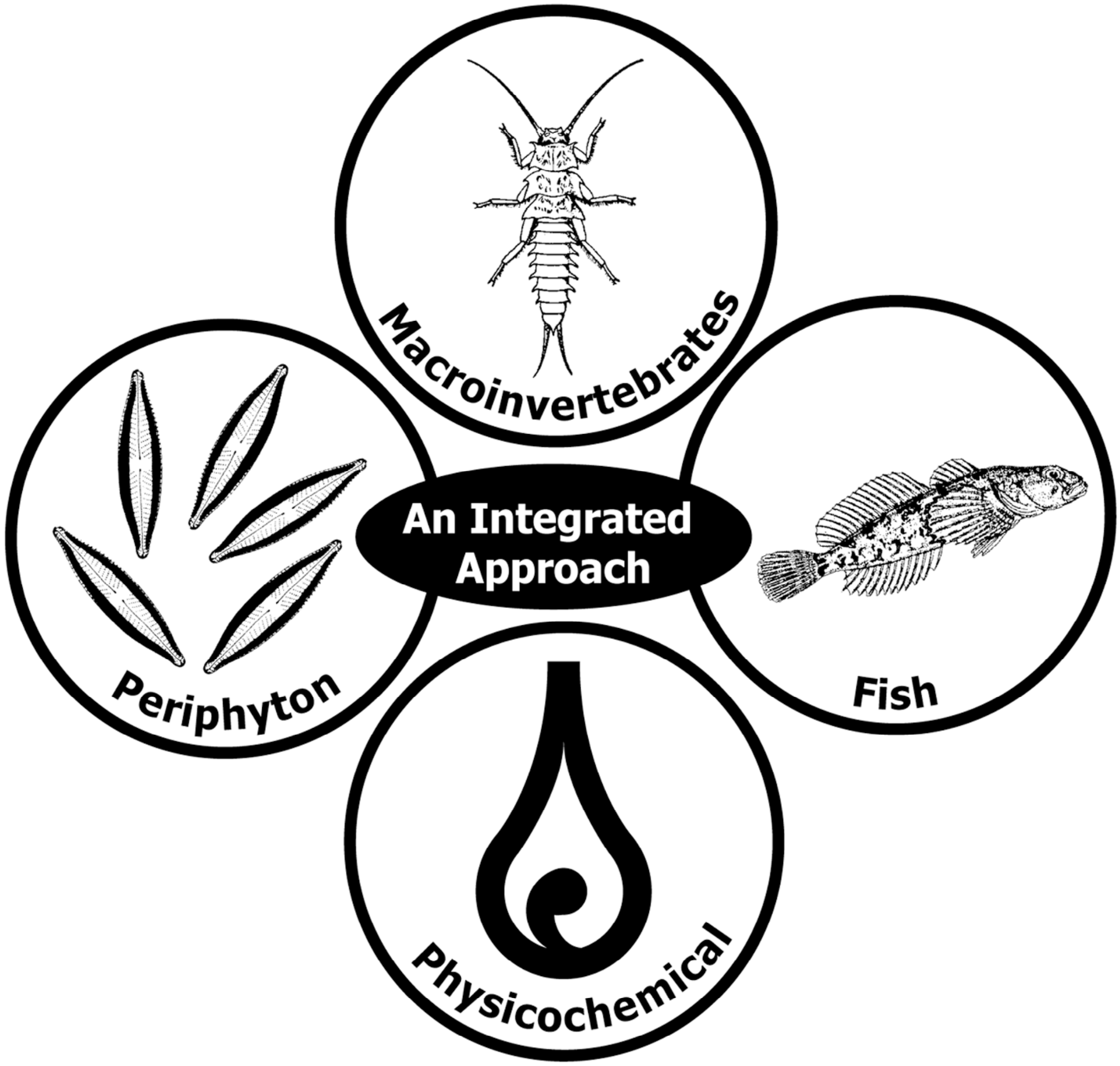
Idaho River Ecological Assessment Framework



Idaho Department of Environmental Quality
Final – April 2002

Idaho River
Ecological Assessment Framework

an Integrated Approach

Final
April 2002

IDAHO DEPARTMENT OF ENVIRONMENTAL QUALITY

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Acronyms

ANOVA	Analysis of Variance
BOD	Biochemical Oxygen Demand
BURP	Beneficial Use Reconnaissance Project
CaCO	Calcium Carbonate
cfs	cubic feet per second
cm	centimeters
cm^2	centimeters squared
CPUE	Catch per unit effort
CV	Coefficients of Variance
CWA	Clean Water Act
DELT	Deformities, eroded fins, lesions, or tumors
DEQ	Idaho Department of Environmental Quality
DO	Dissolved Oxygen
EM	eastern mountains
EMAP	Environmental Monitoring and Assessment Project
EPA	Environmental Protection Agency
EPT	Ephemeroptera, Plectoptera, Trichoptera
FS	Fully supporting
GIS	Geographic Information System
HBI	Hilsenhoff's Biotic Index
HUC	Hydrologic unit codes
IBI	Index of Biotic Integrity
ISU	Idaho State University
KDEP	Kentucky Department of Environmental Protection
km	kilometer
m	meter
m^3	cubic meter
m^3/s	cubic meter per second
MBI	Macroinvertebrate Biotic Index
MDD	Minimum Detectable Difference
mg	millogram
mi	mile
mi^2	square mile
NA	Not Assessed
NAWQA	National Water Quality Assessment Program
NFS	Not Fully Supporting
OWQI	Oregon Water Quality Index
PTI	Pollution Tolerance Index
QA/QC	quality assurance/quality control
RDI	River Diatom Index
RFI	River Fish Index
RMI	River Macroinvertebrate Index

RPI	River Physicochemical Index
SD	standard deviation
S/N Ratio	Signal to Noise Radio
USGS	United States Geological Survey
WBAG	Water Body Assessment Guidance
WQI	Water Quality Index

Abstract

This document describes the Idaho Department of Environmental Quality's (DEQ) ecological assessment approach to determine aquatic life use support in Idaho's rivers. DEQ uses biological indicators, physicochemical data and numeric water quality criteria to assess aquatic life use support for rivers. The intent of this document is to provide detailed technical information concerning the development and integration of the River Macroinvertebrate Index (RMI), River Fish Index (RFI), and River Diatom Index (RDI) used in the cold water aquatic life use support determination. The River Physicochemical Index (RPI), another interpretive tool, is also discussed.

DEQ developed a separate bioassessment for rivers because biological communities naturally change as stream size increases from headwaters to mouth. Also, practical sampling and safety considerations make biological monitoring of rivers different from monitoring small streams. Further, larger systems have highly variable biological and physical properties with often extensive, complex human impacts that require a much larger scope of analysis. DEQ applies the river ecological assessment approach based on results from three water body size criteria: stream order, width, and depth. In general, the river method is applied to water bodies that have an average water body size criteria rating of greater than or equal to 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. The RMI is a multimetric index consisting of five macroinvertebrate metrics: taxa richness, EPT richness, percent dominance, percent Elmidae (riffle beetles), and percent predators. This macroinvertebrate index was basically a variation of the framework designed for small streams which implies that some methods currently used for small streams can be modified for use on larger rivers.

