA054	PAN	F	R	92	Forest
S Fk CdA at Silverton 00	USGS 12413150	PAN	F	T	58	Forest
S Fk CdA nr Mullan 00	USGS 12413020	PAN	F	R	100	Forest
S Fk CdA nr Mullan 98	USGS 12413020	PAN	F	R	92	Forest
S Fk CdA nr Pinehurst 00b	USGS 12413470	PAN	F	T	52	Forest
S Fk CdA nr Pinehurst 98	USGS 12413470	PAN	F	T	35	Forest
S Fk CdA nr Pinehurst 99a	USGS 12413470	PAN	F	T	51	Forest
S Fk CdA nr Pinehurst 99b	USGS 12413470	PAN	F	T	47	Forest
S Fk CdA nr Pinehurst 99c	USGS 12413470	PAN	F	T	55	Forest
SF Palouse R. at Colfax, WA	USGS SFP002 9/27/93	PAN	R	T	0	Rangeland
SF Palouse R. at Colfax, WA	USGS SFP002 8/31/94	PAN	R	T	0	Rangeland
SF Palouse R. at Colfax, WA	USGS SFP002 9/01/94	PAN	R	T	0	Rangeland
St Joe at Calder	USGS 12414500	PAN	F	R	48	Forest
St Joe at Red Ives Work Station 00b	USGS 12413875	PAN	F	R	100	Forest
St Joe at Red Ives Work Station 98a	USGS 12413875	PAN	F	R	91	Forest
St Joe at Red Ives Work Station 99a	USGS 12413875	PAN	F	R	99	Forest
St Joe at Red Ives Work Station 99b	USGS 12413875	PAN	F	R	99	Forest
St Joe at Red Ives Work Station 99c	USGS 12413875	PAN	F	R	99	Forest
St Regis abv Rainy Ck 00	USGS 472510/1153608	PAN	F	R	100	Forest
St Regis nr Haugen 00	USGS 472304/1152359	PAN	F	R	100	Forest
St Regis nr St Regis 00	USGS 12354000	PAN	F	R	100	Forest
TWO MOUTH	1994SCDAA018	PAN	F	R	70	Forest
W Fk Eagle Ck blw Settlers Grove	USGS 474206/1155134	PAN	F	R	99	Forest
Bear	1996SIDFY031	USNK	F	R	61	Forest
Elk	1996SIDFY013	USNK	F	R	70	Forest
Fall	1996SIDFY017	USNK	F	O	49	Forest
Fall , S Fork	1996SIDFY018	USNK	F	O	68	Forest
Gibson	1996SIDFY024	USNK	F	R	88	Forest
Indian	1996SIDFY008	USNK	F	R	70	Forest
Pine	1996SIDFZ020	USNK	F	R	81	Forest
Pine	1996SIDFY026	USNK	F	R	73	Forest
Pine Cr, N Fork	1996SIDFZ122	USNK	F	R	87	Forest
Rainey	1996SIDFZ123	USNK	F	R	78	Forest
Rainey , N. Fork	1996SIDFZ022	USNK	F	R	94	Forest
Sheep	1996SIDFZ005	USNK	F	T	Barren	Forest
Tie Canyon	1996SIDFY027	USNK	F	R	86	Forest
West Pine	1996SIDFY028	USNK	F	R	72	Forest

FOREST INDEX						
Stream	**Site ID**	**Stream Basin**	**Bio-region**	**Class**	**SFI-Forest**	**Recommended Index to Apply**
Chick	1997SIDFM070	USNK	F	O	50	Forest
Fish	1997SIDFM076	USNK	F	R	9	Forest
Henry's Fork	1997SIDFM068	USNK	F	O	48	Forest
Hotel	1997SIDFM073	USNK	F	O	69	Forest
Icehouse	1995SIDFa041	USNK	F	R	84	Forest
Icehouse	1997SIDFM072	USNK	F	T	57	Forest
Jesse	1994SIDFA004	USNK	F	T	79	Forest
Porcupine	1997SIDFL072	USNK	F	R	58	Forest
Reas Pass	1996SIDFY040	USNK	F	O	0	Forest
Robinson Cr + Rock Cr	1996SIDFY055	USNK	F	R	73	Forest
Robinson Cr nr Warm R	USNK-6	USNK	F	R	73	Forest
Rock Cr	1996SIDFY053	USNK	F	R	47	Forest
Rock Cr	1996SIDFY052	USNK	F	T	18	Forest
Sheridan	1995SIDFA062	USNK	F	R	66	Forest
Sheridan	1995SIDFA065	USNK	F	T	0	Forest
Sheridan	1995SIDFA063	USNK	F	T	0	Forest
Sheridan	1995SIDFA064	USNK	F	T	0	Forest
Snow Cr	1996SIDFY046	USNK	F	R	56	Forest
Thirsty	1996SIDFz120	USNK	F	O	40	Forest
Twin	1997SIDFM067	USNK	F	T	75	Forest
Warm River	1997SIDFM071	USNK	F	R	41	Forest
Warm River	1997SIDFM075	USNK	F	R	55	Forest
Yale	1996SIDFY041	USNK	F	O	44	Forest
Conant	1997SIDFL068	USNK	F	O	19	Forest
Conant	1996SIDFz127	USNK	F	O	24	Forest
Conant	1997SIDFL061	USNK	F	O	46	Forest
Conant	1997SIDFL067	USNK	F	O	27	Forest
Dry	1997SIDFL062	USNK	F	O	Barren	Forest
Squirrel	1997SIDFL069	USNK	F	O	27	Forest
Bitch Cr	1996SIDFZ131	USNK	F	R	74	Forest
Bitch Cr	USNK-8	USNK	F	R	87	Forest
Calamity	1997SIDFL016	USNK	F	O	75	Forest
Canyon	1995SIDFA117	USNK	F	R	69	Forest
Darby	1997SIDFL073	USNK	F	O	61	Forest
Darby	1995SIDFB052	USNK	F	R	69	Forest
Drake	1996SIDFZ017	USNK	F	R	34	Forest
Fish	1997SIDFM015	USNK	F	R	78	Forest
Fox	1995SIDFA094	USNK	F	R	39	Forest
Fox	1995SIDFB050	USNK	F	T	Barren	Forest
Game	1997SIDFL058	USNK	F	R	40	Forest
Henderson	1996SIDFZ024	USNK	F	R	Barren	Forest
Horseshoe	1995SIDFB004	USNK	F	R	86	Forest
Horseshoe, NF	1997SIDFL057	USNK	F	R	80	Forest
Little Pine	1996SIDFZ025	USNK	F	R	33	Forest
Mahogany	1996SIDFZ121	USNK	F	R	64	Forest
Middle Twin	1997SIDFL065	USNK	F	O	Barren	Forest
Mike Harris	1996SIDFZ029	USNK	F	R	33	Forest
Moody	1995SIDFB082	USNK	R	O	59	Rangeland
Moody, N	1997SIDFL015	USNK	F	R	40	Forest
Moody, S	1997SIDFL014	USNK	F	R	79	Forest

FOREST INDEX						
Stream	**Site ID**	**Stream Basin**	**Bio-region**	**Class**	**SFI-Forest**	**Recommended Index to Apply**
Murphy	1996SIDFZ027	USNK	F	R	72	Forest
N. Leigh	1995SIDFB058	USNK	F	R	49	Forest
North Twin	1996SIDFZ023	USNK	F	R	70	Forest
Packsaddle	1995SIDFB003	USNK	F	R	40	Forest
Packsaddle , N Fork	1996SIDFZ032	USNK	F	R	46	Forest
Sheep	1997SIDFL013	USNK	F	R	40	Forest
South Leigh	1995SIDFB054	USNK	F	R	69	Forest
South Twin	1997SIDFL064	USNK	F	T	Barren	Forest
Spring	1995SIDFB024	USNK	F	O	45	Forest
Spring	1997SIDFM152	USNK	F	O	Barren	Forest
State	1997SIDFM014	USNK	F	R	91	Forest
Teton	1995SIDFA112	USNK	F	R	83	Forest
Teton	1997SIDFL076	USNK	F	T	Barren	Forest
Warm	1997SIDFL063	USNK	F	O	44	Forest
Warm	1997SIDFL018	USNK	F	T	0	Forest
Woods	1997SIDFL071	USNK	F	O	25	Forest
Wright	1997SIDFL019	USNK	F	T	Barren	Forest
Birch	1996SIDFZ037	USNK	R	T	39	Rangeland
Birch	1996SIDFZ041	USNK	F	T	35	Forest
Birch	1996SIDFZ038	USNK	F	T	46	Forest
Bridge Cr	1998SIDFD001	USNK	R	O	67	Rangeland
Brockman	1994SIDFA017	USNK	F	T	37	Forest
Brockman Cr	1998SIDFC002	USNK	F	T	Barren	Forest
Buck	1996SIDFY002	USNK	F	T	0	Forest
Bulls Fork	1997SIDFL001	USNK	F	T	Barren	Forest
Bulls Fork	1997SIDFM001	USNK	F	T	Barren	Forest
Bulls Fork Cr	1997SIDFL001	USNK	F	T	Barren	Forest
Bulls Fork Cr	1997SIDFM001	USNK	F	T	Barren	Forest
Canyon Cr	1997SIDFL010	USNK	F	T	Barren	Forest
Corral	1994SIDFA084	USNK	F	T	38	Forest
Crane Cr	1998SIDFD009	USNK	F	T	Barren	Forest
Crane Cr	1997SIDFM005	USNK	F	T	0	Forest
Crane Cr	1997SIDFM006	USNK	F	T	0	Forest
Dan	1996SIDFY126	USNK	F	T	0	Forest
Dan Cr	1998SIDFC001	USNK	F	T	Barren	Forest
Deep Cr	1997SIDFL004	USNK	R	T	Barren	Rangeland
Eagle Cr, North Fork	1998SIDFD002	USNK	F	T	Barren	Forest
Gravel Cr	1998SIDFD007	USNK	F	R	35	Forest
Gravel Cr	1998SIDFD008	USNK	F	R	35	Forest
Grays Lake Outlet	1997SIDFM141	USNK	F	R	1	Forest
Grays Lake Outlet	1995SIDFB073	USNK	R	R	16	Rangeland
Grays Lake Outlet	1995SIDFB069	USNK	R	R	31	Rangeland
Grays Lake Outlet	1997SIDFM141	USNK	F	T	1	Forest
Hancock	1995SIDFA017	USNK	F	T	34	Forest
Hell	1994SIDFA014	USNK	F	T	35	Forest
Hell	1995SIDFA001	USNK	F	T	9	Forest
Homer	1995SIDFA018	USNK	F	R	1	Forest
Indian Fork Cr	1997SIDFM002	USNK	F	T	Barren	Forest
Lava	1994SIDFA081	USNK	F	T	37	Forest
Lava	1994SIDFA082	USNK	F	T	45	Forest

FOREST INDEX						
Stream	**Site ID**	**Stream Basin**	**Bio-region**	**Class**	**SFI-Forest**	**Recommended Index to Apply**
Lava, WF	1996SIDFY134	USNK	F	T	36	Forest
Long Valley	1997SIDFL007	USNK	F	T	0	Forest
Long Valley Cr	1997SIDFL008	USNK	F	T	Barren	Forest
Meadow	1996SIDFZ001	USNK	F	O	Barren	Forest
Meadow	1995SIDFA004	USNK	F	R	83	Forest
Meadow	1996SIDFY001	USNK	R	T	64	Rangeland
Meadow Cr	1998SIDFD010	USNK	F	R	Barren	Forest
Meadow Cr	1998SIDFD005	USNK	F	R	75	Forest
Mill	1996SIDFY003	USNK	F	O	66	Forest
Mud Cr	1997SIDFL009	USNK	F	T	6	Forest
Mud Spring Cr	1997SIDFL003	USNK	R	T	Barren	Rangeland
Mud Spring Cr	1998SIDFC003	USNK	R	T	Barren	Rangeland
North Fork Meadow Cr	1998SIDFC004	USNK	F	R	65	Forest
Peterson Cr	1998SIDFD011	USNK	F	T	Barren	Forest
Right Cr	1998SIDFD012	USNK	F	T	Barren	Forest
Sawmill	1994SIDFA015	USNK	F	O	46	Forest
Sawmill	1994SIDFA016	USNK	F	T	18	Forest
Sellars	1996SIDFZ003	USNK	F	R	Barren	Forest
Sellars , S. Fork	1995SIDFB017	USNK	F	R	94	Forest
Seventy	1995SIDFB015	USNK	F	T	0	Forest
Shirley Cr	1998SIDFD004	USNK	F	T	0	Forest
Tex	1995SIDFA106	USNK	R	T	0	Rangeland
Twin Cr	1997SIDFL011	USNK	F	T	Barren	Forest
Willow	1997SIDFM003	USNK	F	O	35	Forest
Willow	1994SIDFA079	USNK	R	O	13	Rangeland
Willow Cr	1998SIDFD003	USNK	F	R	30	Forest
Willow Cr	1995SIDFB72	USNK	F	R	36	Forest
Webb Cr	1997SPOCA066	USNK	R	O	88	Rangeland
Crooked	1997SIDFM139	USNK	F	T	Barren	Forest
Divide	1997SIDFM136	USNK	F	R	Barren	Forest
Edie	1995SIDFB029	USNK	F	R	80	Forest
Fritz	1995SIDFB028	USNK	F	O	Barren	Forest
Horse	1997SIDFM135	USNK	F	R	88	Forest
Irving	1995SIDFB059	USNK	F	R	89	Forest
Medicine Lodge	1997SIDFM151	USNK	F	R	87	Forest
Medicine Lodge	1994SIDFA067	USNK	F	R	74	Forest
Medicine Lodge	1994SIDFA085	USNK	F	R	83	Forest
Medicine Lodge Cr	1994SIDF066	USNK	R	T	Barren	Rangeland
Middle	1997SIDFM137	USNK	F	O	56	Forest
Myers	1997SIDFM138	USNK	F	O	Barren	Forest
Myers Cr	1997SIDF138	USNK	F	T	Barren	Forest
Warm	1995SIDFB025	USNK	F	R	70	Forest
Warm Cr	1994SIDF077	USNK	F	R	84	Forest
Webber	1997SIDFM134	USNK	F	R	68	Forest
Iron Cr	1997SIDF0L36	USNK	F	R	86	Forest
Iron Cr	1997SIDF0L35	USNK	F	R	67	Forest
Main Fork Cr	1997SIDF0L28	USNK	F	R	94	Forest
Main Fork Cr	1998SIDFD024	USNK	F	R	72	Forest
Medicine Lodge Cr nr Small	USNK-23	USNK	F	R	86	Forest

FOREST INDEX						
Stream	**Site ID**	**Stream Basin**	**Bio-region**	**Class**	**SFI-Forest**	**Recommended Index to Apply**
Smithie Cr, Right Fork	1998SIDFD030	USNK	F	R	Barren	Forest
Smithie Cr.	1997SIDFL027	USNK	F	R	78	Forest
South Cr	1998SIDFD014	USNK	F	R	48	Forest
Timber Cr	1997SIDFL24	USNK	F	R	83	Forest
Timber Cr	1997SIDFL026	USNK	F	R	67	Forest
Timber Cr	1998IDFSD021	USNK	F	R	Barren	Forest
Wet Cr	1995IDFA034	USNK	F	R	69	Forest
Wet Cr	1995IDFA011	USNK	F	R	52	Forest
Boone Cr	1998SIDFD073	USNK	F	T	Barren	Forest
3rd Fork Creek	ISU-8	USNK	R	R	33	Rangeland
Angus, lower	ISU-60	USNK	F	R	67	Forest
Angus, upper	ISU-61	USNK	F	R	0	Forest
Bell Marsh	1995POC003	USNK	R	R	61	Rangeland
Big	1996STWFB018	USNK	F	T	0	Forest
Big Willow Cr	ISU-44	USNK	R	R	0	Rangeland
Camas Cr	ISU-51	USNK	F	R	0	Forest
Cassia	ISU-28	USNK	R	R	39	Rangeland
Cherry Cr	1996SPOCA020	USNK	F	R	32	Forest
Chippy	ISU-62	USNK	R	R	0	Rangeland
Clyde Cr	ISU-64	USNK	F	R	50	Forest
Cold Springs Cr	ISU-45	USNK	R	R	33	Rangeland
Cottonwood	1996STWFB061	USNK	R	T	0	Rangeland
Crow	ISU-65	USNK	F	R	18	Forest
Devils Washbowl Spring	USNK-15	USNK	R	S	38	Rangeland
Dry Cr, EF	1996TWFB030	USNK	R	R	78	Rangeland
Goose Cr	1994STWFA013	USNK	R	R	72	Rangeland
Goose Cr	1997STWFA072	USNK	R	R	87	Rangeland
Hot	1996STWFA013	USNK	F	T	0	Forest
Lake Fork Cr	ISU-18	USNK	R	R	37	Rangeland
Lanes	ISU-67	USNK	F	R	0	Forest
Little Beaver	1995STWFB012	USNK	F	T	26	Forest
Little Granite Cr, nr Bondurant, WY	USNK-2	USNK	F	R	96	Forest
Maple	1995SPOCA062	USNK	F	R	88	Forest
Marsh Cr	1994STWFA025	USNK	R	T	67	Rangeland
Marsh Cr@McCammon	usgs-130075000-97	USNK	R	T	10	Rangeland
Mink, SF	ISU-49	USNK	F	R	0	Forest
Paradise	1995STWFA074	USNK	F	T	79	Forest
Pearl	ISU-68	USNK	F	R	67	Forest
Pebble	ISU-85	USNK	F	R	50	Forest
Raft R. (narrows)	1999STWFA01	USNK	R	O	0	Rangeland
Rock (Holbrook)	ISU-86	USNK	R	R	0	Rangeland
Sage Creek	1996SPOCA43	USNK	R	R	57	Rangeland
Salt R near Smoot, WY	USNK-4	USNK	F	R	92	Forest
Sheep Cr	1996SIDFZ005	USNK	F	T	Barren	Forest
Slug Cr	ISU-71	USNK	F	R	0	Forest
Spring Cr nr Ft. Hall	USNK-13	USNK	R	R	64	Rangeland
Station Cr	ISU-19	USNK	R	R	67	Rangeland
Sublett Cr U	1994STWF001	USNK	F	R	50	Forest
Trapper	ISU-31	USNK	R	R	1	Rangeland