The RFI is a quantitative fish index applicable to cold water rivers of the interior Columbia River basin (Idaho, Montana, Oregon, Washington, and Wyoming). The index comprises the following metrics: number of cold water native species, number of sculpin age classes or percent sculpin (data dependent), percent sensitive native individuals, percent cold water individuals, percent tolerant individuals, number of non-indigenous species, number of selected salmonid age classes, number of cold water individuals per minute of electrofishing, percent carp (if carp introduced), and anomalies.

The third biological index, the RDI, also uses a multimetric approach. This diatom index consists of seven attributes of relative abundance including percent: sensitive to disturbance, very tolerant of disturbance, nitrogen heterotrophs, polysaprobic, requiring high oxygen, very motile, and deformed valves. The RDI also includes two measures of taxon richness: eutrophic and alkaliphilic species. The index significantly correlated with measures of human disturbance at the site and at the level of the catchment.

The RPI is based on the Oregon Water Quality Index. This index has been tested and used extensively in Oregon to assess water quality conditions. The RPI consists of eight water quality parameters: temperature, dissolved oxygen, biochemical oxygen demand, pH, total solids, ammonia + nitrate nitrogen, total phosphorus, and fecal coliform.

DEQ integrates the RMI, RDI, and RFI index scores 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 2 are fully supporting of aquatic life, while scores less than or equal to 2 are not fully supporting. The RPI is not integrated in the averaging process, but may provide additional information in interpreting physicochemical data.

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 rivers. 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 River Macroinvertebrate Index (RMI), River Fish Index (RFI), River Diatom Index (RDI) and River Physicochemical Index (RPI). The RMI, RFI, and RDI are directly used in the ALUS determination.

The ALUS for rivers is addressed in this document, while the small stream ALUS is addressed in the DEQ *Idaho Small Stream 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.

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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].

DEVELOPMENT OF RIVER PROTOCOL

DEQ has had an established bioassessment process for smaller water bodies for several years, but not specifically for rivers. There are several reasons why rivers should have a separate bioassessment protocol from smaller streams. Stream ecosystem theory predicts that benthic macroinvertebrate communities naturally change as stream size progressively increases from headwaters to rivers (Vannote et al., 1980, Minshall et al. 1983). Further, practical sampling and safety considerations make biological monitoring of rivers different from monitoring small streams. Such large systems have highly variable biological and physical properties with often extensive, complex human impacts that require a much larger scope of analysis (Bain 1992).

In 1995, DEQ anticipated that rivers would require different assessment methods and contracted the Idaho State University Stream Ecology Center (ISU) to develop protocols and tools for a bioassessment process addressing Idaho rivers. The ISU researchers developed a benthic macroinvertebrate index, called the River Macroinvertebrate Index (RMI), based on sampling and analyses of sites covering the range of environmental conditions from nearly pristine to obviously degraded[3]. From 1995-1999, ISU completed several studies on sampling methodology for large and medium size rivers, data interpretation, validation sampling, and landscape analyses (Royer and Minshall 1996, 1997, 1999; Schomberg et al. 1998).

To continue building on the ISU research effort, DEQ began collecting reconnaissance monitoring data in 1997. DEQ used ISU and U.S. Geological Survey (USGS-NAWQA) protocols to collect samples on 70 sites in 40 rivers statewide in 1997 and 1998 (see Appendix A).

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

[2] Henceforth, subsection 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.”
[3] The authors of the RMI (Royer and Minshall 1996, 1999) called the index the Idaho River Index. However, since other indexes for Idaho rivers were developed for other assemblages, River Macroinvertebrate Index is more appropriate and consistent with the DEQ index naming convention.

measure of the aquatic life beneficial use. DEQ uses biological indicators, physicochemical data and numeric water quality criteria to assess ALUS for rivers. Levels of aquatic life protection and maintenance are evaluated within the context of the Idaho water quality standards goals.

CONCEPT OF MULTIPLE ASSESSMENT TOOLS

Many surface water biological monitoring programs rely primarily upon macroinvertebrate assemblages for stream assessments. The need to efficiently and cost-effectively interpret conditions in streams is one of the reasons for this reliance. However, the approach of using more than one biological or physicochemical assessment tool is well established in the aquatic assessment field. For example, the effects of pollution in estuaries have been investigated by measuring in-situ benthic macroinvertebrate assemblages, conducting laboratory toxicity tests of field-collected sediments, analyzing sediment chemistry, and in some cases, assessing condition indicators of fish (Chapman 1986, Chapman et al. 1992, EPA 1993). This "sediment quality triad" approach using several assessment endpoints that respond to different pollutants has also been successfully applied to reservoirs and rivers (Canfield et al. 1994, Pastorak et al. 1994). Additionally, an integrated assessment approach (habitat, fish, and macroinvertebrates) was used to evaluate stream sites in Pennsylvania (Snyder et al. 1996). Further, Barbour et al. (1999) illustrate the integration of physical, macroinvertebrate, and fish assemblages in the most recently revised EPA rapid bioassessment protocols.

Distinct assemblages may be expected to respond differently to certain pollutants or restoration activities. Therefore, surveying more than one assemblage often results in a more complete assessment of the biological condition, particularly for larger, more ecologically complex water bodies. There are several cases that support this concept. Barbour et al. (1997) cite examples from Ohio of fish assemblages recovering more quickly in improved water quality than benthic macroinvertebrates. Cases where altered fish populations occurred in the presence of subtle or no benthic invertebrate impacts have also been reported (Pascoe et al. 1994, Royer and Minshall 1999).

LINE OF EVIDENCE APPROACH

Single indicators or measures of a biological assemblage appear to inadequately represent all other assemblages in the river system. Additionally, data used to calculate certain indexes, such as the RFI, may be limited due to greater sampling resource requirements, endangered or threatened species sampling restrictions, and incompatible sampling protocols. Therefore, DEQ uses several bioassessment tools to limit reliance on just one tool and still ensure direct measurements of aquatic life. Most of these bioassessment tools are multimetric indexes based on rapid bioassessment concepts developed by EPA (Barbour et al. 1999). Using several integrated bioassessment tools allows DEQ to detect water quality impairment cost-effectively and offer this information in an understandable format. The river ecological assessment framework integrates potentially three indexes in the ALUS determination: RMI, RFI, and RDI. The RPI may be used to provide additional information regarding physicochemical data. Each leg of this assessment reflects an important component of water quality integrity for rivers.