FOREST INDEX						
Stream	**Site ID**	**Stream Basin**	**Bio-region**	**Class**	**SFI-Forest**	**Recommended Index to Apply**
Upper Portneuf	ISU-69	USNK	R	R	0	Rangeland
Wolverine	ISU-50	USNK	F	R	100	Forest
Wright Cr	ISU-73	Name?	R	USNK	Barren	Rangeland

Appendix I.
Correlation of Habitat Measures with Disturbance Measures, Fish Metrics, and Macroinvertebrate Metrics in the Northern Basin and Range Ecoregion

Northern Basin and Range sites, habitat measures, whether they are included in the original habitat index (s=scored measure, r=raw measure), correlation with urban, agricultural, forested, and riparian land cover, number of human activities, two-sample comparison for test and unknown sites (Mann-Whitney U test). Sample sizes for all sites are shown but only significant *r* values are shown (* $p < 0.05$, * * $p < 0.01$).

Table I-1. Basin and Range human disturbance correlations.

Habitat Measure	Included in HI	% Urban	% Ag	% Forest	% Ripar	# Activities	Filter
Habitat index		-0.36 *	-0.56 * *	0.47 * *	0.43 * *		* *
		35	35	35	35	21	15/42
Instream cover	s	-0.39 *	-0.59 * *	0.43 * *	0.47 * *		* *
		35	35	35	35	21	15/42
Large organic debris			-0.41 * *	0.56 * *	0.29 *		*
		35	35	35	35	21	15/42
Submerged cover (p)		5	5	5	5	5	1/18
Undercut bank (p)		6	6	6	6	6	1/19
% Fines	r		0.51 * *	-0.59 * *	-0.31 *		* *
(<6.5 mm)		35	35	35	35	21	15/42
% Fines	s		-0.54 * *	0.59 * *	0.34 *		* *
(<6.5 mm)		35	35	35	35	21	15/42
% Fines			0.62 *	-0.84 * *	-0.62 *		* *
(< 2 mm)		13	13	13	13	13	4/31
% Fines			0.56 *	-0.86 * *	-0.54 *		*
(< 2mm) WW		13	13	13	13	13	4/31
% Fines				-0.64 * *	-0.49 *		*
(< 2mm) OW		13	13	13	13	13	4/31
Embeddedness	s	-0.29 *	-0.54 * *	0.38 *	0.5 * *		* *
		35	35	35	35	21	15/42
Wolman size classes			-0.59 *	0.56 *			*
		13	13	13	13	13	4/31

Habitat Measure	Included in HI	% Urban	% Ag	% Forest	% Ripar	# Activities	Filter
Velocity/depth	s		-0.47 * *	0.4 * *	0.58 * *	-0.52 * *	* *
		35	35	35	35	21	15/42
Substrate size (p)		6	6	6	6	6	1/19
Width/depth	r						
		35	35	35	35	21	15/20
Width/depth	s						
		35	35	35	35	21	15/42
Channel shape	s						* *
		35	35	35	35	21	15/42
Pool/riffle	r				0.46 * *	-0.43 *	
		35	35	35	35	21	15/42
Pool/riffle	s				0.45 * *	-0.42 *	
		35	35	35	35	21	15/42
Sinuosity	s						
		35	35	35	35	21	15/42
Bank stability	r						
		35	35	35	35	21	15/42
Bank stability	s						
		35	35	35	35	21	15/42
Bank cover	r						
		35	35	35	35	21	15/42
Bank cover	s						
		35	35	35	35	21	15/42
% Canopy	r			0.29 *			*
		35	35	35	35	21	15/42
% Canopy	s						*
		35	35	35	35	21	15/42
% Cover (p)				0.79 *			
		6	6	6	6	6	1/19
Disruptive pressures	s	-0.46 * *	-0.32 *				* *
		35	35	35	35	21	15/42
Zone of influence	s						*
		35	35	35	35	21	15/42
Pool quality index (avg)		6	6	6	6	6	1/20
Number of pools		6	6	6	6	6	1/19
Max depth (p)							
		6	6	6	6	6	1/19
Tail out depth (p)		6	6	6	6	6	1/27

Habitat Measure	Included in HI	% Urban	% Ag	% Forest	% Ripar	# Activities	Filter
Length (p)		6	6	6	6	6	1/19
Max width (p)		6	6	6	6	6	1/19
Residual depth (p)		6	6	6	6	6	1/19
Residual depth (p) – avg.		6	6	6	0.77 * 6	6	1/5
Substrate size (p) – avg.		6	6	0.83 * 6	6	6	1/5
% Cover (p) – avg.		6	6	6	6	6	1/5
Undercut bank (p) – avg.		6	6	6	6	6	1/5

Table I-2. Basin and Range fish correlations.

	Number of Native Species	Percent Non-indigenous Individuals	Percent Omnivores and Herbivores	Percent Anomalies	Number of Cold Water Native Species	Number of Sculpin Age Classes	Percent Sensitive Native Individuals	Percent Cold Water Individuals	Number of Salmonid Age Classes	Relative Abundance of Cold Water Fishes (CPUE)	COLDINDV
RECALCHI						-0.46 **	0.37 *		0.53 **		
	34	21	34	34	34	34	34	34	34	34	34
instream cover						-0.31 *			0.52 **		
	34	21	34	34	34	34	34	34	34	34	34
large organic debris											
	34	21	34	34	34	34	34	34	34	34	34
pool submerged cover								0.45 *	0.54 *		0.45 *
	14	5	14	14	14	14	14	14	14	14	14
pool percent undercut banks		0.77 *				-0.46 *			0.8 **		
	15	6	15	15	15	15	15	15	15	15	15
percent fines						0.42 **	-0.46 **		-0.68 **		-0.34 *
	34	21	34	34	34	34	34	34	34	34	34
bottom substrate score		0.39 *				-0.4 **	0.45 **		0.7 **		0.35 *
	34	21	34	34	34	34	34	34	34	34	34
percent fines in stream channel			0.39 *					-0.43 **	-0.41 *		-0.36 *
	25	12	25	25	25	25	25	25	25	25	25
percent fines in wetted width	0.41 *						-0.36 *	-0.45 **	-0.56 **		
	25	12	25	25	25	25	25	25	25	25	25
percent fines outside wetted width							-0.56 **	-0.48 **	-0.57 **		-0.36 *
	25	12	25	25	25	25	25	25	25	25	25
embeddedness		0.51 **				-0.29 *			0.62 **		
	34	21	34	34	34	34	34	34	34	34	34
number of Wolmann size classes									0.34 *		
	25	12	25	25	25	25	25	25	25	25	25
pool substrate											
	34	21	34	34	34	34	34	34	34	34	34
velocity/depth score									0.3 *		
	34	21	34	34	34	34	34	34	34	34	34
pool variability score											
	34	21	34	34	34	34	34	34	34	34	34
pool substrate size		-0.74 *						-0.6 **	-0.46 *		-0.81 **
	15	6	15	15	15	15	15	15	15	15	15

	Number of Native Species	Percent Non-indigenous Individuals	Percent Omnivores and Herbivores	Percent Anomalies	Number of Cold Water Native Species	Number of Sculpin Age Classes	Percent Sensitive Native Individuals	Percent Cold Water Individuals	Number of Salmonid Age Classes	Relative Abundance of Cold Water Fishes (CPUE)	COLDINDV
width/depth ratio	0.61 *										
	12	12	12	12	12	12	12	12	12	12	12
width/depth ratio score									-0.43 **		
	34	21	34	34	34	34	34	34	34	34	34
channel shape score						-0.33 *	0.41 **		0.32 *	0.41 **	0.38 **
	34	21	34	34	34	34	34	34	34	34	34
pool/riffle ratio									0.44 **		
	34	21	34	34	34	34	34	34	34	34	34
pool/riffle ratio score									0.45 **		
	34	21	34	34	34	34	34	34	34	34	34
channel sinuosity score	0.41 **		0.36 *		0.29 *	0.51 **					
	34	21	34	34	34	34	34	34	34	34	34
bank stability											
	34	21	34	34	34	34	34	34	34	34	34
bank stability score											
	34	21	34	34	34	34	34	34	34	34	34
bank vegetation protection											
	34	21	34	34	34	34	34	34	34	34	34
bank cover score											
	34	21	34	34	34	34	34	34	34	34	34
percent canopy cover								0.29 *	0.41 **	0.29 *	
	34	21	34	34	34	34	34	34	34	34	34
canopy cover score								0.34 *	0.41 **	0.3 *	
	34	21	34	34	34	34	34	34	34	34	34
pool overhead cover											-0.45 *
	15	6	15	15	15	15	15	15	15	15	15
disruptive pressures score						-0.33 *			0.35 *		
	34	21	34	34	34	34	34	34	34	34	34
zone of influence score						-0.37 **	0.35 *		0.32 *	0.28 *	
	34	21	34	34	34	34	34	34	34	34	34
APQI											
	16	6	16	16	16	16	16	16	16	16	16
POOLNUM								0.65 **			
	15	6	15	15	15	15	15	15	15	15	15
PTOUT											
	1	1	1	1	1	1	1	1	1	1	1
apresdepth											

	Number of Native Species	**Percent Non-indigenous Individuals**	**Percent Omnivores and Herbivores**	**Percent Anomalies**	**Number of Cold Water Native Species**	**Number of Sculpin Age Classes**	**Percent Sensitive Native Individuals**	**Percent Cold Water Individuals**	**Number of Salmonid Age Classes**	**Relative Abundance of Cold Water Fishes (CPUE)**	**COLDINDV**
	1	1	1	1	1	1	1	1	1	1	1
pmaxdepth											
	1	1	1	1	1	1	1	1	1	1	1
pool residual depth	0.53 *		0.6 **		0.49 *	0.77 **	-0.56 *	-0.43 *		0.54 *	
	15	6	15	15	15	15	15	15	15	15	15
Apsubsize											
	1	1	1	1	1	1	1	1	1	1	1
APCOVER											
	1	1	1	1	1	1	1	1	1	1	1
APUCBANK											
	1	1	1	1	1	1	1	1	1	1	1

Table I-3. Basin and Range bug correlations.

	Total Taxa	Ephemeropt Era Taxa	Plecoptera Taxa	Trichoptera Taxa	Percent Plecoptera	HBI	Percent 5 Dominant Taxa	Clinger Taxa	Sensitive Taxa Richness	Long-lived Taxa Richness
RECALCHI	0.41 **	0.53 **	0.37 **	0.29 *	0.24 *	-0.4 **	-0.36 **	0.46 **		
	57	57	57	57	57	57	57	57	35	57
instream cover	0.47 **	0.53 **	0.38 **	0.41 **	0.23 *	-0.29 **	-0.4 **	0.54 **	0.32 *	0.23 *
	57	57	57	57	57	57	57	57	35	57
large organic debris		0.3 **	0.24 *		0.33 **		-0.33 **	0.31 **		
	57	57	57	57	57	57	57	57	35	57
pool submerged cover			0.44 *				-0.66 **			
	19	19	19	19	19	19	19	19	5	19
pool percent undercut banks	0.43 *	0.56 **	0.67 **		0.57 **		-0.55 **	0.49 **		
	20	20	20	20	20	20	20	20	6	20
percent fines	-0.36 **	-0.63 **	-0.45 **	-0.31 **	-0.34 **	0.5 **	0.35 **	-0.49 **		-0.23 *
	57	57	57	57	57	57	57	57	35	57
bottom substrate score	0.37 **	0.64 **	0.45 **	0.33 **	0.34 **	-0.5 **	-0.35 **	0.5 **		0.25 *
	57	57	57	57	57	57	57	57	35	57
percent fines in stream channel		-0.43 **	-0.41 **			0.52 **		-0.38 **		
	35	35	35	35	35	35	35	35	13	35
percent fines in wetted width	-0.31 *	-0.63 **	-0.53 **		-0.34 *	0.61 **		-0.44 **		
	35	35	35	35	35	35	35	35	13	35
percent fines outside wetted width		-0.52 **	-0.43 **			0.39 **		-0.38 **	-0.47 *	
	35	35	35	35	35	35	35	35	13	35
embeddedness	0.48 **	0.66 **	0.37 **	0.38 **	0.27 *	-0.53 **	-0.33 **	0.54 **		0.32 **
	57	57	57	57	57	57	57	57	35	57
number of Wolmann size classes	0.57 **	0.56 **	0.37 **	0.49 **		-0.47 **		0.61 **		
	35	35	35	35	35	35	35	35	13	35
pool substrate										
	57	57	57	57	57	57	57	57	35	57
velocity/depth score	0.28 *	0.22 *	0.3 **		0.23 *	-0.25 *		0.29 **	0.37 *	
	57	57	57	57	57	57	57	57	35	57
pool variability score										
	57	57	57	57	57	57	57	57	35	57
pool substrate size			-0.45 *				0.71 **			
	20	20	20	20	20	20	20	20	6	20
width/depth ratio		0.29 *								

	Total Taxa	Ephemeropt Era Taxa	Plecoptera Taxa	Trichoptera Taxa	Percent Plecoptera	HBI	Percent 5 Dominant Taxa	Clinger Taxa	Sensitive Taxa Richness	Long-lived Taxa Richness
	35	35	35	35	35	35	35	35	35	35
width/depth ratio score	-0.26 *	-0.44 **	-0.29 **			0.23 *	0.35 **	-0.33 **		
	57	57	57	57	57	57	57	57	35	57
channel shape score		0.27 *	0.33 **		0.22 *	-0.3 **	-0.41 **			
	57	57	57	57	57	57	57	57	35	57
pool/riffle ratio			0.24 *						0.4 **	
	57	57	57	57	57	57	57	57	35	57
pool/riffle ratio score			0.24 *						0.39 **	
	57	57	57	57	57	57	57	57	35	57
channel sinuosity score							0.27 *			
	57	57	57	57	57	57	57	57	35	57
bank stability	0.31 **	0.23 *		0.22 *				0.28 *		
	57	57	57	57	57	57	57	57	35	57
bank stability score	0.29 *							0.25 *		
	57	57	57	57	57	57	57	57	35	57
bank vegetation protection	0.23 *				0.23 *					
	57	57	57	57	57	57	57	57	35	57
bank cover score	0.27 *				0.25 *			0.21 *		
	57	57	57	57	57	57	57	57	35	57
percent canopy cover	0.23 *	0.5 **	0.4 **		0.3 **	-0.46 **	-0.3 **	0.42 **		0.28 *
	57	57	57	57	57	57	57	57	35	57
canopy cover score		0.4 **	0.31 **			-0.44 **	-0.24 *	0.28 *		
	57	57	57	57	57	57	57	57	35	57
pool overhead cover			-0.44 *			0.44 *	0.8 **			
	20	20	20	20	20	20	20	20	6	20
disruptive pressures score	0.3 **	0.43 **	0.32 **			-0.29 *	-0.27 *	0.31 **		
	57	57	57	57	57	57	57	57	35	57
zone of influence score		0.38 **				-0.3 **	-0.3 **	0.28 *		
	57	57	57	57	57	57	57	57	35	57
APQI										
	21	21	21	21	21	21	21	21	6	21
POOLNUM	0.39 *		0.47 *		0.52 **					
	20	20	20	20	20	20	20	20	6	20
PTOUT	-0.9 **			-0.94 **			0.77 *	-0.81 *		
	6	6	6	6	6	6	6	6	6	6
apresdepth						-0.77 *				0.72 *
	6	6	6	6	6	6	6	6	6	6
pmaxdepth						-0.83 *				0.72 *
	6	6	6	6	6	6	6	6	6	6

	Total Taxa	Ephemeropt Era Taxa	Plecoptera Taxa	Trichoptera Taxa	Percent Plecoptera	HBI	Percent 5 Dominant Taxa	Clinger Taxa	Sensitive Taxa Richness	Long-lived Taxa Richness
pool residual depth				0.45 *			-0.45 *			
	20	20	20	20	20	20	20	20	6	20
Apsubsize		0.77 *								
	6	6	6	6	6	6	6	6	6	6
APCOVER										
	6	6	6	6	6	6	6	6	6	6
APUCBANK	0.72 *									
	6	6	6	6	6	6	6	6	6	6

Appendix J.
Correlation of Habitat Measures with Disturbance Measures, Fish Metrics, and Macroinvertebrate Metrics in the Snake River Basin Ecoregion

Snake River Basin sites, habitat measures, whether they are included in the original habitat index (s=scored measure, r=raw measure), correlation with urban, agricultural, forested, and riparian land cover, and number of human activities. Sample sizes for all sites are shown but only significant *r* values are shown (* $p < 0.05$, * * $p < 0.01$).