River Macroinvertebrate Index

The RMI is a multimetric index developed and tested by Royer et al. (2001) and further tested by Christopher Mebane of DEQ. The index uses five macroinvertebrate metrics: taxa richness, Ephemeroptera, Plecoptera, Trichoptera (EPT) richness, percent dominance, percent Elmidae (riffle beetles), and percent predators to assess water quality in rivers. Chapter 3 summarizes the methods and analysis ISU performed in the RMI development.

River Fish Index

The RFI is a quantitative multimetric index comprised of the following metrics: number of cold water native species, number of sculpin age classes or percent sculpin (data dependent), percent sensitive native individuals, percent cold water individuals, percent tolerant individuals, number of non-indigenous species, number of selected salmonid age classes, number of cold water individuals per minute of electrofishing, percent carp (if carp introduced), and anomalies. Chapter 4 describes the methods used to develop the RFI and the supporting tests.

River Diatom Index

Periphyton, specifically diatom, indexes have been developed and applied in Montana, Oklahoma, and Kentucky (Kentucky Department of Environmental Protection [KDEP] 1993, Bahls 1993, Oklahoma Conservation Commission [CC] 1993). Additionally, periphyton indexes have been effectively used in Europe for river biomonitoring since the 1970s, particularly in the United Kingdom and France. The RDI consists of seven attributes of relative abundance including percent: sensitive to disturbance, very tolerant of disturbance, nitrogen heterotrophs, polysaprobic, requiring high oxygen, very motile, and deformed valves. The index also includes two measures of taxon richness: eutrophic and alkaliphilic species. Chapter 5 describes the use of diatoms to assess the biological integrity of large Idaho rivers.

River Physicochemical Index

The RPI is based on the Oregon Water Quality Index (Cude 2001). Since the working definition of “water quality” has been expanded through the 1990s to include biological conditions, the term “physicochemical index” more accurately describes this index’s application in Idaho and is used in favor of the original term “water quality index.” This index has been tested and used extensively in Oregon to assess water quality conditions. The RPI consists of eight water quality parameters: temperature, dissolved oxygen, biochemical oxygen demand, pH; total solids, ammonia + nitrate nitrogen, total phosphorus, and fecal coliform. Chapter 6 describes the rationale for using physicochemical information and the additional analyses DEQ performed to determine if this index is applicable to Idaho rivers.

DATA INTEGRATION AND ASSEMBLAGES REPORTING

To be meaningful to managers and the public, biological data need to be translated into coherent information that conveys the assessment results. The question is how to interpret and report all the results from different assemblages, particularly if the results are varied or contradictory. DEQ integrates multiple data types using an average score approach. Results from the RMI, RFI, and RDI are classified using a 1, 2, 3 scoring system. The converted scores are then averaged to provide a single score. Chapter 7 describes the data integration approach and provides an example using actual data to more clearly explain the method.

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Chapter 2.
WATER BODY SIZE CRITERIA

Cynthia S. Grafe[4]

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 (Hughes et al. 1986; Royer and Minshall 1999). This chapter describes the reasoning to adopt certain criteria, the application of the criteria, and supporting analysis.

The river bioassessment process should be used with caution on water bodies considered Idaho "great" rivers. Simon and Lyons (1995) defined great rivers as having drainage areas greater than 2,300 mi^2. DEQ considered great rivers to be those too large to sample safely without specialized equipment and protocol for the greater depth, flow, and size. DEQ has identified the following water bodies as "great" rivers: Snake River below American Falls Dam; Clearwater River below Orofino; Coeur d'Alene River below Cataldo Mission; and Pend Oreille River below Lake Pend Oreille;. As seen in Appendix B, these water bodies generally meet the definition provided by Simon and Lyons (1995).

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

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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 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 Selection

Table 2-1 summarizes the DEQ's discussion of the strengths and weaknesses of using the different criteria. DEQ decided that site discharge (November-March) and average greatest depth at baseflow should not be used because of the weaknesses noted in Table 2-1. Further, DEQ was concerned about using mean annual site discharge and site drainage area since these criteria were not recommended or used by ISU. DEQ also believed that it would be difficult to obtain this criteria information, particularly mean annual site discharge data, for all the water bodies. Given changes in weather conditions and climate, the actual sampling-day value might be very different from the long-term daily flow.

DEQ selected the criteria recommended by ISU (i.e., stream order, average width at baseflow, and average depth at baseflow) to distinguish among different size water bodies when choosing appropriate monitoring and assessment protocols. This recommended criteria was, in some cases, used to develop the macroinvertebrate indexes (Royer and Minshall 1999). DEQ recommends using the same criteria to ensure consistency in the application of the macroinvertebrate assessment tools developed by ISU.

Table 2-1. Summary of water body size criteria strengths and weaknesses.

Criteria	Strengths	Weaknesses
Stream order	- constant - used by ISU	- difficult to determine for larger water bodies
Average width at baseflow	- recommended by ISU - considers baseflow conditions	- not representative of flow regulated river (e.g., Payette River)
Average depth at baseflow	- recommended by ISU - considers baseflow conditions	- difficult to obtain a *priori* without disturbing substrate where macroinvertebrates are collected - not representative of regulated river
Average greatest depth at baseflow	- determines if possible to use Hess sampler	- doesn't provide better information than average depth at baseflow
Site Discharge	- considers baseflow conditions	- not representative of regulated river
Mean annual site discharge	- reflective of general size - suggested by Hughes et al. (1986)	- difficult to obtain for all water bodies
Site drainage area	- constant - suggested by Hughes et al. (1986)	- difficult to obtain for all water bodies - need to factor in climate information to compare properly

DEQ considered several methods to integrate various size criteria depending on data availability. Initially, DEQ discussed using a flexible "weight of evidence" approach using a minimum of 3 of 5 criteria: stream order, average width at baseflow, average depth at baseflow, mean annual site discharge, and site drainage area. However, in comparing the "weight of evidence" approach to the ISU criteria, only four (6%) of the 70 DEQ sites had different water body size determinations. DEQ decided that the extra information gained was not worth the resources required to collect data for the additional criteria.

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 2-2.

Table 2-2. 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 2-3).

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 2-3. Water Body Size Average Score Rating Categories.

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

Tables 2-4 and 2-5 provide an example of the rating and scoring method. Table 2-3 shows the rating for each criterion and the water body size score using the data from Table 2-2. Appendix B provides data, criteria ratings, and scores for all the river sites.

Table 2-4. Example of data used to rate criteria.

River	Site I.D.	Stream Order	Ave. Width (m)	Ave. Depth (m)
SF Clearwater	1997RNCIROQ002	5	30.63	0.35

Table 2-5. Example of rating each criterion.