Table J-1. Snake River human disturbance correlations.

Habitat measure	Included in HI	% Urban	% Ag	% Forest	% Ripar	# Activities
Habitat index			-0.39 *			-0.38 *
		31	31	31	31	26
Instream cover	s		-0.44 * *			
		31	31	31	31	26
Large organic debris				0.42 * *		
		31	31	31	31	26
Submerged cover (p)		6	6	6	6	6
Undercut bank (p)		14	14	14	14	14
% Fines (<6.5 mm)	r					
		31	31	31	31	26
% Fines (<6.5 mm)	s					
		31	31	31	31	26
% Fines (< 2 mm)		19	19	19	19	19
% Fines (< 2mm) WW		19	19	19	19	19
% Fines (< 2mm) OW		18	18	18	18	18
Embeddedness	s					-0.37 *
		31	31	31	31	26
Wolman size classes		x				
		19	19	19	19	19
Velocity/depth	s	31	31	31	31	26

Habitat measure	Included in HI	% Urban	% Ag	% Forest	% Ripar	# Activities
Substrate size (p)		14	14	14	0.56 * 14	14
Width/depth	r	31	31	31	31	26
Width/depth	s	31	31	31	31	26
Channel shape	s	31	31	31	31	26
Pool/riffle	r	31	31	31	31	26
Pool/riffle	s	31	31	31	31	26
Sinuosity	s	31	31	31	31	26
Bank stability	r	31	31	31	31	26
Bank stability	s	31	31	31	31	26
Bank cover	r	31	31	31	31	-0.36 * 26
Bank cover	s	31	31	31	31	-0.44 * 26
% Canopy	r	31	31	31	0.31 * 31	26
% Canopy	s	31	31	31	0.32 * 31	26
% Cover (p)		14	14	14	14	14
Disruptive pressures	s	31	-0.47 * * 31	31	31	26
Zone of influence	s	31	31	31	31	26
Pool quality index (avg)		14	14	14	14	14
Number of pools		14	14	14	14	14
Max depth (p)		14	14	14	14	14
Tail out depth (p)		14	14	14	14	14
Length (p)		14	14	14	x 14	14

Habitat measure	Included in HI	% Urban	% Ag	% Forest	% Ripar	# Activities
Max width (p)					x	
		14	14	14	14	14
Residual depth (p)		14	14	14	14	14
Residual depth (p) – avg.		14	14	14	14	14
Substrate size (p) – avg.					0.68 * *	
		14	14	14	14	14
% Cover (p) – avg.		14	14	14	14	14
Undercut bank (p) – avg.		14	14	14	14	14

Table J-2. Snake River fish correlations.

	Number of Native Species	Percent Non-Indigenous Individuals	Percent Omnivores and Herbivores	Percent Anomalies	Number of Cold Water Native Species	Number of Sculpin Age Classes	Percent Sensitive Native Individuals	Percent Coldwater Individuals	Number of Salmonid Age Classes	Relative Abundance of Cold Water Fishes (CPUE)	COLDINDV
RECALCHI			-0.26 *		0.46 **		0.29 *	0.42 **	0.47 **	0.53 **	0.31 *
	40	21	40	40	40	40	40	40	40	40	40
instream cover					0.58 **	0.38 **	0.38 **	0.46 **	0.5 **	0.57 **	0.39 **
	40	21	40	40	40	40	40	40	40	40	40
large organic debris							0.32 *		0.29 *		
	40	21	40	40	40	40	40	40	40	40	40
pool submerged cover	-0.38 *										
	22	9	22	22	22	22	22	22	22	22	22
pool percent undercut banks										0.34 *	
	24	11	24	24	24	24	24	24	24	24	24
percent fines	-0.37 **	0.43 *			-0.54 **	-0.33 *	-0.42 **	-0.45 **	-0.44 **	-0.59 **	-0.44 **
	40	21	40	40	40	40	40	40	40	40	40
bottom substrate score	0.35 **	-0.39 *			0.55 **	0.33 *	0.43 **	0.47 **	0.47 **	0.63 **	0.45 **
	40	21	40	40	40	40	40	40	40	40	40
percent fines in stream channel	-0.48 **	0.47 *		0.29 *	-0.62 **	-0.43 **	-0.39 **	-0.44 **	-0.44 **	-0.51 **	-0.42 **
	36	17	36	36	36	36	36	36	36	36	36
percent fines in wetted width	-0.3 *	0.52 *			-0.53 **	-0.4 **	-0.36 *	-0.44 **	-0.41 **	-0.63 **	-0.38 **
	36	17	36	36	36	36	36	36	36	36	36
percent fines outside wetted width					-0.38 **		-0.46 **	-0.5 **	-0.48 **	-0.44 **	-0.47 **
	34	16	34	34	34	34	34	34	34	34	34
embeddedness					0.3 *				0.26 *	0.46 **	
	40	21	40	40	40	40	40	40	40	40	40
number of Wolmann size classes					0.48 **		0.62 **	0.49 **	0.66 **	0.57 **	0.41 **
	36	17	36	36	36	36	36	36	36	36	36
pool substrate											
	40	21	40	40	40	40	40	40	40	40	40
velocity/depth score						-0.37 **					
	40	21	40	40	40	40	40	40	40	40	40

	Number of Native Species	Percent Non-Indigenous Individuals	Percent Omnivores and Herbivores	Percent Anomalies	Number of Cold Water Native Species	Number of Sculpin Age Classes	Percent Sensitive Native Individuals	Percent Coldwater Individuals	Number of Salmonid Age Classes	Relative Abundance of Cold Water Fishes (CPUE)	COLDINDV
pool variability score											
	40	21	40	40	40	40	40	40	40	40	40
pool substrate size	0.4 *										
	24	11	24	24	24	24	24	24	24	24	24
width/depth ratio											
	6	6	6	6	6	6	6	6	6	6	6
width/depth ratio score	-0.35 **										
	40	21	40	40	40	40	40	40	40	40	40
channel shape score											
	40	21	40	40	40	40	40	40	40	40	40
pool/riffle ratio						-0.37 **					
	40	21	40	40	40	40	40	40	40	40	40
pool/riffle ratio score						-0.37 **					
	40	21	40	40	40	40	40	40	40	40	40
channel sinuosity score											
	40	21	40	40	40	40	40	40	40	40	40
bank stability					0.39 **	0.39 **					
	40	21	40	40	40	40	40	40	40	40	40
bank stability score					0.4 **	0.36 **		0.26 *			
	40	21	40	40	40	40	40	40	40	40	40
bank vegetation protection					0.39 **	0.36 **				0.3 *	
	40	21	40	40	40	40	40	40	40	40	40
bank cover score					0.4 **	0.36 **				0.32 *	
	40	21	40	40	40	40	40	40	40	40	40
percent canopy cover					0.28 *	-0.27 *	0.51 **	0.37 **	0.52 **	0.44 **	
	40	21	40	40	40	40	40	40	40	40	40
canopy cover score							0.27 *		0.37 **	0.36 **	
	40	21	40	40	40	40	40	40	40	40	40
pool overhead cover		-0.67 **					0.44 *				
	24	11	24	24	24	24	24	24	24	24	24
disruptive pressures score											

	Number of Native Species	Percent Non-Indigenous Individuals	Percent Omnivores and Herbivores	Percent Anomalies	Number of Cold Water Native Species	Number of Sculpin Age Classes	Percent Sensitive Native Individuals	Percent Coldwater Individuals	Number of Salmonid Age Classes	Relative Abundance of Cold Water Fishes (CPUE)	COLDINDV
	40	21	40	40	40	40	40	40	40	40	40
zone of influence score			-0.26 *								
	40	21	40	40	40	40	40	40	40	40	40
APQI											
	26	11	26	26	26	26	26	26	26	26	26
POOLNUM											
	24	11	24	24	24	24	24	24	24	24	24
PTOUT											
	2	2	2	2	2	2	2	2	2	2	2
apresdepth											
	2	2	2	2	2	2	2	2	2	2	2
pmaxdepth											
	2	2	2	2	2	2	2	2	2	2	2
pool residual depth	0.4 *	0.56 *	0.51 **			0.44 *	-0.35 *	-0.37 *			
	24	11	24	24	24	24	24	24	24	24	24
Apsubsize											
	2	2	2	2	2	2	2	2	2	2	2
APCOVER											
	2	2	2	2	2	2	2	2	2	2	2
APUCBANK											
	2	2	2	2	2	2	2	2	2	2	2

Table J-3. Snake River bug correlations.

	Total Taxa	Ephemeropt Era Taxa	Plecoptera Taxa	Trichoptera Taxa	Percent Plecoptera	HBI	Percent 5 Dominant Taxa	Clinger Taxa	Sensitive Taxa Richness	Long-lived Taxa Richness
RECALCHI			0.28 **	0.22 *	0.25 *			0.24 *		
	65	65	65	65	65	65	65	65	31	65
instream cover			0.35 **	0.27 *	0.26 *	-0.22 *		0.3 **		
	65	65	65	65	65	65	65	65	31	65
large organic debris			0.32 **		0.3 **	-0.25 *	-0.21 *			
	65	65	65	65	65	65	65	65	31	65
pool submerged cover					0.4 *	-0.32 *				
	28	28	28	28	28	28	28	28	6	28
pool percent undercut banks		0.29 *								
	36	36	36	36	36	36	36	36	14	36
percent fines						0.24 *				
	65	65	65	65	65	65	65	65	31	65
bottom substrate score						-0.25 *				
	65	65	65	65	65	65	65	65	31	65
percent fines in stream channel			-0.27 *		-0.31 **	0.33 **	0.25 *			
	53	53	53	53	53	53	53	53	19	53
percent fines in wetted width	-0.27 *	-0.32 **	-0.26 *	-0.26 *		0.33 **		-0.41 **		
	53	53	53	53	53	53	53	53	19	53
percent fines outside wetted width	-0.32 **	-0.32 **	-0.24 *		-0.28 *	0.37 **				
	51	51	51	51	51	51	51	51	18	51
embeddedness			0.32 **		0.35 **			0.26 *		
	65	65	65	65	65	65	65	65	31	65
number of Wolmann size classes			0.23 *		0.28 *	-0.37 **				
	53	53	53	53	53	53	53	53	19	53
pool substrate										
	65	65	65	65	65	65	65	65	31	65
velocity/depth score							0.27 *			
	65	65	65	65	65	65	65	65	31	65
pool variability score										
	65	65	65	65	65	65	65	65	31	65
pool substrate size							0.57 **	0.27 *		0.3 *
	36	36	36	36	36	36	36	36	14	36
width/depth ratio			-0.31 *							-0.31 *
	31	31	31	31	31	31	31	31	31	31

	Total Taxa	Ephemeropt Era Taxa	Plecoptera Taxa	Trichoptera Taxa	Percent Plecoptera	HBI	Percent 5 Dominant Taxa	Clinger Taxa	Sensitive Taxa Richness	Long-lived Taxa Richness
width/depth ratio score										
	65	65	65	65	65	65	65	65	31	65
channel shape score		-0.26 *				0.24 *				
	65	65	65	65	65	65	65	65	31	65
pool/riffle ratio										
	65	65	65	65	65	65	65	65	31	65
pool/riffle ratio score										
	65	65	65	65	65	65	65	65	31	65
channel sinuosity score										
	65	65	65	65	65	65	65	65	31	65
bank stability		-0.26 *								
	65	65	65	65	65	65	65	65	31	65
bank stability score		-0.22 *								
	65	65	65	65	65	65	65	65	31	65
bank vegetation protection	0.21 *			0.22 *				0.2 *		
	65	65	65	65	65	65	65	65	31	65
bank cover score	0.22 *			0.21 *						
	65	65	65	65	65	65	65	65	31	65
percent canopy cover	0.2 *		0.31 **		0.43 **	-0.2 *				
	65	65	65	65	65	65	65	65	31	65
canopy cover score			0.25 *		0.38 **		-0.21 *			
	65	65	65	65	65	65	65	65	31	65
pool overhead cover							0.69 **			
	36	36	36	36	36	36	36	36	14	36
disruptive pressures score										
	65	65	65	65	65	65	65	65	31	65
zone of influence score										
	65	65	65	65	65	65	65	65	31	65
APQI						-0.27 *				
	38	38	38	38	38	38	38	38	14	38
POOLNUM										
	36	36	36	36	36	36	36	36	14	36
PTOUT							0.46 *			
	14	14	14	14	14	14	14	14	14	14
apresdepth										
	14	14	14	14	14	14	14	14	14	14
pmaxdepth							0.59 **			
	14	14	14	14	14	14	14	14	14	14

	Total Taxa	Ephemeropt Era Taxa	Plecoptera Taxa	Trichoptera Taxa	Percent Plecoptera	HBI	Percent 5 Dominant Taxa	Clinger Taxa	Sensitive Taxa Richness	Long-lived Taxa Richness
pool residual depth							-0.73 **			
	36	36	36	36	36	36	36	36	14	36
apsubsize					0.82 **					
	14	14	14	14	14	14	14	14	14	14
APCOVER			0.45 *		0.64 **	-0.78 **	-0.51 *			
	14	14	14	14	14	14	14	14	14	14
APUCBANK						-0.5 *				
	14	14	14	14	14	14	14	14	14	14

Appendix K.
Correlation of Habitat Measures with Disturbance Measures, Fish Metrics, and Macroinvertebrate Metrics in the Northern and Middle Rockies Ecoregion

Northern and Middle Rockies sites, habitat measures, whether they are included in the original habitat index (s=scored measure, r=raw measure), correlation with urban, agricultural, forested, and riparian land cover, number of human activities, two-sample comparison for test and reference sites (Mann-Whitney U test). Sample sizes for all sites are shown but only significant *r* values are shown (* $p < 0.05$, * * $p < 0.01$).

Table K-1. Northern human disturbance correlations.