River	Site I.D.	Stream Order	Ave. Width (m)	Ave. Depth (m)	Criteria Ave. and Score
SF Clearwater	1997RNCIROQ002	3	3	1	2.3

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Chapter 3.
RIVER MACROINVERTEBRATE INDEX

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INTRODUCTION

This chapter is divided in two parts. The first part presents the rationale, development, and testing of the RMI. Part one also summarizes several years of research conducted by ISU to address the lack of bioassessment protocols for Idaho's large rivers. For clarity and conciseness, some of the details of development and testing have been omitted from this chapter but are available in various technical reports on file with DEQ. Part two presents an analysis examining the applicability of the RMI to medium-sized rivers. Although designed specifically for large rivers, the RMI appears also to function well as a bioassessment tool for medium-sized rivers.

PART ONE: DEVELOPMENT AND TESTING OF THE RMI

Introduction

This chapter presents the results of a study designed to develop a multimetric index (see Karr and Chu 1999, Barbour et al. 1995, Gerritsen 1995) for the bioassessment of large rivers in Idaho. The analytical development of the multimetric index followed the framework established by Barbour et al. (1996). This method involved sampling several reference (defined here as minimally impacted or least disturbed) and impaired sites, identifying macroinvertebrate metrics that differed between reference and impaired sites, and developing a scoring scheme with which to classify sites of unknown condition. Idaho contains numerous rivers that cross broad geographic and climatic regions. Many of the rivers flow through relatively undisturbed landscapes, such as designated wilderness areas or national forests, and thus provided an opportunity to acquire data from a variety of river types in a near natural condition. The goal of this research was to develop and test a relatively rapid protocol for assessing the overall ecological integrity of Idaho's large rivers, based on the structure of the macroinvertebrate assemblage at each site.

Rationale for a Large River Index

Large rivers are vital economic resources used for recreational and industrial purposes, as well as for sustaining populations of threatened and endangered species (Sparks 1995). Despite their importance, some form of anthropogenic regulation occurs on every major river system in the northern third of the world (Dynesius and Nilsson 1994). Benthic

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macroinvertebrates have been used to assess the biological integrity of stream ecosystems with relatively good success throughout the world (Rosenberg and Resh 1993, Resh et al. 1995, Barbour et al. 1996). The majority of these efforts have been conducted on wadeable streams (typically 4^{th} order or smaller, after Strahler 1957), while knowledge about the structure and function of large rivers remains limited. Clearly, there exists a strong need to expand and develop bioassessment protocols for use in monitoring larger rivers (Resh and Jackson 1993). Although sampling methodologies have been developed for such rivers (Cuffney et al. 1993), the additional logistic, economic, and statistical constraints of sampling rivers are a challenge to working in these systems.

The composition of macroinvertebrate communities changes with progression from headwaters to large rivers (e.g., Minshall et al. 1992, Vannote et al. 1980). Large rivers also are not linked as tightly to the immediate terrestrial environment as are small streams. Hence, the metrics used to describe the ecological condition of a biotic community in a small stream may not be relevant or indicate the same condition in a larger river. For example, in forested, headwater streams, an abundance of collector-filterers may be indicative of organic sediment inputs, whereas collector-filterers are expected to be more abundant in larger rivers (*sensu* Vannote et al. 1980). Although the same metrics are potentially useful in both systems, the interpretation of those metrics may differ, thereby necessitating the development of separate indexes for large rivers.

Justification for a Statewide Index

The rivers of Idaho appear to have initially (i.e., pre-European settlement) shared several physicochemical characteristics. For example, salmon once spawned in the large rivers of southern Idaho, including the Owyhee, Weiser, Boise, and Snake (as far upstream as Auger Falls near the city of Twin Falls) indicating that these rivers and their tributaries were clear, cobble/gravel-bottomed, and cold water rivers (see Evermann 1896). Indeed, Evermann (1896) stated, "The spawning grounds of chinook salmon in the Snake River between Huntington and Auger Falls have been . . . the most important in Idaho." The historical distribution of salmon spawning suggests that rivers within this geographic distribution (from the Owyhee River to the Clearwater River) must have been similar in numerous physical characteristics important to the successful spawning of salmon, such as temperature, current velocity, substrata composition, and sediment load, in addition to displaying a general erosional geomorphology. Although anecdotal, descriptions such as those of Evermann's certainly suggest that rivers in very different geologic and climatic settings within the state of Idaho were nevertheless similar in important abiotic and biotic conditions.

Furthermore, there is a lack of evidence to suggest that the rivers of northern, central, and southern Idaho historically were so disparate in physicochemical properties as to make comparisons between them ecologically inappropriate. It is true that some rivers in different parts of the state now display very different physicochemical characteristics, such as substrata composition and temperature regimes. However, these differences likely have arisen as a result of the types of impacts rapid bioassessment techniques are employed to detect. For example, the mud-bottom of the Middle Reach of the Snake River is not an inherent property of that river, rather it is a consequence of anthropogenic impacts to the river, albeit impacts that have been in place for many years. Based on available evidence, it appears that a statewide index is justified for the rapid bioassessment of Idaho's rivers.

Methods

Selection and Description of Sites

The first component of the study was to develop the index; for this 22 sites were selected from within Idaho representing nine different river systems: Bear, Snake, Owyhee, Boise, Payette, Salmon, Clearwater, St. Joe, and Coeur d'Alene (Figure 3-1). In terms of stream order, most sites were 6th order or greater although several were less than 6th order (after Strahler 1957). Stream orders provide a rough approximation of river size and can underestimate the size of a river because of factors such as large drainage areas, links, groundwater inputs and springs, and the map scale used to calculate the stream order. Large river sites were selected for the present study based on stream order, baseflow discharge (a minimum of approximately 3 m^3/s), and on-site examination by personnel from Idaho State University.

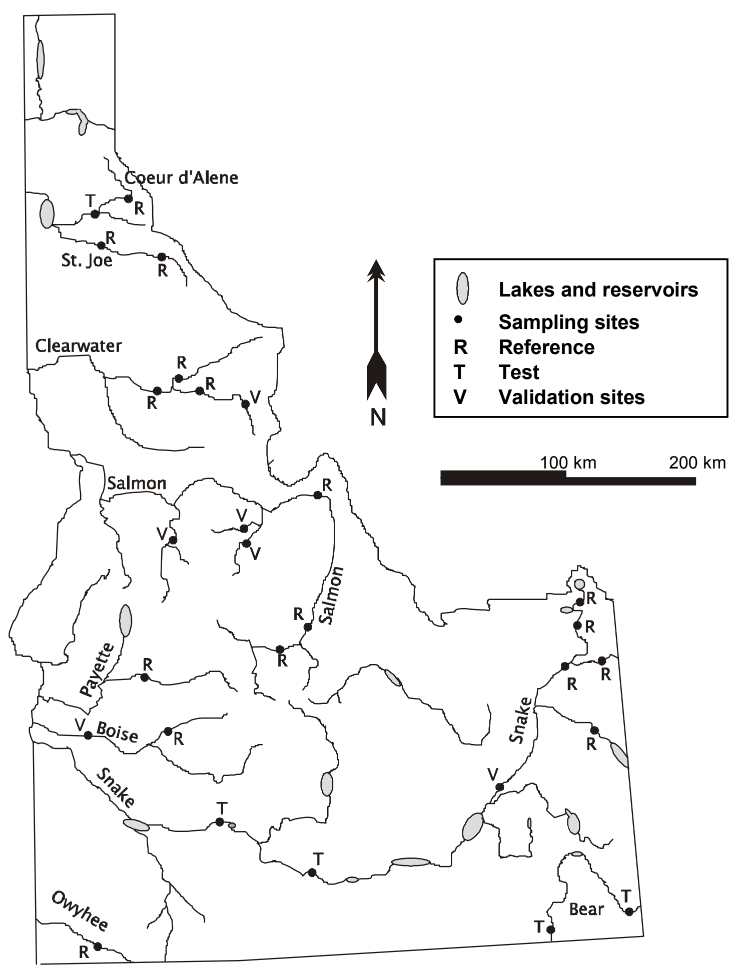

Figure 3-1. RMI Development and Testing Site Map

For development of the index, sites were selected to fit in one of two categories: reference or test (Figure 3-1). Reference sites (n=17) represented as unimpaired conditions as possible, whereas test sites (n=5) were known to be impaired as a result of anthropogenic stresses. On-site examinations, basic water chemistry, and historical and anecdotal evidence also were used to determine reference and test sites (see Royer and Minshall 1996, Schomberg et al. 1998). The large river sites used in the study ranged in mean width from 15 - 180 m and in mean depth (excluding pools) from 35 - 185 cm. Chemically, the sites ranged in total alkalinity from 5 - 158 mg $CaCO_3$/l and in specific conductance from 20 - 550 µS/cm. Although the variability in water chemistry was large, these values represent the natural range of conditions in the surface waters of Idaho.

The second component of the study involved validating the index. Six sites were selected for the validation study: three sites believed to be impaired and three reference sites located within federally-designated Wilderness areas (Figure 3-1). Selection criteria included the availability of long-term discharge records (see Schomberg et al. 1998), location within wilderness areas (for reference sites), and inclusion on the 303(d) list of impaired streams (for impaired sites).

When used with small streams, the reference-condition approach usually relies on a classification scheme, such as ecoregions (*sensu* Omernik 1987), to identify the group of reference sites to which a particular test site should be compared (e.g., Reynoldson et al. 1997, Barbour et al. 1996). The present analysis did not use an ecoregion stratification because, in part, that approach would have resulted in a very low number of sites within some ecoregions, due simply to the paucity of large rivers. Instead, the analysis operated on the assumption that the large rivers examined in the study were similar enough in basic physical characteristics as to warrant the inclusion of all sites in a single index (see above).

Sample Collection and Processing

Benthic macroinvertebrates were collected at three equidistant transects situated perpendicular to flow along a 500 m reach of river. At each transect, benthic samples were collected from the center of the channel and midway between the margin and center on both sides of the river unless water depth or velocity precluded safely sampling the center of the channel. If the center of the channel could not be sampled, the samples were collected as close to the center of the channel as possible. Samples were collected with a Slack sampler (Cuffney et al. 1993) which is essentially a modified Surber net; mesh size = 250 µm, sampling area = 0.25 m^2. A Petite Ponar-dredge (sampling area = 0.024 m^2) was used for sampling locations on the Middle Reach of the Snake River. At all sites, a total area of approximately 2.0 - 2.25 m^2 was sampled, encompassing a variety of locations within the riffle/run habitats. The samples from each site were composited to facilitate processing. Samples were preserved on-site with five percent formalin. All sites were sampled under baseflow conditions during late summer and early autumn (August - September) of 1994 or 1995.

In the laboratory, large and “rare” taxa were removed from each sample. Following removal of these organisms, each sample was divided into eighths and all macroinvertebrates removed from one or more subsamples until a minimum of 300 organisms was reached (called "two-phase processing", see Courtemanch 1996). Macroinvertebrates from both the initial sorting and the subsample were identified, enumerated, dried at 60 °C (except voucher specimens), and weighed for determination of total biomass. Taxonomic identifications were to the lowest feasible level, typically genus, although some groups were left at a coarser level of resolution (e.g., Chironomidae, Oligochaeta) and others were taken to species. A collection of voucher specimens was established and deposited at the Orma J. Smith Museum, Albertson College of Idaho, Caldwell.

Metric selection and index development

In general, we followed the procedure described by Barbour et al. (1996) for selecting metrics and developing the index, although the initial set of metrics examined were those thought to be applicable to large rivers based on existing knowledge of Idaho rivers and stream ecosystem theory (e.g., Vannote et al. 1980). The initial 24 metrics comprised diversity indexes, relative abundances of individual taxa, and trophic measures (Table 3-1). To be included in the final index, a given metric must have satisfied the following criteria: (1) show potential for change associated with habitat degradation, (2) provide unique information (i.e., not be linearly correlated with another metric or metrics), and (3) have measurably different values in known reference sites and known impaired sites. Data from reference sites were used in determining if a metric met the first criterion. The decision was based on examination of the 25th percentile, median, and 75th percentile values for each metric (Barbour et al. 1996).

Table 3-1. Definitions of the proposed metrics for Idaho rivers and the expected direction of change following anthropogenic disturbance.

Metric	Definition	Change
Number of taxa	Number of distinct taxa	Decrease
Number of EPT taxa	Number of distinct taxa in the orders Ephemeroptera, Plecoptera, and Trichoptera	Decrease
Number of Ephemeroptera taxa	Number of distinct taxa in the order	Decrease
Number of Plecoptera taxa	Number of distinct taxa in the order	Decrease
Number of Trichoptera taxa	Number of distinct taxa in the order	Decrease
Simpson's dominance index	An index measuring the dominance of the community by one or a few taxa	Increase
Percent dominant taxon	Relative abundance of the most common taxa	Increase
Hilsenhoff's Biotic Index	Calculated using tolerance values for Idaho invertebrates	Increase
Percent Elmidae	Relative abundance of the riffle beetles (Coleoptera : Elmidae)	Decrease
Percent Hydropsychidae	Relative abundance of the net-spinning caddisflies (Trichoptera : Hydropsychidae)	Increase
Percent Hirudinea	Relative abundance of leeches	Increase
Percent Gastropoda	Relative abundance of snails	Increase
Percent Pteronarcys	Relative abundance of the stonefly nymph Pteronarcys (Plecoptera : Pteronarcyidae)	Decrease
Percent Amphipoda	Relative abundance of amphipods	Increase
Percent Chironomidae	Relative abundance of midges (Diptera : Chironomidae)	Increase
Percent Oligochaeta	Relative abundance of aquatic worms	Increase
Percent predators	Relative abundance of this functional group	Variable