Habitat Measure	Included in HI	% Urban	% Ag	% Forest	% Ripar	# Activities	Call (BPJ)
Habitat index						-0.22 * *	* *
		162	162	162	162	113	50/40
Instream cover	s						* *
		162	162	162	162	113	50/40
Large organic debris			-0.24 * *	0.26 * *	x		
		162	162	162	162	113	50/40
Submerged cover (p)				0.47 * *			
		35	35	35	35	35	8/13
Undercut bank (p)							* *
		61	61	61	61	61	16/18
% Fines (<6.5 mm)	r			-0.32 * *	x		
		162	162	162	162	113	50/40
% Fines (<6.5 mm)	s			0.33 * *	x	-0.16 *	
		162	162	162	162	113	50/40
% Fines (< 2 mm)				-0.23 *			
		72	72	72	72	71	16/23
% Fines (< 2mm) WW				-0.34 * *			
		74	74	74	74	73	18/23
% Fines (< 2mm) OW							
		70	70	70	70	70	16/22
Embeddedness	s					-0.26 * *	* *
		162	162	162	162	113	50/40
Wolman size classes			-0.24 *				
		71	71	71	71	71	16/22

Habitat Measure	Included in HI	% Urban	% Ag	% Forest	% Ripar	# Activities	Call (BPJ)
Velocity/depth	s						
		162	162	162	162	113	50/40
Substrate size (p)				0.24 *	x		
		61	61	61	61	61	16/18
Width/depth	r		-0.13 *	0.24 * *			* *
		160	160	160	160	112	50/40
Width/depth	s		0.14 *	-0.23 * *			* *
		162	162	162	162	113	50/40
Channel shape	s		-0.18 *				* *
		162	162	162	162	113	50/40
Pool/riffle	r			0.14 *			x
		162	162	162	162	113	50/40
Pool/riffle	s			0.13 *			x
		162	162	162	162	113	50/40
Sinuosity	s				0.16 *		
		162	162	162	162	113	50/40
Bank stability	r			0.19 * *	x		* *
		162	162	162	162	113	50/40
Bank stability	s			0.14 *	x	-0.23 * *	* *
		162	162	162	162	113	50/40
Bank cover	r			0.27 * *	x		*
		162	162	162	162	113	50/40
Bank cover	s			0.21 * *	x	-0.22 * *	*
		162	162	162	162	113	50/40
% Canopy	r				x		* *
		160	160	160	160	111	50/39
% Canopy	s					-0.17 *	*
		162	162	162	162	113	50/40
% Cover (p)					x		
		61	61	61	61	61	16/18
Disruptive pressures	s					-0.37 * *	* *
		162	162	162	162	113	50/40
Zone of influence	s			x		-0.25 * *	* *
		162	162	162	162	113	50/40
Pool quality index (avg)				0.25 *	x		*
		61	61	61	61	61	16/18
Number of pools						-0.22 *	
		62	62	62	62	61	16/19
Max depth (p)				0.28 *			
		62	62	62	62	61	16/19
Tail out depth (p)				0.21 *			
		62	62	62	62	61	16/19

Habitat Measure	Included in HI	% Urban	% Ag	% Forest	% Ripar	# Activities	Call (BPJ)
Length (p)				0.26 *			
		62	62	62	62	61	16/19
Max width (p)		x					x
		62	62	62	62	61	16/19
Residual depth (p)				0.32 * *			
		61	61	61	61	61	16/18
Residual depth (p) – avg.				0.31 * *			
		61	61	61	61	61	16/18
Substrate size (p) – avg.				0.27 *	x		
		61	61	61	61	61	16/18
% Cover (p) – avg.					x		
		61	61	61	61	61	16/18
Undercut bank (p) – avg.					x		* *
		61	61	61	61	61	16/18

Table K-2. Northern fish correlations.

	Native Species	% Non-Indigenous	% Omni +Herb	% Anomalies	Cold Natives	Sculpin Age Classes	% Sens. Native	% Cold Individuals	Salmon. Age Classes	(CPUE) Cold	# Cold Individ.
Habitat index			0.23 *						0.25 *		
	60	60	60	60	60	60	60	60	60	60	60
Instream cover											
	60	60	60	60	60	60	60	60	60	60	60
Large organic debris		-0.21 *			0.26 *						0.26 *
	60	60	60	60	60	60	60	60	60	60	60
Submerged cover (p)					0.57 *						
	10	10	10	10	10	10	10	10	10	10	10
Undercut bank (p)	-0.41 *										
	24	24	24	24	24	24	24	24	24	24	24
% Fines (<6.5 mm)	-0.3 **					-0.38 **		0.26 *		-0.25 *	-0.36 **
	60	60	60	60	60	60	60	60	60	60	60
% Fines (<6.5 mm)	0.28 **					0.37 **		-0.25 *		0.24 *	0.35 **
	60	60	60	60	60	60	60	60	60	60	60
% Fines (<2 mm)	-0.43 **		-0.41 *								
	26	26	26	26	26	26	26	26	26	26	26
% Fines (<2 mm)	-0.44 **		-0.49 **			-0.34 *	0.33 *	0.48 **			
	26	26	26	26	26	26	26	26	26	26	26
% Fines (<2 mm)	-0.56 **		-0.49 **			-0.44 **		0.42 *			-0.4 *
	26	26	26	26	26	26	26	26	26	26	26
Embeddedness			0.21 *					-0.29 **			
	60	60	60	60	60	60	60	60	60	60	60
Wolmann size classes											
	26	26	26	26	26	26	26	26	26	26	26
Substrate size (p)											
	60	60	60	60	60	60	60	60	60	60	60
Velocity/depth											
	60	60	60	60	60	60	60	60	60	60	60
pool variability score											
	60	60	60	60	60	60	60	60	60	60	60
Substrate size (p)		-0.4 *		-0.39 *							
	24	24	24	24	24	24	24	24	24	24	24
Width/depth	0.44 **			-0.23 *	0.4 **	0.41 **		-0.25 *			0.39 **
	60	60	60	60	60	60	60	60	60	60	60

	Native Species	% Non-Indigenous	% Omni +Herb	% Anomalies	Cold Natives	Sculpin Age Classes	% Sens. Native	% Cold Individuals	Salmon. Age Classes	(CPUE) Cold	# Cold Individ.
Width/depth	-0.45 **			0.22 *	-0.38 **	-0.43 **		0.26 *			-0.38 **
	60	60	60	60	60	60	60	60	60	60	60
Channel shape		-0.22 *					0.24 *				
	60	60	60	60	60	60	60	60	60	60	60
Pool/riffle									0.29 **		
	60	60	60	60	60	60	60	60	60	60	60
Pool/riffle									0.29 **		
	60	60	60	60	60	60	60	60	60	60	60
Sinuosity						0.28 *				0.22 *	0.21 *
	60	60	60	60	60	60	60	60	60	60	60
Bank stability											
	60	60	60	60	60	60	60	60	60	60	60
Bank stability											
	60	60	60	60	60	60	60	60	60	60	60
Bank cover											
	60	60	60	60	60	60	60	60	60	60	60
Bank cover											
	60	60	60	60	60	60	60	60	60	60	60
% Canopy											
	60	60	60	60	60	60	60	60	60	60	60
% Canopy											
	60	60	60	60	60	60	60	60	60	60	60
% Cover (p)											
	24	24	24	24	24	24	24	24	24	24	24
Disruptive pressures	0.24 *		0.29 **								
	60	60	60	60	60	60	60	60	60	60	60
Zone of influence		0.23 *	0.23 *								
	60	60	60	60	60	60	60	60	60	60	60
Pool quality index (avg.)		-0.51 **									
	24	24	24	24	24	24	24	24	24	24	24
Number of pools				-0.41 *				0.38 *			
	24	24	24	24	24	24	24	24	24	24	24
Tail out depth (p)									-0.36 *		
	24	24	24	24	24	24	24	24	24	24	24
Residual depth (p) - avg.											

	Native Species	% Non-Indigenous	% Omni +Herb	% Anomalies	Cold Natives	Sculpin Age Classes	% Sens. Native	% Cold Individuals	Salmon. Age Classes	(CPUE) Cold	# Cold Individ.
	24	24	24	24	24	24	24	24	24	24	24
Max. depth (p)											
	24	24	24	24	24	24	24	24	24	24	24
Residual depth (p)											
	24	24	24	24	24	24	24	24	24	24	24
Length (p)											
	24	24	24	24	24	24	24	24	24	24	24
Max. width (p)	0.47 **				0.52 **						
	24	24	24	24	24	24	24	24	24	24	24
Substrate size (p) - avg.		-0.38 *		-0.34 *							
	24	24	24	24	24	24	24	24	24	24	24

Table K-3. Northern bug correlations.

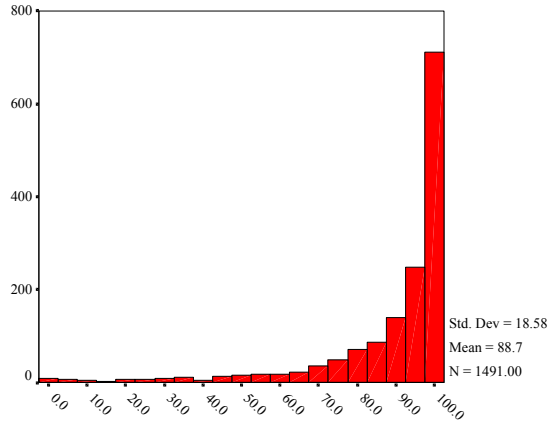
	Total Taxa	Ephemeropt Era Taxa	Plecoptera Taxa	Trichoptera Taxa	Percent Plecoptera	HBI	Percent 5 Dominant Taxa	Clinger Taxa	Sensitive Taxa Richness	Long-lived Taxa Richness
RECALCHI	0.17 **	0.21 **	0.25 **		0.26 **	-0.38 **	-0.32 **		0.3 **	0.25 **
	162	162	162	162	162	162	162	162	162	162
instream cover		0.19 **	0.19 **	0.16 *		-0.33 **	-0.26 **	0.14 *	0.2 **	0.24 **
	162	162	162	162	162	162	162	162	162	162
large organic debris	0.25 **	0.22 **	0.3 **	0.24 **	0.22 **	-0.18 **	-0.22 **	0.28 **	0.29 **	0.25 **
	162	162	162	162	162	162	162	162	162	162
pool submerged cover										
	35	35	35	35	35	35	35	35	35	35
pool percent undercut banks										
	61	61	61	61	61	61	61	61	61	61
percent fines	-0.18 **	-0.22 **	-0.15 *	-0.17 **	-0.19 **			-0.21 **		-0.13 *
	162	162	162	162	162	162	162	162	162	162
bottom substrate score	0.17 **	0.21 **	0.15 *	0.17 *	0.18 **			0.2 **		
	162	162	162	162	162	162	162	162	162	162
percent fines in stream channel									0.19 *	
	74	74	74	74	74	74	74	74	74	74
percent fines in wetted width	-0.21 *	-0.21 *	-0.29 **		-0.31 **	0.26 **		-0.22 *		-0.2 *
	74	74	74	74	74	74	74	74	74	74
percent fines outside wetted width					-0.21 *					
	70	70	70	70	70	70	70	70	70	70
embeddedness		0.18 **			0.17 *	-0.33 **	-0.2 **		0.24 **	
	162	162	162	162	162	162	162	162	162	162
number of Wolmann size classes		0.23 *		0.23 *		-0.2 *		0.22 *		
	71	71	71	71	71	71	71	71	71	71
pool substrate										
	162	162	162	162	162	162	162	162	162	162
velocity/depth score		-0.15 *		-0.17 **	0.15 *		0.15 *	-0.16 *		
	162	162	162	162	162	162	162	162	162	162
pool variability score										
	162	162	162	162	162	162	162	162	162	162
pool substrate size		0.35 **	0.23 *	0.29 **		-0.51 **		0.3 **	0.32 **	0.25 *
	61	61	61	61	61	61	61	61	61	61
width/depth ratio				0.14 *		0.17 *	0.14 *	0.14 *	-0.18 **	
	160	160	160	160	160	160	160	160	160	160

	Total Taxa	Ephemeropt Era Taxa	Plecoptera Taxa	Trichoptera Taxa	Percent Plecoptera	HBI	Percent 5 Dominant Taxa	Clinger Taxa	Sensitive Taxa Richness	Long-lived Taxa Richness
width/depth ratio score						-0.17 **	-0.16 *		0.17 *	
	162	162	162	162	162	162	162	162	162	162
channel shape score	0.18 **	0.19 **	0.28 **	0.16 *		-0.15 *		0.19 **	0.25 **	0.19 **
	162	162	162	162	162	162	162	162	162	162
pool/riffle ratio					0.18 **					
	162	162	162	162	162	162	162	162	162	162
pool/riffle ratio score					0.17 *					
	162	162	162	162	162	162	162	162	162	162
channel sinuosity score					-0.15 *	0.21 **	0.17 **		-0.19 **	
	162	162	162	162	162	162	162	162	162	162
bank stability	0.2 **	0.18 **	0.18 **	0.2 **		-0.23 **	-0.31 **	0.2 **	0.19 **	0.29 **
	162	162	162	162	162	162	162	162	162	162
bank stability score	0.19 **	0.17 **	0.19 **	0.2 **		-0.23 **	-0.3 **	0.2 **	0.21 **	0.3 **
	162	162	162	162	162	162	162	162	162	162
bank vegetation protection	0.2 **	0.2 **	0.15 *		0.13 *	-0.2 **	-0.28 **	0.13 *	0.16 *	0.2 **
	162	162	162	162	162	162	162	162	162	162
bank cover score	0.18 **	0.17 *	0.15 *		0.14 *	-0.18 **	-0.25 **		0.18 **	0.18 **
	162	162	162	162	162	162	162	162	162	162
percent canopy cover			0.24 **		0.3 **	-0.28 **	-0.17 *		0.33 **	0.22 **
	160	160	160	160	160	160	160	160	160	160
canopy cover score			0.14 *		0.13 *				0.24 **	0.13 *
	162	162	162	162	162	162	162	162	162	162
pool overhead cover	0.26 *	0.23 *	0.25 *	0.21 *		-0.26 *	-0.22 *	0.23 *	0.28 **	
	61	61	61	61	61	61	61	61	61	61
disruptive pressures score	0.16 *	0.18 **	0.17 **	0.16 *	0.17 **	-0.26 **	-0.25 **	0.14 *	0.21 **	0.22 **
	162	162	162	162	162	162	162	162	162	162
zone of influence score			0.16 *	0.13 *	0.19 **	-0.33 **	-0.21 **		0.19 **	0.2 **
	162	162	162	162	162	162	162	162	162	162
APQI		0.31 **	0.21 *	0.24 *		-0.26 *	-0.27 *	0.22 *	0.32 **	
	61	61	61	61	61	61	61	61	61	61
POOLNUM	0.29 **		0.29 **	0.36 **	0.28 **	-0.56 **	-0.25 *	0.29 **	0.41 **	0.35 **
	62	62	62	62	62	62	62	62	62	62
PTOUT		0.22 *			-0.29 **				-0.25 *	
	62	62	62	62	62	62	62	62	62	62
apresdepth										
	61	61	61	61	61	61	61	61	61	61
pmaxdepth										
	62	62	62	62	62	62	62	62	62	62

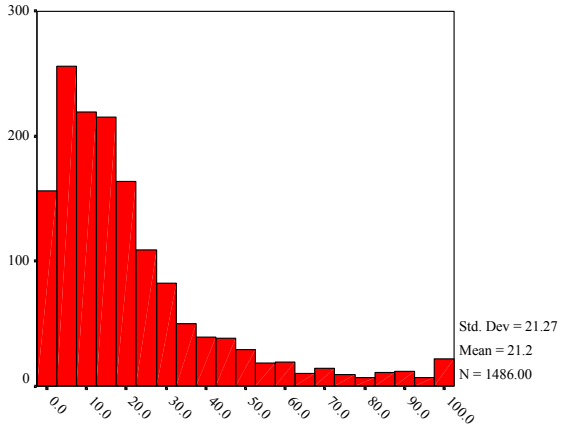
	Total Taxa	Ephemeropt Era Taxa	Plecoptera Taxa	Trichoptera Taxa	Percent Plecoptera	HBI	Percent 5 Dominant Taxa	Clinger Taxa	Sensitive Taxa Richness	Long-lived Taxa Richness
pool residual depth										
	61	61	61	61	61	61	61	61	61	61
Apsubsize	0.21 *	0.35 **	0.23 *	0.31 **		-0.51 **		0.31 **	0.29 **	0.25 *
	61	61	61	61	61	61	61	61	61	61
APCOVER		0.3 **	0.3 **			-0.35 **	-0.24 *		0.38 **	
	61	61	61	61	61	61	61	61	61	61
APUCBANK							-0.23 *		0.25 *	
	61	61	61	61	61	61	61	61	61	61

Appendix L.
Distribution of Values of SHI Habitat Measures

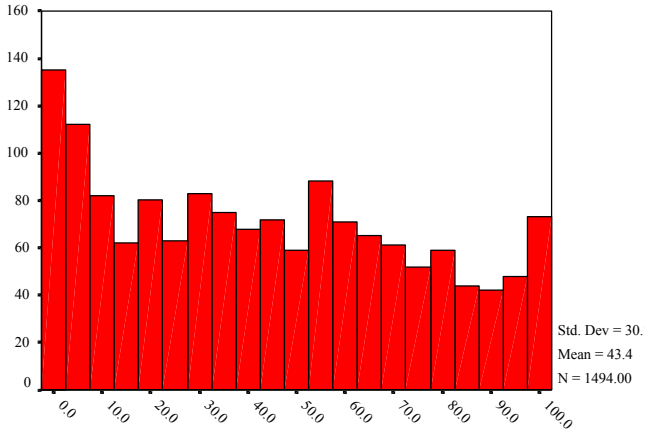
Northern and Middle Rockies, Snake River Basin and Northern Basin and Range combined histograms: 1,494 sites