Metric	Definition	Change
Percent gatherers	Relative abundance of this functional group	Variable
Percent scrapers	Relative abundance of this functional group	Decrease
Percent shredders	Relative abundance of this functional group	Decrease
Percent filterers	Relative abundance of this functional group	Increase
Percent miners	Relative abundance of this functional group	Increase
Total biomass	Total abundance of invertebrates (mg/m^2)	Variable
Total density	Total abundance of invertebrates ($No./m^2$)	Variable

Metrics that satisfied the first criterion were analyzed next by Pearson correlation (metric values from reference sites) to determine compliance with the second criterion. A correlation coefficient of 0.90 or greater indicated redundant metrics; only one of the redundant metrics was retained for index development. The rationale for deciding which metric to retain among redundant metrics is described under Results. Box plots were used to determine which metrics of those that satisfied the first two criteria also met the third criterion and were included in the final index. The ability of a metric to distinguish between reference and test sites was assessed by the amount of overlap in the range of respective values (Barbour et al. 1996). Metrics that displayed no overlap of interquartile ranges were considered to have good discriminatory power.

The final index was developed by creating a scoring range, using values from references sites for each metric. A system of 1, 3, or 5 points was developed for each metric; a score of 1 indicated a poor condition and a score of 5 indicated a good condition. For example, a metric score of 5 was given if the respective value from a site was > 25th percentile of the reference values. A metric score of 3 was given if the value for a site was between the minimum value and the 25th percentile of the reference sites, and a metric score of 1 was given if the value was less than the minimum value observed for reference sites. The final index value for a site was calculated by summing the individual metric scores.

Validation of the index

The six validation sites were used to provide an independent assessment of the accuracy and robustness of the final index. The macroinvertebrate assemblage at each validation site was sampled using the methods described above. All sites were sampled under baseflow conditions in September 1997. For each site, the appropriate macroinvertebrate metrics were calculated (see below), the site was scored according to the final index, and the correspondence examined between the believed (*a priori*) and index-predicted condition of the site. As with the other sites, a voucher collection of macroinvertebrate specimens was established and deposited as described above.

Results

Development of the Index

Nine of the initial 24 metrics thought to be applicable to large rivers in Idaho did not satisfy the first criterion: the metrics were either too variable or too low to be reliable indicators of habitat degradation (Table 3-2). The rejected metrics included: percent Hirudinea, percent

Gastropoda, percent Amphipoda, percent Oligochaeta, percent Pteronarcys, percent gatherers, percent shredders, biomass, and density. Of the remaining 14 metrics, strong correlations (r>0.90) were observed between Simpson's dominance index, percent dominant taxon, % Chironomidae, and % miners. These four metrics were inter-correlated in a linear fashion suggesting that each provided the same biotic information in terms of ecological integrity. The percent dominant taxon was considered the most robust of these four metrics and was retained for index development.

Table 3-2. Summary statistics of the initial 24 candidate metrics for large rivers in Idaho. Metrics in bold and * were considered further, the others were rejected for the reasons given.

Metric	25th percentile	Median	75th percentile	Reason for rejection
Number of taxa*	23	25	29	
Number of EPT[a] taxa*	17	22	26	
Number of Ephemeroptera taxa*	8	9	12	
Number of Plecoptera taxa*	3	4	5	
Number of Trichoptera taxa*	5	6	7	
Simpson's dominance*	0.120	0.142	0.224	
Percent dominant taxon*	21.6	28.9	37	
HBI*	3.8	4.0	4.6	
Percent Elmidae*	1.7	3.0	6.3	
Percent Hydropsychidae*	1.5	6.5	15.0	
Percent Chironomidae*	19.0	28.9	37.0	
Percent Predators*	3.8	9.8	15.0	
Percent Scrapers*	13.0	19.8	23.8	
Percent Filterers*	11.0	15.4	25.5	
Percent Miners*	25.0	34.7	38.2	
Percent Hirudinea	0.0	0.0	0.0	Values low
Percent Gastropoda	0.0	0.0	1.3	Values low
Percent Pteronarcys	0.0	0.0	0.2	Values low
Percent Amphipoda	0.0	0.0	0.0	Values low
Percent Oligochaeta	0.8	4.0	5.1	Values low
Percent Gatherers	6.2	14.6	22.8	Variable
Percent Shredders	0.0	0.3	1.3	Values low
Total biomass	4,214	5,658	12,584	Variable
Total density	9,201	24,739	39,338	Variable

[a] EPT: Ephemeroptera, Plecoptera, Trichoptera
[b] HBI: Hilsenhoff Biotic Index

Twelve of the initial 24 metrics satisfied the first and second criteria. Evaluation of the box plots revealed that taxa richness, EPT taxa richness, Ephemeroptera taxa richness, Plecoptera taxa richness, Trichoptera taxa richness, and percent Elmidae displayed different values between reference and test sites (Figure 3-2). Only one metric, percent dominant taxon, displayed some overlap of interquartile ranges, but with median values outside the interquartile range. This metric was considered to have moderate discriminatory power between reference and test sites. The percent predators metric had weak discriminatory power with moderate overlap between interquartile ranges and a median value from the test sites that was within the interquartile range of the reference sites. The remaining metrics (Hilsenhoff's Biotic Index, percent Hydropsychidae, percent scrapers, and percent filterers) displayed considerable overlap in interquartile ranges indicating little or no ability to distinguish between reference and test sites and thus were not included. Finally, EPT taxa richness was included in the final index, but the individual orders were not. The presence of EPT taxa was assessed in two metrics: total taxa richness and EPT taxa richness. Although they distinguished reference from test sites, including the individual E, P, and T richness metrics would have placed too great an emphasis on these taxa in the final index (see Discussion). Therefore, the final metrics were number of taxa, number of EPT taxa, percent Elmidae, percent dominant taxon, and percent predators.

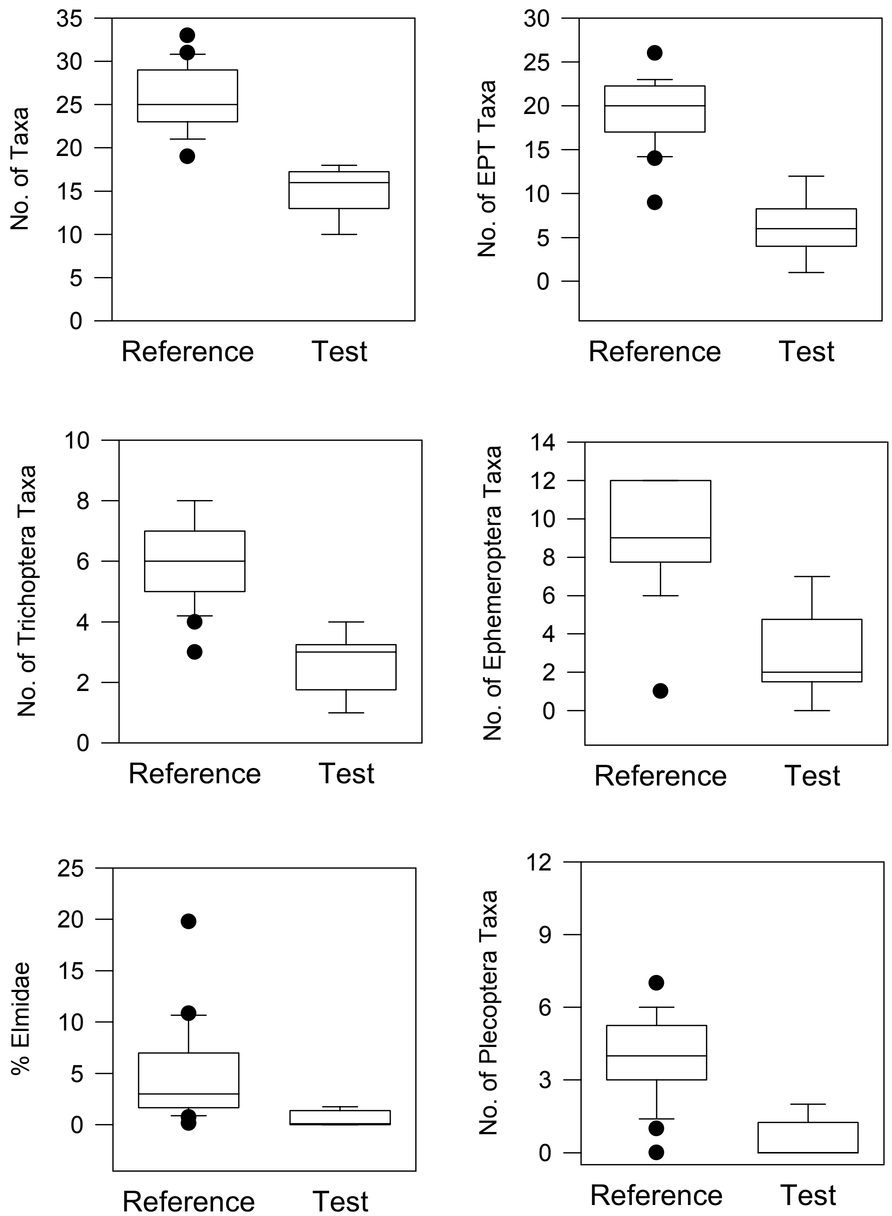

Figure 3-2. Box plots
Box plots comparing the various macroinvertebrate metrics between Reference and Test sites on large rivers. The center horizontal bar is the median value, the upper horizontal bar is the 75th percentile, the lower horizontal bar is the 25th percentile, and the “error bars” are the 10th and 90th percentiles. Solid circles are values (sites) outside the 10th or 90th percentiles.

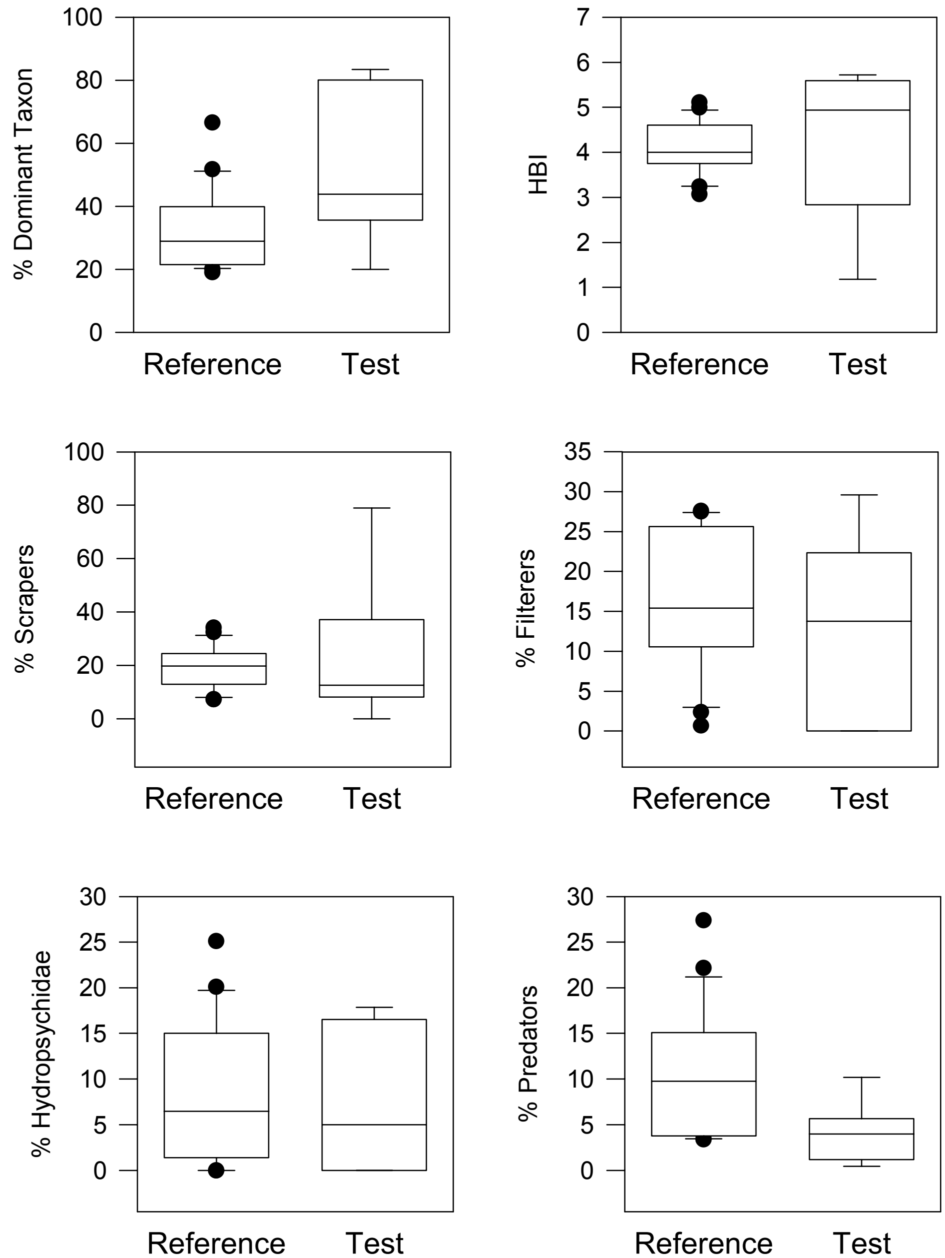

Figure 3-2. Box plots, *continued*

Using the final five metrics, a scoring range for the index was designed whereby each metric contributed equally to the overall score except percent predators. Because of its weaker discriminatory power, this metric was "down-scaled" to reduce its influence on the final index by allowing only two possible scores (1 or 3) for a site (Barbour et al. 1996). The final index is presented in Table 3-3 with the descriptive statistics from the twenty-two reference sites and the corresponding scoring ranges. To maintain consistency in the terminology used by resource managers in Idaho, the final index is referred to as the River Macroinvertebrates Index (RMI). Royer et al. (2001) originally referred to the index as the Idaho River Index

(IRI). The maximum score a site could achieve was 23. An RMI score was calculated for each of the 22 sites and plotted as for the individual metrics (Figure 3-3). Based on the interquartile ranges, an RMI score >16 indicated a site in good condition, relative to the reference sites used in the development of the index. Scores of 14-15 suggested intermediate conditions and a score <14 indicated poor biotic conditions.