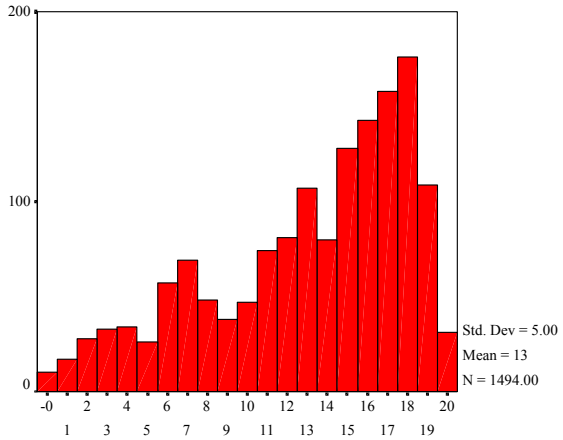
bank cover raw



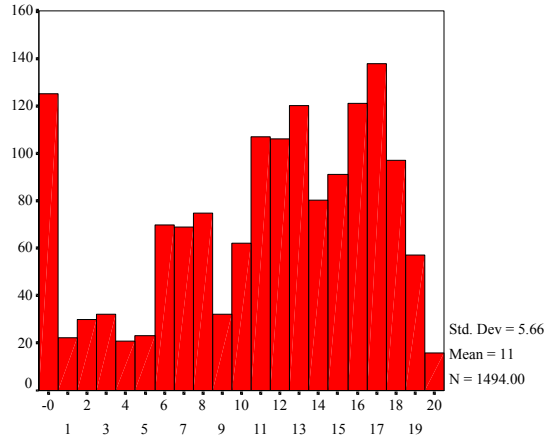
pct fines



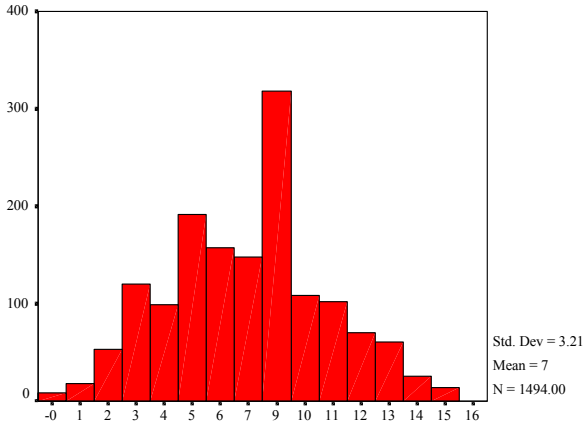
PCT_CAN



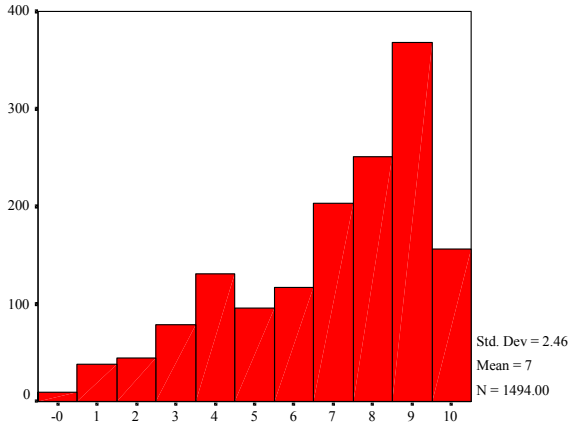
STREAMCO



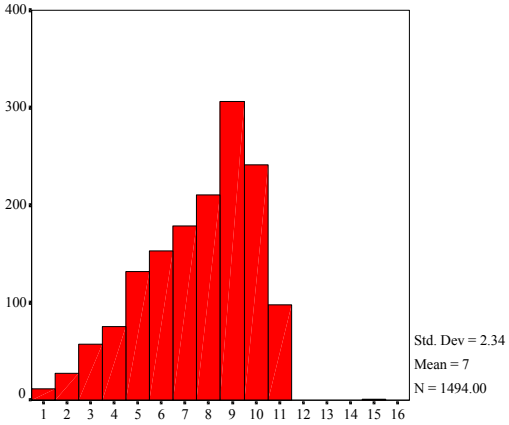
EMBED



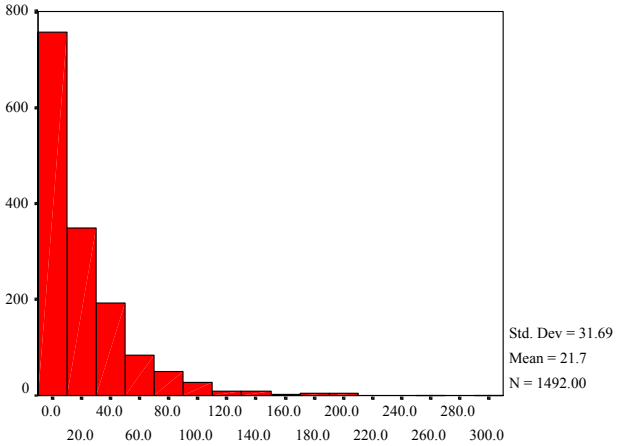
CSHAPE



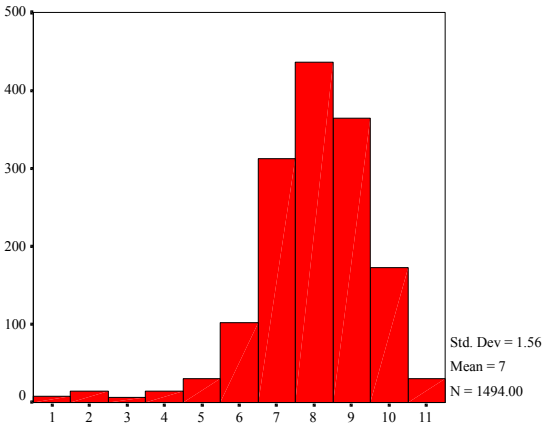
DISPRES



ZONEINFL

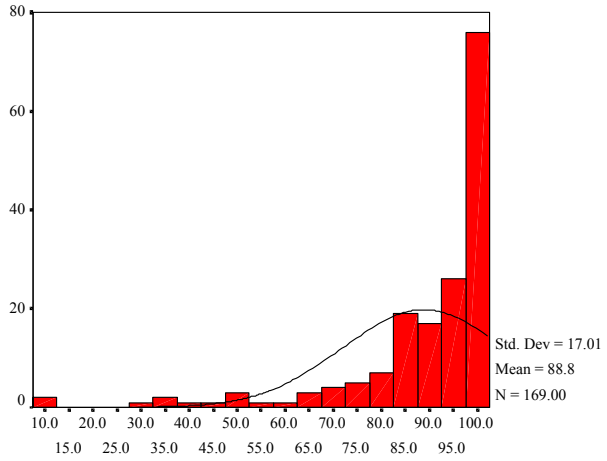


LOD

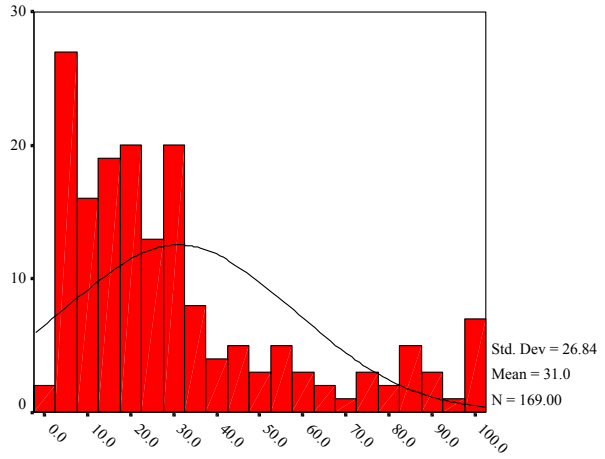


wolmann size classes

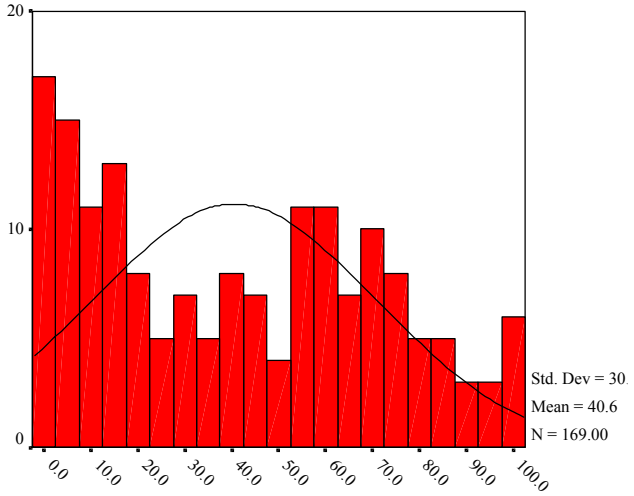
Northern Basin and Range histograms: 169 sites



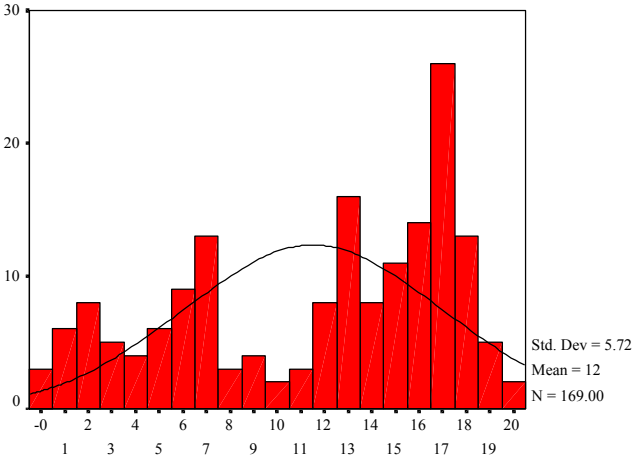
bank cover raw



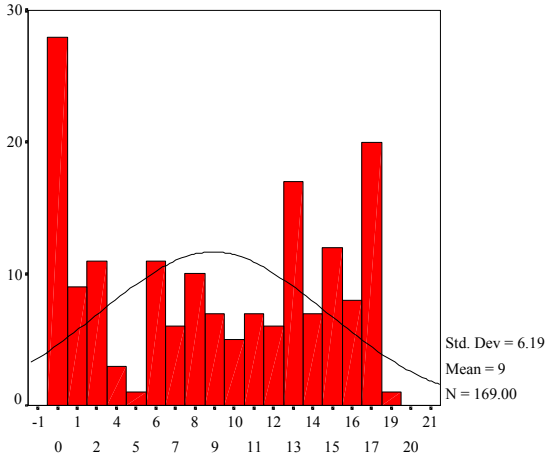
pct fines



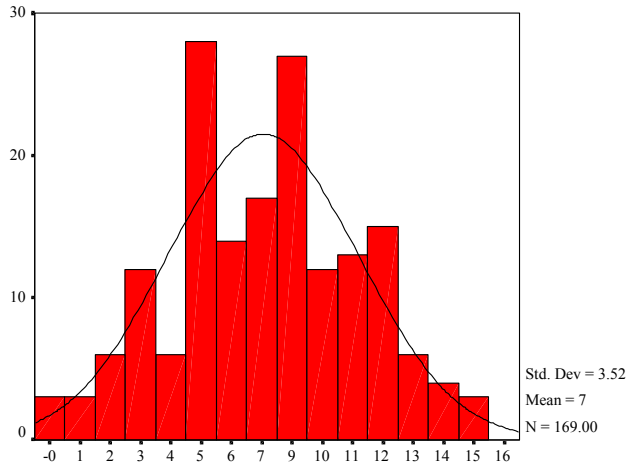
PCT_CAN



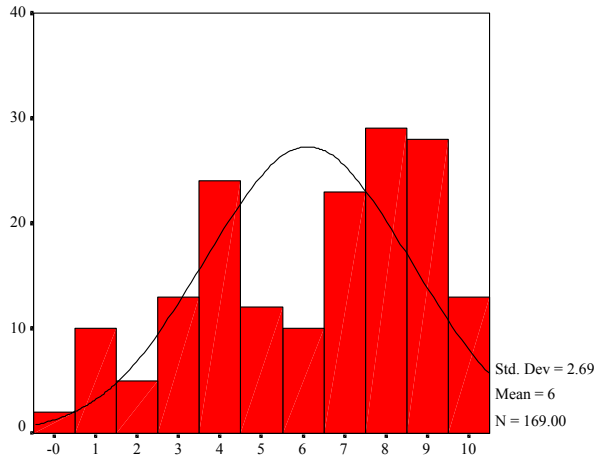
STREAMCO



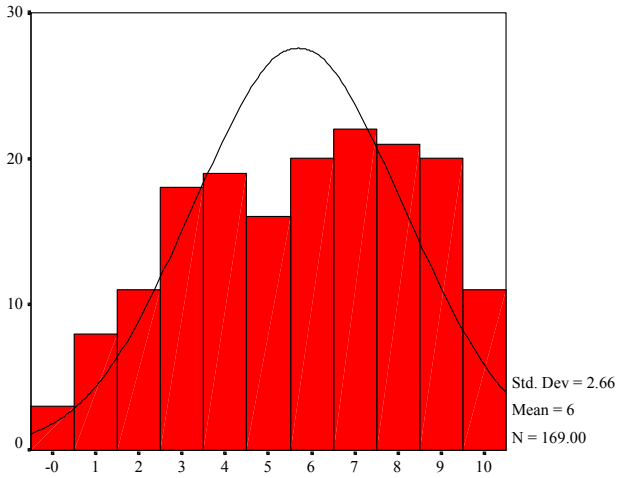
EMBED



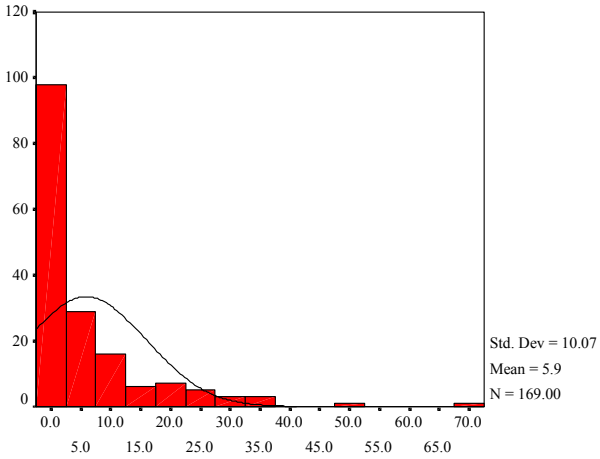
CSHAPE



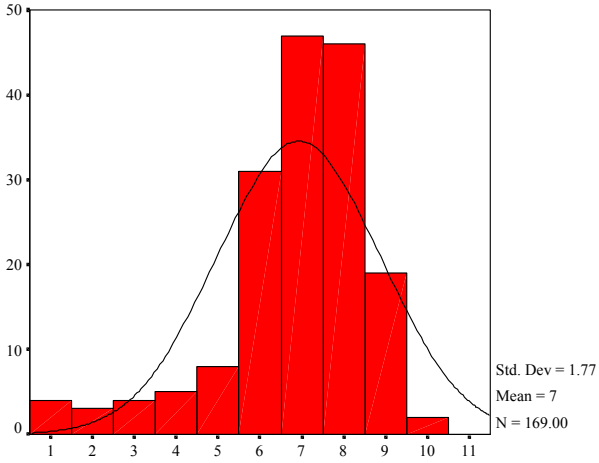
DISPRES



ZONEINFL

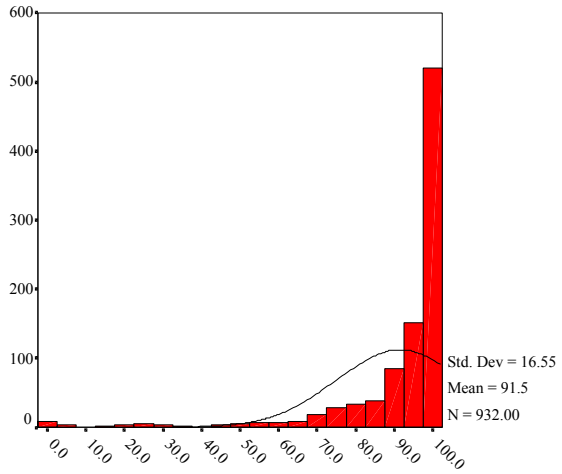


LOD

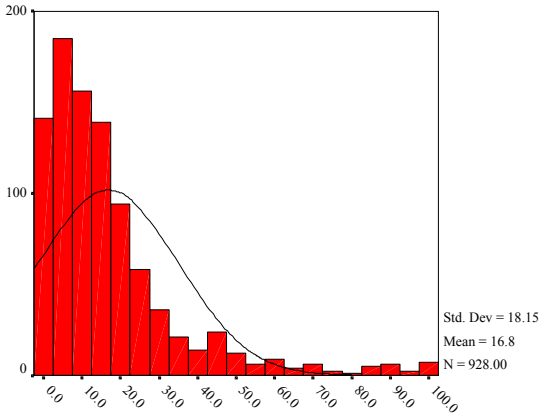


wolmann size classes

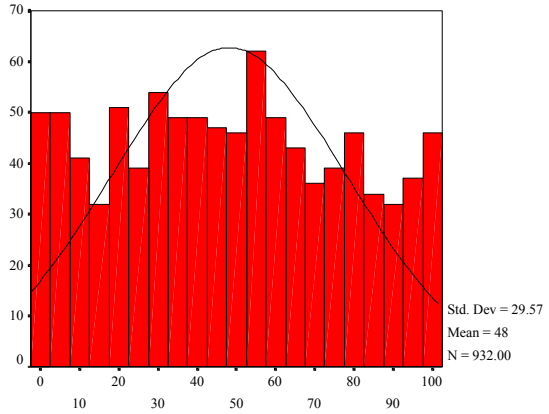
Northern and Middle Rockies histograms: 932 sites



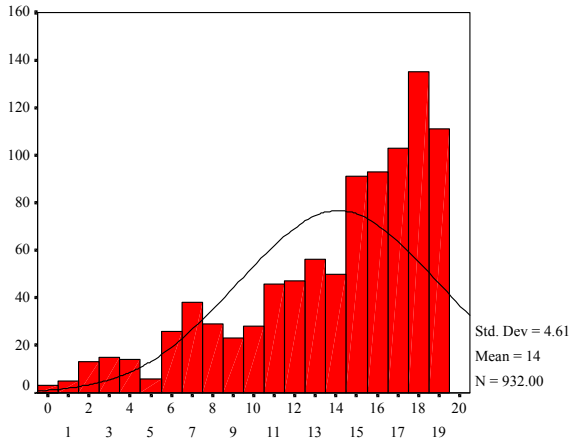
bank cover raw



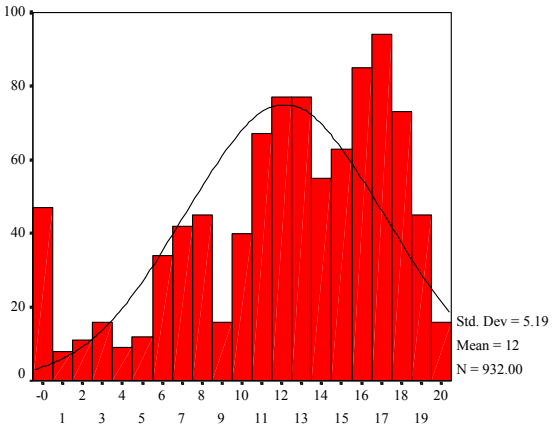
pct fines



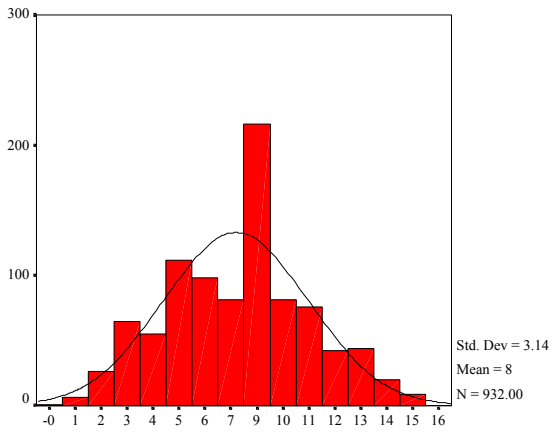
PCT_CAN



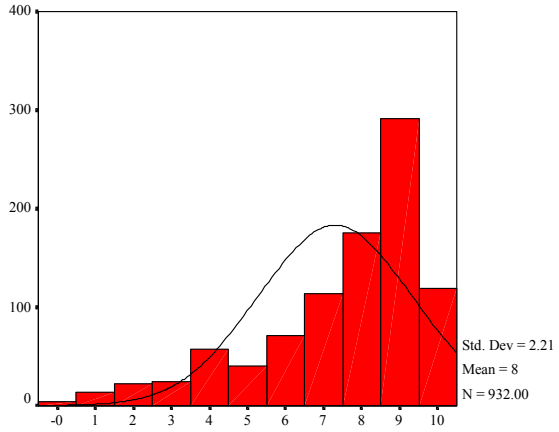
STREAMCO



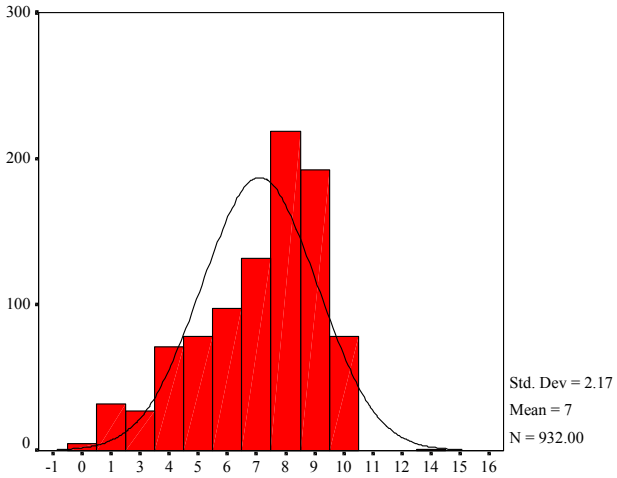
EMBED



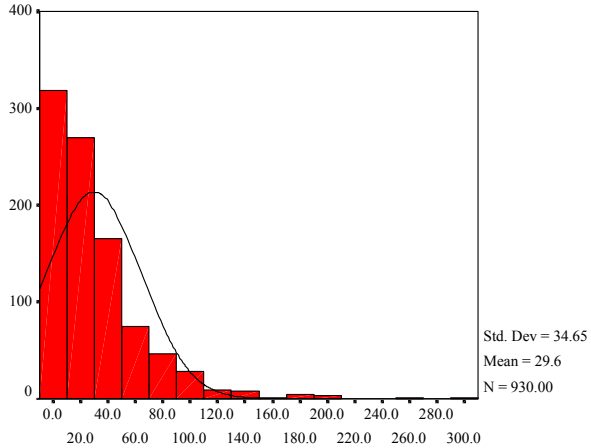
CSHAPE



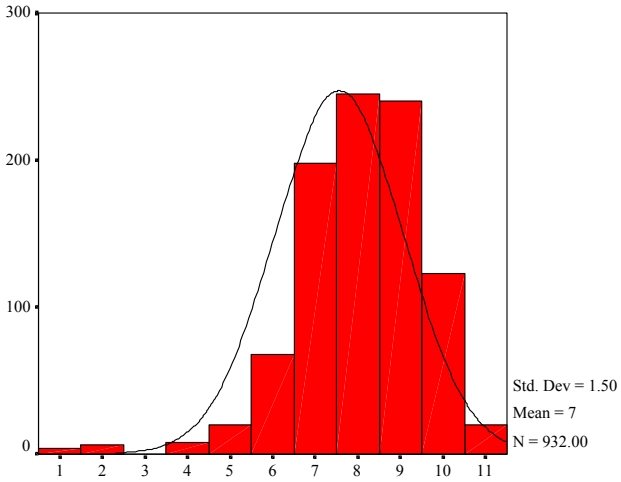
DISPRES



ZONEINFL

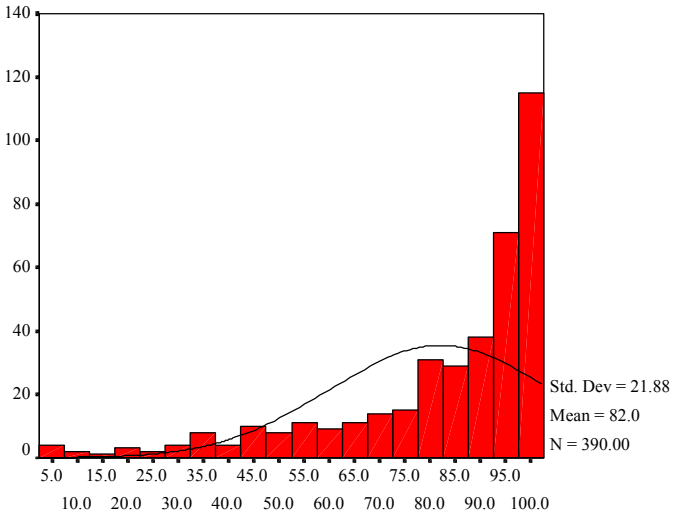


LOD

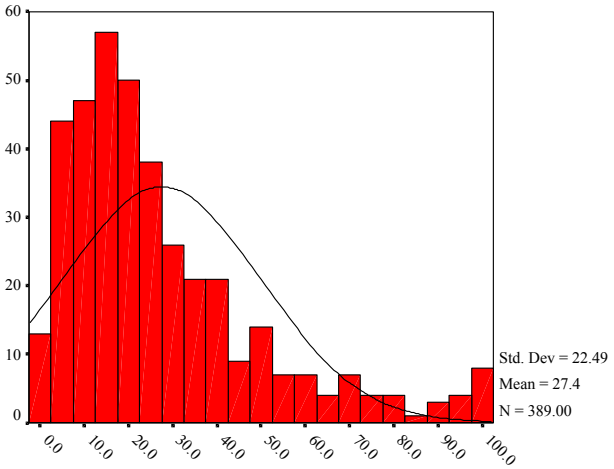


wolmann size classes

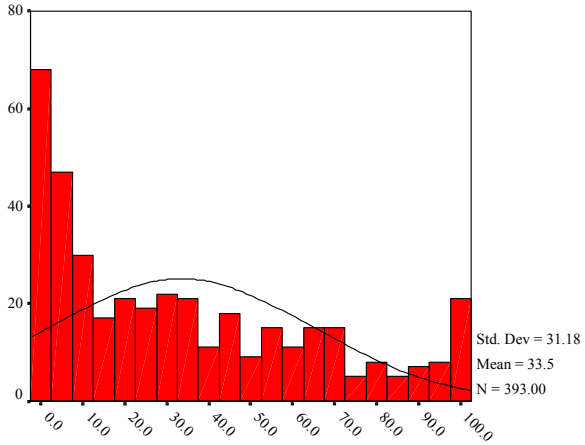
Snake River histograms: 393 sites



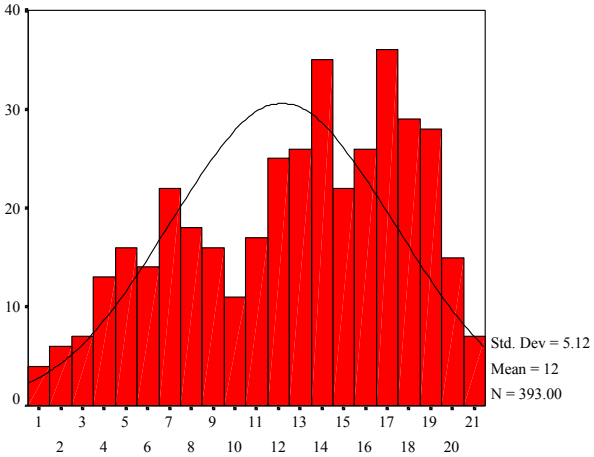
bank cover raw



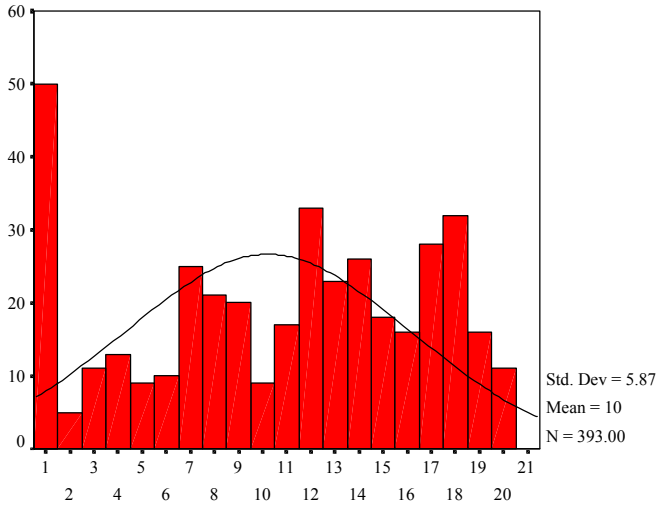
pct fines



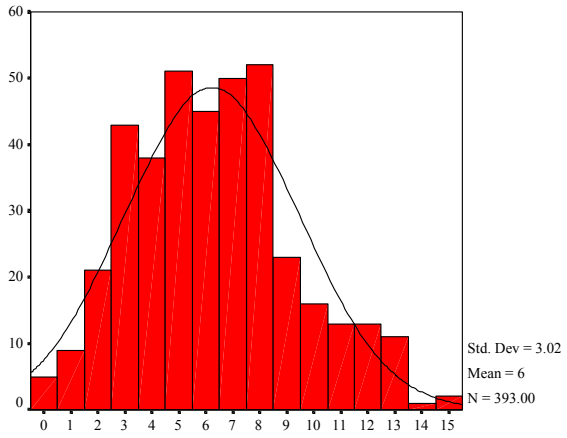
PCT_CAN



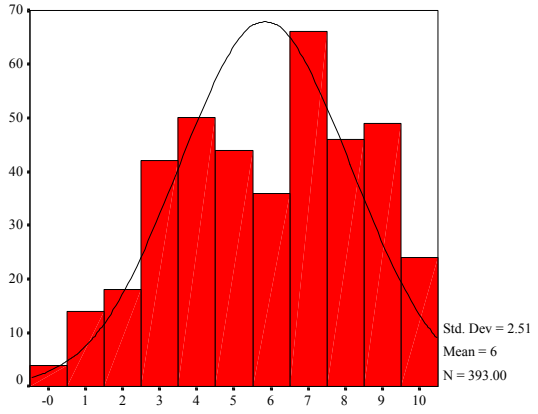
STREAMCO



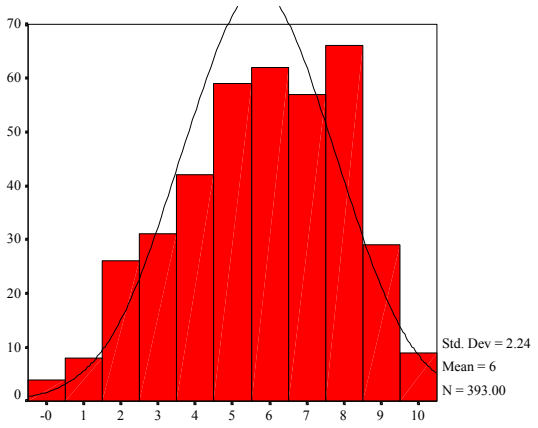
EMBED



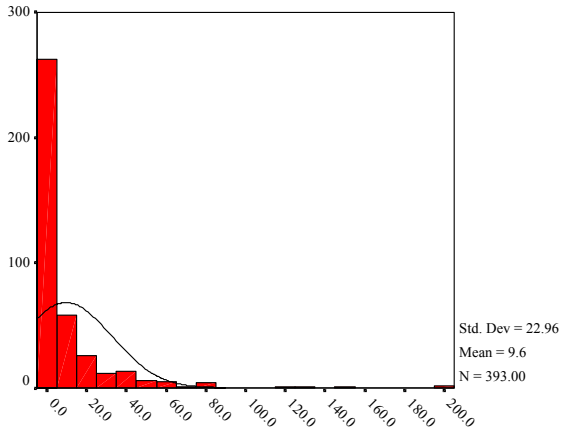
CSHAPE



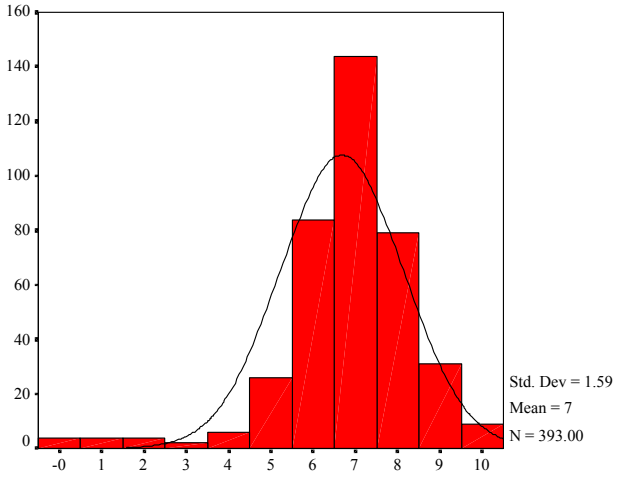
DISPRES



ZONEINFL

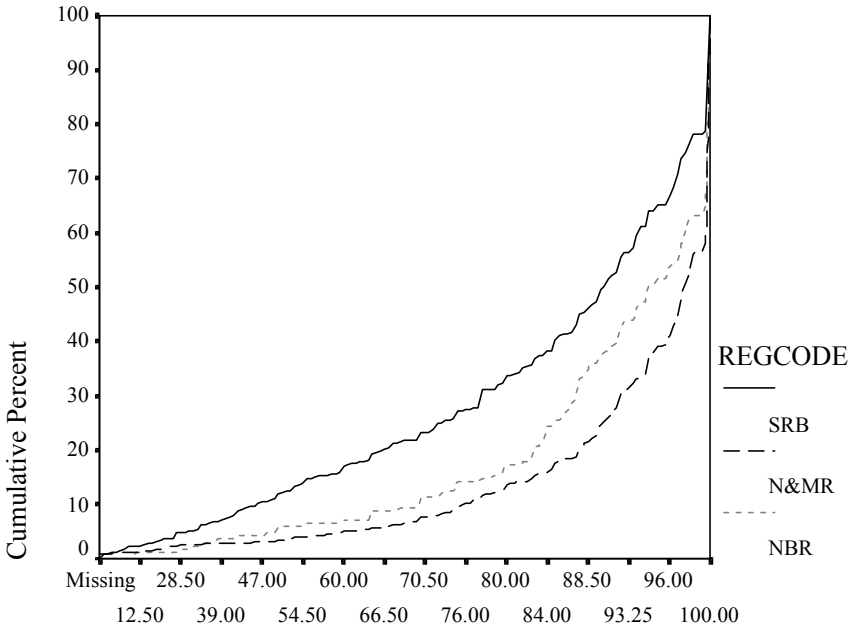


LOD

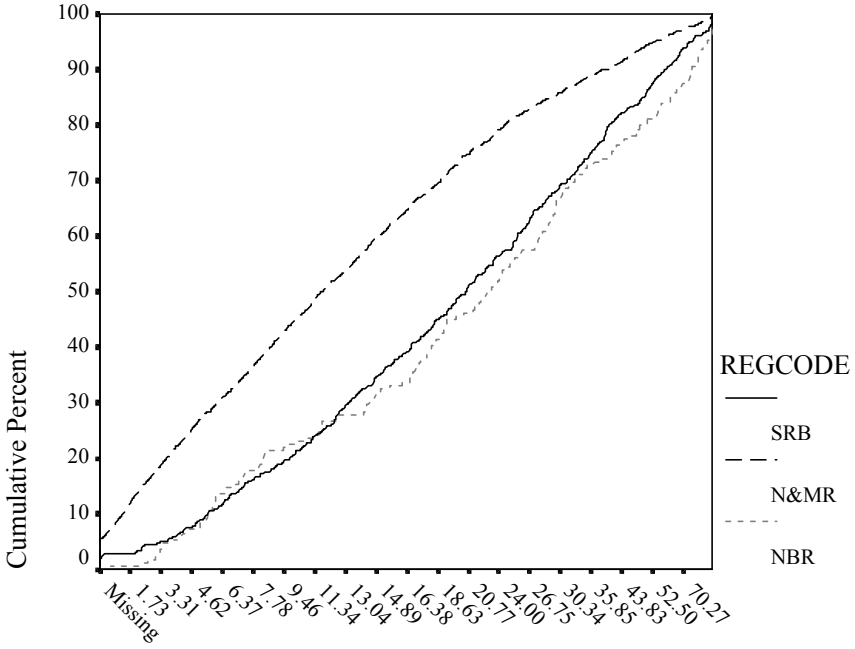


wolmann size classes

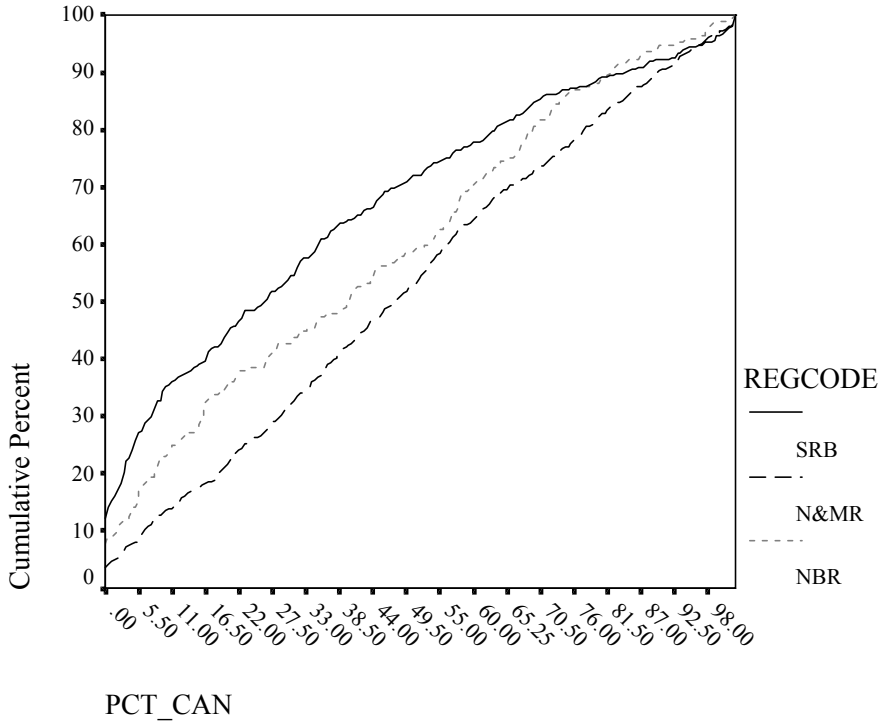
Appendix M.
Cumulative Distribution Functions of SHI Habitat Measures

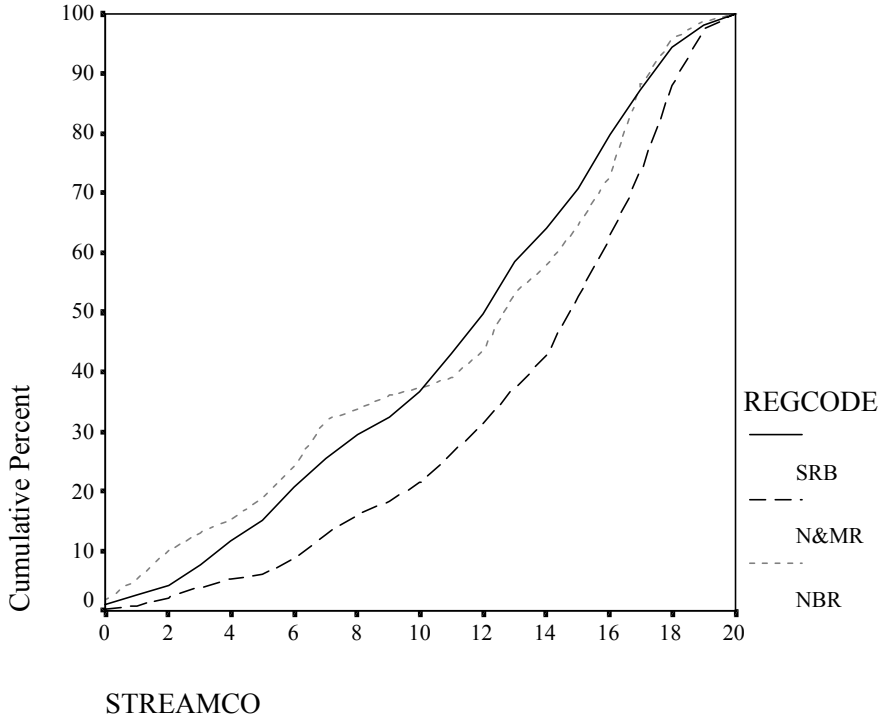


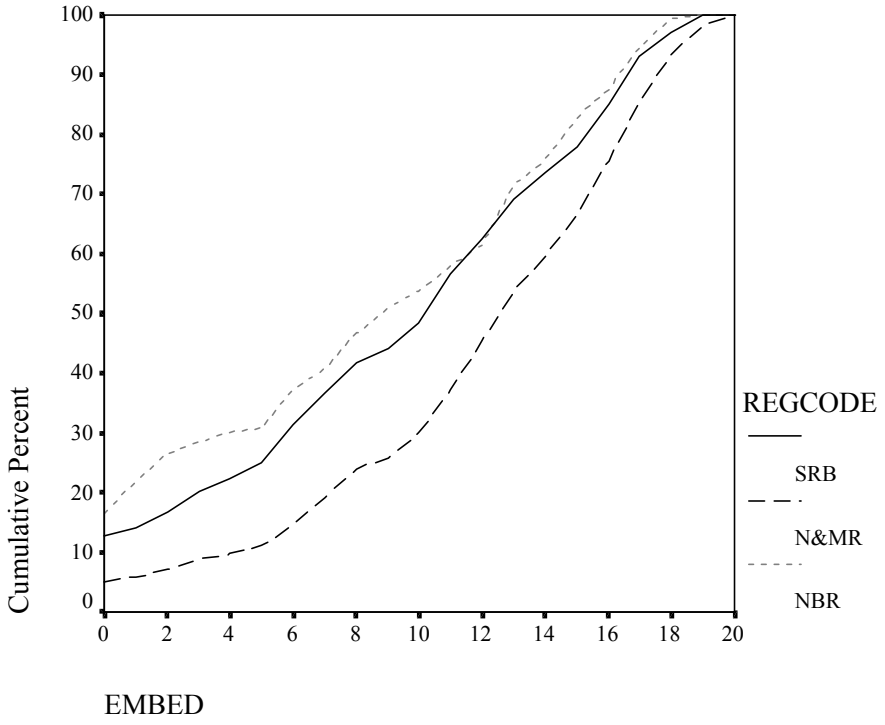
bank cover raw

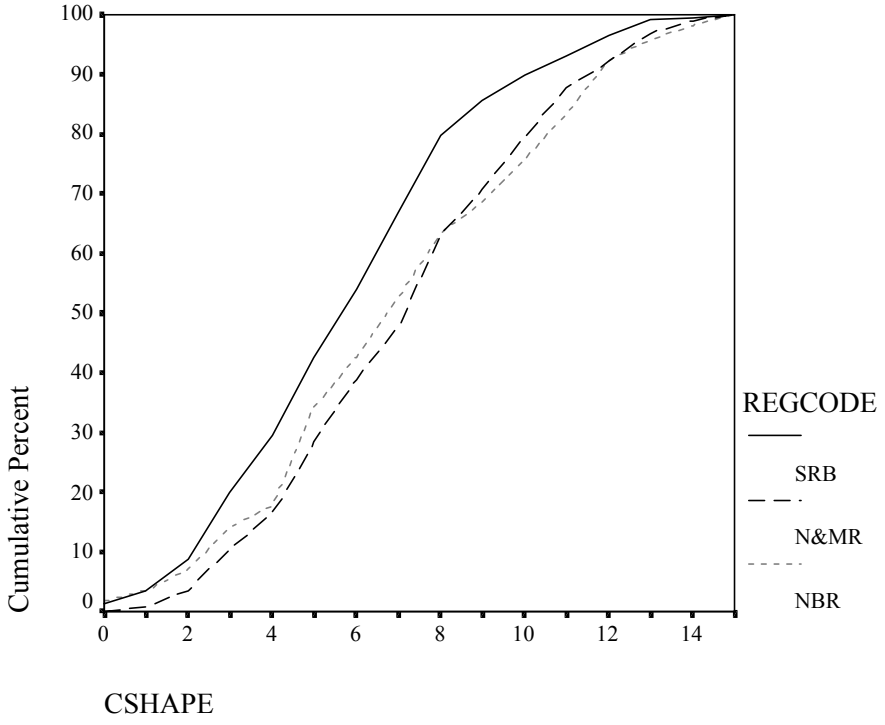


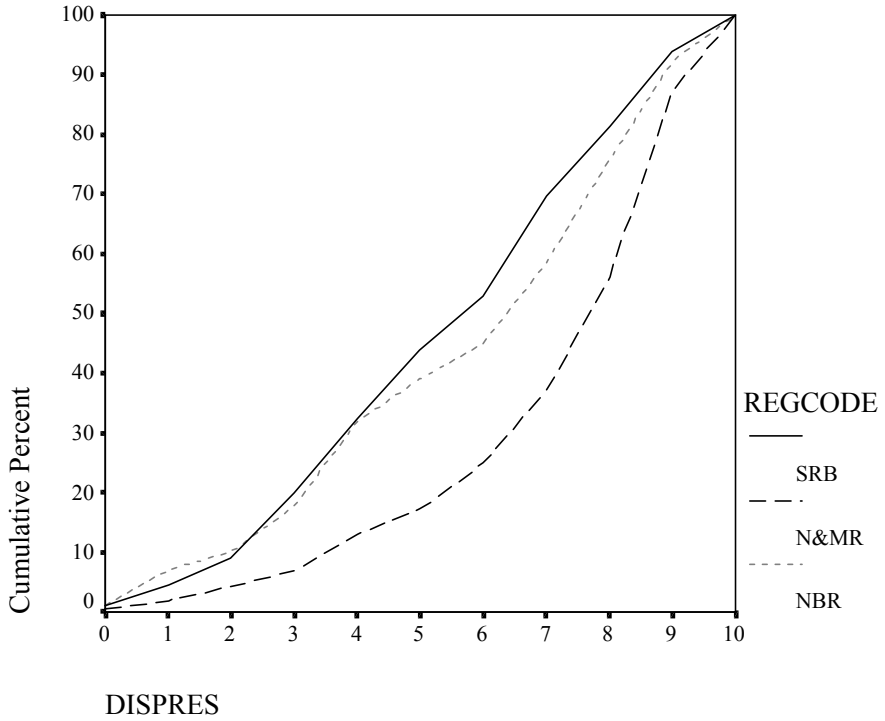
pct fines

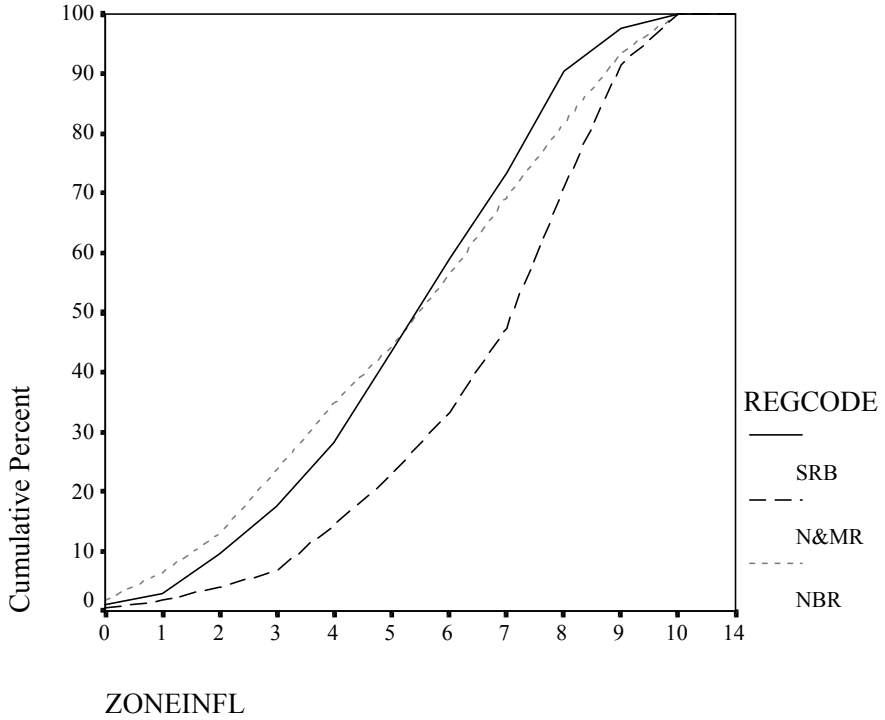

Cumulative Percent
100
90
80
70
60
50
40
30
20
10
0
.00
5.50
11.00
16.50
22.00
27.50
33.00
38.50
44.00
49.50
55.00
60.00
65.25
70.50
76.00
81.50
87.00
92.50
98.00
PCT_CAN
REGCODE
SRB
N&MR
NBR

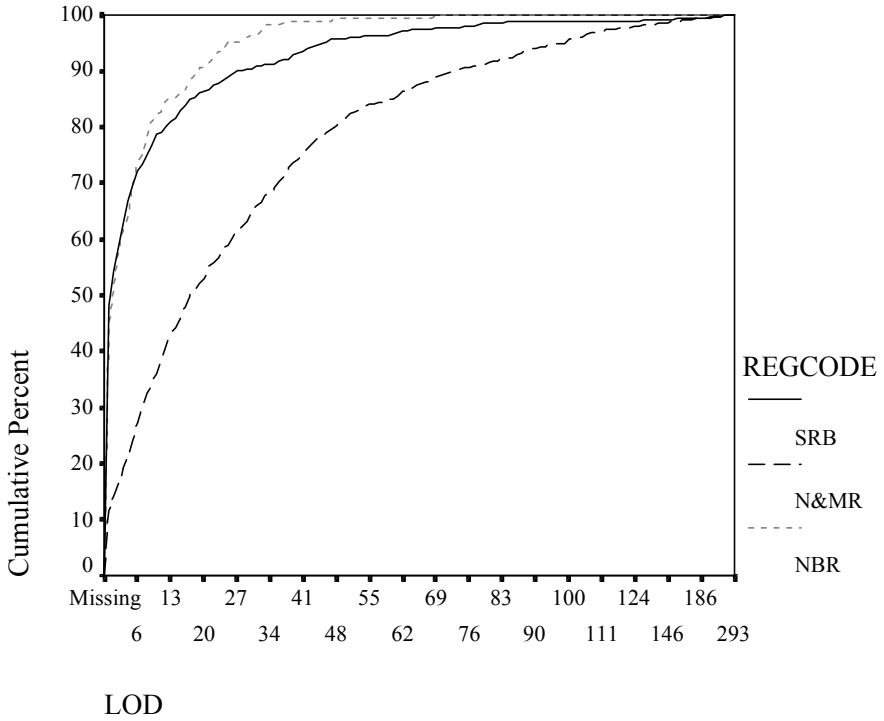

Cumulative Percent
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
STREAMCO
REGCODE
SRB
N&MR
NBR

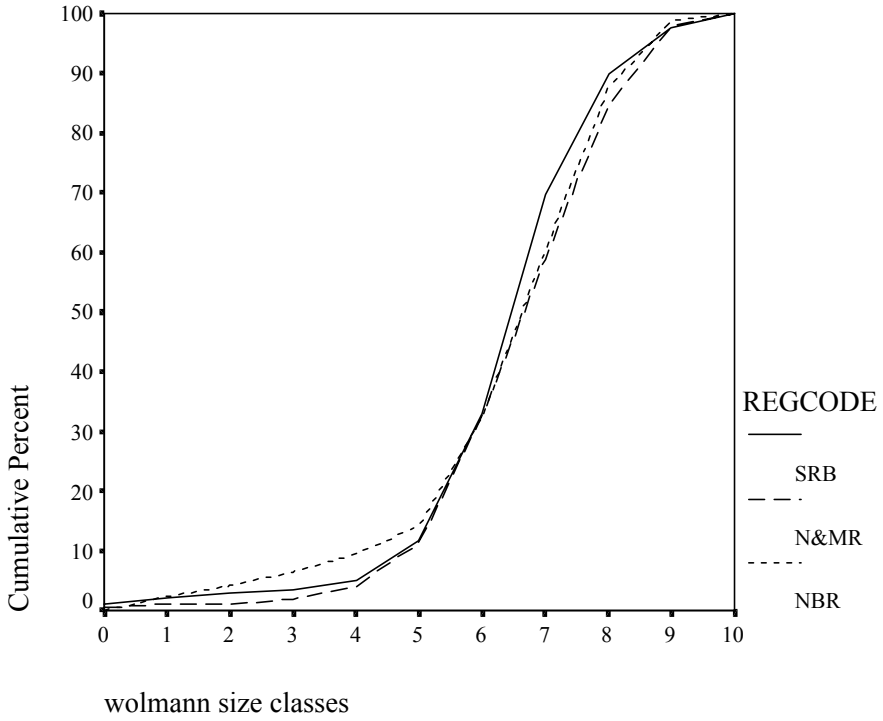

Cumulative Percent
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
EMBED
REGCODE
SRB
N&MR
NBR


Cumulative Percent
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
CSHAPE
REGCODE
SRB
N&MR
NBR


Cumulative Percent
100
90
80
70
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9 10
REGCODE
SRB
N&MR
NBR
DISPRES


Cumulative Percent
100
90
80
70
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9 10 14
REGCODE
SRB
N&MR
NBR
ZONEINFL


Cumulative Percent
100
90
80
70
60
50
40
30
20
10
0
Missing 13 27 41 55 69 83 100 124 186
6 20 34 48 62 76 90 111 146 293
LOD
REGCODE
SRB
N&MR
NBR


Cumulative Percent
100
90
80
70
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9 10
wolmann size classes
REGCODE
SRB
N&MR
NBR

Glossary

This glossary is intended to define terms in the context used in the *Idaho Small Streams Ecological Assessment Framework*.

Term	Definition
Ambient	General conditions in the environment. In the context of water quality, ambient waters are those representative of general conditions, not associated with episodic perturbations, or specific disturbances such as a wastewater outfall (Armantrout 1998, EPA 1996).
Anthropogenic	Made by humans. Includes waterways such as canals, flumes, ditches, and similar structures constructed for the purpose of water conveyance.
Aquatic	Pertaining to water. In this context, usually refers to plants or animal life living in, growing in, or adapted to water.
Assemblage (aquatic)	An association of interacting populations of organisms in a given water body; for example, a fish assemblage, or a benthic macroinvertebrate assemblage (Also see Community) (EPA 1996).
Beneficial use	Any of the various uses of water, including, but not limited to, aquatic biota, recreation, water supply, wildlife habitat, and aesthetics.
Beneficial Use Reconnaissance Program (BURP)	Systematic biological and physical habitat surveys of water bodies in Idaho. BURP protocols address wadeable streams and small rivers, large rivers, lakes, and reservoirs.
Best professional judgment	A conclusion and/or interpretation derived by a trained and/or technically competent individual by applying interpretation and synthesizing information.
Biological integrity	1) The condition of an aquatic community inhabiting unimpaired water bodies of a specified habitat as measured by an evaluation of multiple attributes of the aquatic biota (EPA 1996). 2) The ability of an aquatic ecosystem, to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to the natural habitats of a region (Karr 1991).

Term	Definition
Biota	The animal and plant life of a given region.
Biotic community	A naturally occurring assemblage of plants and animals that live in the same environment and are mutually sustaining and interdependent.
Clean Water Act	The Federal Pollution Control Act (PL92-500, commonly known as the Clean Water Act), as last reauthorized by the Water Quality Act of 1987 (PL100-4), establishes a process for state to use to develop information on the quality of the nation's water resources.
Community (aquatic)	An association of interacting assemblages in a given water body; the biotic component of an ecosystem (also see Assemblage) (EPA 1996).
Criteria	Descriptive factors taken into account by EPA in setting standards for various pollutants. These factors are used to determine limits on allowable concentration levels, and to limit the number of violations per year. When issued by EPA, the criteria provide guidance to the states on how to establish their standards.
Designated uses	Those water uses identified in state water quality standards that must be achieved and maintained as required under the Clean Water Act.
Discharge	The amount of water flowing in the stream channel at the time of measurement. Usually expressed as cubic feet per second (cfs).
Disturbance	Any event or series of events that disrupt ecosystem, community, or population structure and alter the physical environment.
Diversity	Variation that occurs in plant and animal taxonomy (i.e., species composition), habitats, or ecosystems within a geographic location.
Ecological indicator	A characteristic of an ecosystem that is related to, or derived from, a measure of a biotic or abiotic variable that can provide quantitative information on ecological structure and function. An indicator can contribute to a measure of integrity and sustainability. Ecological indicators are often used within the multimetric index framework.

Term	Definition
Ecological integrity	1) A living system exhibits integrity if, when subjected to disturbance, it sustains and organizes self-correcting ability to recover toward a biomass end-state that is normal for that system. 2) The condition of an unimpaired ecosystem as measured by combined chemical, physical (including habitat), and biological attributes (EPA 1996).
Ecosystem	The interacting system of a biological community and its non-living environmental surroundings.
Endangered species	Animals, birds, fish, plants, or other living organisms threatened with extinction by anthropogenic (human-caused) or other natural changes in their environment. Requirements for declaring a species endangered are contained in the Endangered Species Act.
Exceedance	Violation of the pollutant levels permitted by environmental protection standards.
Extrapolation	Estimation of unknown values by extending or projecting from known values.
Fully supporting	In compliance with water quality standards and criteria, and meeting the reference conditions for all designated and existing beneficial uses as determined through the WBAG.
Fully supporting of cold water biota	Reliable data indicate functioning, sustainable cold-water biological assemblages (e.g., fish, macroinvertebrates, or algae), none of which have been modified significantly beyond the natural range of reference conditions (EPA 1995).
GIS	Geographic Information System, a georeferenced database.
Habitat	The place where a population (e.g., human, animal, plant, microorganism) lives and its surroundings, both living and non-living.
Heavy metals	Metallic elements with high atomic weights; (e.g., mercury, chromium, cadmium, arsenic, and lead); that can damage living things at low concentrations and tend to accumulate in the food chain.
Human made	Relating to or resulting from the influence of human beings on nature (anthropogenic)

Term	Definition
Hydrologic Unit Code (HUC)	A watershed numbering system developed by the U.S. Geological Survey. All waters that flow to a common point have the same number.
Lotic	Aquatic system with rapidly flowing water such as a brook, stream, or river where the net flow of water is unidirectional from the headwaters to the mouth.
Macroinvertebrate	An invertebrate animal (without backbone) large enough to be seen without magnification and retained by a 0.595 mm (U.S.#30) screen.
Metric	One discrete measure of an ecological indicator (e.g., number of distinct taxon).
Monitoring	Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.
Natural condition	A condition without human-based disruptions.
Not fully supporting	Not in compliance with water quality standards or criteria, or not meeting reference conditions for each beneficial use as determined through the WBAG.
Not fully supporting cold water biota	At least one biological assemblage has been significantly modified beyond the natural range of its reference condition (EPA 1995).
Oligotrophic	A body of water with low levels of nutrients.
Parameter	A variable, measurable property whose value is a determinant of the characteristics of a system; e.g., temperature, pressure, and density are parameters of the atmosphere.
Periphyton	Attached microflora growing on the bottom, or on other submerged substrates, including higher plants. Epilithic periphyton is flora growing on the surface of rock or stones. Diatoms are a type of periphyton.

Term	Definition
Physicochemical	In the context of bioassessment, the term is commonly used to mean the physical and chemical factors of the water column that relate to aquatic biota. Examples in bioassessment usage include saturation of dissolved gases, temperature, pH, conductivity, dissolved or suspended solids, forms of nitrogen, and phosphorus. This term is used interchangeably with the term physical/chemical or physiochemical.
Pollutant	Generally, any substance introduced into the environment that adversely affects the usefulness of a resource or the health of humans, animals, or ecosystems.
Pollution	Generally, the presence of a substance in the environment that because of its chemical composition or quantity prevents the functioning of natural processes and produces undesirable environmental and health effects. Under the Clean Water Act, for example, the term has been defined as the human-made or human-induced alteration of the physical, biological, chemical, and radiological integrity of water and other media.
Population	A group of interbreeding organisms occupying a particular space; the number of humans or other living creatures in a designated area.
Protocol	A series of formal steps for conducting a test or survey.
Qualitative	Descriptive of kind, type, or direction, as opposed to size, magnitude, or degree.
Quantitative	Descriptive of size, magnitude, or degree.
Reconnaissance	An exploratory or preliminary survey of an area.
Reference	A physical or chemical quantity whose value is known, and thus is used to calibrate or standardize instruments.
Reference condition	(1) A condition that fully supports applicable beneficial uses with little affect from human activity and represents the highest level of support attainable. (2) A benchmark for populations of aquatic ecosystems used to describe desired conditions in a biological assessment and acceptable or unacceptable departures from them. The reference condition can be determined through examining regional reference sites, historical conditions, quantitative models, and expert judgment (Hughes 1995).

Term	Definition
Reference site	A specific locality on a water body that is minimally impaired and is representative of the expected ecological integrity of other localities on the same water body or nearby water bodies (EPA 1996).
Representative sample	A portion of material or water that is as nearly identical in content and consistency as possible to that in the larger body of material or water being sampled.
River	Large, natural, or human-modified stream that flows in a defined course or channel, or a series of diverging and converging channels. See Chapter 2 for water body size criteria.
Site discharge	This is the discharge measured, either by the crew or by a nearby gaging station, on the sampling day.
Site drainage area	This criterion, which measures the drainage area above the site, is calculated using GIS hydrography (1:100,000) and Hydrologic unit codes (HUC) (4th and 5th field) coverages.
Species	1) A reproductively isolated aggregate of interbreeding organisms having common attributes and usually designated by a common name. 2) An organism belonging to such a category.
Stream	A natural water course containing flowing water, at least part of the year, together with dissolved and suspended materials, that normally supports communities of plants and animals within the channel and the riparian vegetation zone. See Chapter 2 for water body size criteria.
Stream order	Hierarchical ordering of streams based on the degree of branching. A first-order stream is an unforked or unbranched stream. Two first-order streams flow together to form a second-order stream, two second-order streams combine to make a third-order stream, etc. (Strahler 1957).
Taxon	Any formal taxonomic unit or category of organisms (e.g., species, genus, family, order). The plural of taxon is taxa (Armantrout 1998).
Water body	A homogeneous classification that can be assigned to rivers, lakes, estuaries, coastlines, or other water features.

Term	Definition
Water quality	A term used to describe the biological, chemical, and physical characteristics of water with respect to its suitability for a beneficial use.
Water quality criteria	Levels of water quality expected to render a body of water suitable for its designated use. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, or industrial processes.
Water quality standards	State-adopted and EPA-approved ambient standards for water bodies. The standards prescribe the use of the water body and establish the water quality criteria that must be met to protect designated uses.
Watershed	The land area that drains into a stream. An area of land that contributes runoff to one specific delivery point; large watersheds may be composed of several smaller Asubwatersheds.≅ each of which contributes runoff to different locations that ultimately combine at a common delivery point.
WBID	Water body identification number; a number that identifies a water body, and correlates to Idaho Water Quality Standards, and GIS information.
Weight of scientific evidence	Considerations in assessing the interpretation of available information--quality of testing methods, size of study design, consistency of results across studies, and biological plausibility of exposure-response relationships and statistical associations.

REFERENCES

Armantrout, N.B. (compiler). 1998. Glossary of aquatic habitat inventory terminology. American Fisheries Society. Bethesda, MD.

EPA. 1990. Biological criteria: National program guidance for surface waters. EPA 440/5-90-004. US Environmental Protection Agency, Office of Water, Washington, DC

EPA. 1995. Guidelines for preparation of the 1996 state water quality assessments (305(b) Reports). EPA 841 B-95-001. US Environmental Protection Agency. Washington, DC.

EPA. 1996. Biological Criteria: technical guidance for streams and small rivers. EPA 822-B-96-001. US Environmental Protection Agency, Office of Water, Washington, DC.

Hughes, R.M., 1995. Defining acceptable biological status by comparing with reference conditions. Pages 31-48 in Davis, W.S. and T.P. Simon (editors): 1995. Biological assessment and criteria: tools for water resource planning. CRC Press, Boca Raton, Florida.

Minshall, G.W. 1996. Organic matter budgets. Pages 591-606 in Hauer, F.R. and G.A. Lamberti (editors): Methods in stream ecology. Academic Press, San Diego, CA.

Rand, G.M. (editor) 1995. Fundamentals of aquatic toxicology: effects, environmental fate, and risk assessment. Second edition. Taylor and Francis, Washington, DC. 1125 pp.

Rules of the Department of Environmental Quality, IDAPA 58.01.02, Water Quality Standards and Wastewater Treatments Requirements.

Strahler, A.N. 1957. Quantitative analysis of watershed geomorphology. American Geophysics Union Transactions. 38:913-920.

Suter, G.W. III. 1993. Ecological Risk Assessment. Lewis Publishers, Chelsea, MI. 538 pp.