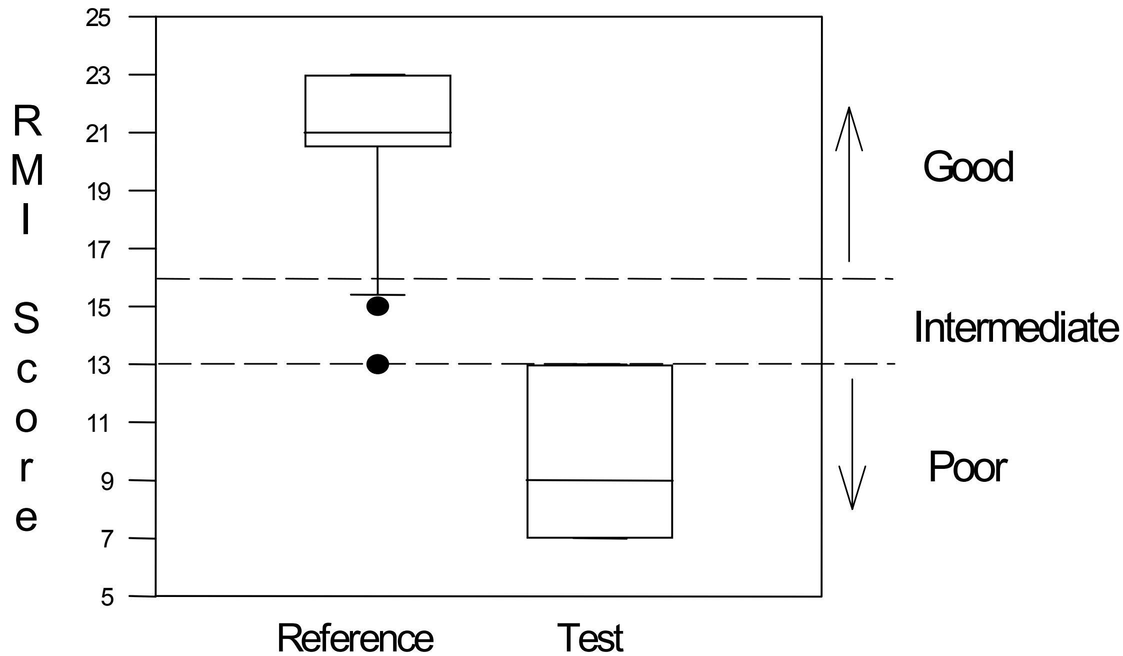

Figure 3-3. Box plot comparing RMI scores between the Reference and Test sites. See Figure 3-2 for description of box plots.

Table 3-3. Descriptive statistics and the scoring range for the metrics included in the RMI.

	Statistics					Scoring		
Metric	**Min.**	**25th percentile**	**Median**	**75th percentile**	**Max.**	**5**	**3**	**1**
Number of taxa	19	23	25	29	33	> 23	19 - 22	< 19
Number of EPT taxa	9	17	20	22	26	> 17	9 - 16	< 9
Percent Elmidae	0.2	1.7	3.0	6.3	19.8	> 1.7	0.2 - 1.6	< 0.2
Percent dominant taxon	19.0	21.6	28.9	37.0	59.0	< 37	38 - 59	> 59
Percent predators[a]	3.4	3.8	9.8	15.0	27.4		> 3.4	< 3.4

[a] The weak discriminatory power of this metric allowed for only two scores.

Validation of the index

Results from the validation sampling are summarized in Table 3-4. The sites from within the wilderness areas scored 21 - 23 (91 - 100 percent of the maximum possible) indicating that these sites were in good condition and in agreement with the *a priori* classification. The sites believed to be impaired; however, scored better than expected. The three sites scored 15, 15, and 23 (65, 65, and 100 percent of the maximum possible, respectively), which indicates that two of the sites were intermediate in condition and the final site actually was in good condition.

Table 3-4. Summary of results from validation sampling in 1997.

	Selway	Big Creek	MF Salmon	Snake	Boise	SF Salmon
Metrics						
Number of taxa	36	33	44	22	19	33
Number of EPT taxa	22	22	29	12	12	19
Percent Elmidae	5.6	2.2	4.9	0.4	0.0	20.4
Percent dominant taxon	23.2	40.9	22.2	65.9	30.5	16.4
Percent predators	13.1	9.7	16.6	6.3	16.4	23.3
Metric Score						
Number of taxa	5	5	5	3	3	5
Number of EPT taxa	5	5	5	3	3	5
Percent Elmidae	5	5	5	3	1	5
Percent dominant taxon	5	3	5	3	5	5
Percent predators	3	3	3	3	3	3
RMI score	23	21	23	15	15	23
Percent of Maximum	100	91	100	65	65	100
a priori classification	ref.	ref.	ref	impaired	impaired	impaired
RMI classification	good	good	good	intermed.	intermed	good

Discussion

The RMI as a Rapid Bioassessment Tool

One area in which work on large rivers has progressed less rapidly than on smaller streams is bioassessment techniques, including data analysis (Resh and Jackson 1993). In the present study, we have attempted to adapt a bioassessment framework developed for small streams (Barbour et al. 1996) for use in large rivers in Idaho. Although sampling macroinvertebrate assemblages in large rivers can be a major undertaking, quantitative methods exist (e.g., Cuffney et al. 1993). We applied the analytical technique developed for small streams in Florida (Barbour et al. 1996) to large rivers in Idaho. The method successfully identified biotic metrics that could discriminate reference sites from impaired sites, suggesting that techniques used for wadeable streams can be adapted for assessing large rivers. Although continually under refinement, bioassessment techniques for streams are well-developed and readily available in the literature. Adapting these methods for use in large rivers is primarily a matter of (1) selecting metrics relevant to the rivers of interest; (2) expanding the field sampling to encompass the greater habitat area, and potentially heterogeneity, of large rivers;

and (3) selecting the most appropriate form of analysis (see Fore et al. 1996, Norris 1995 for various types of analyses).

The final index included metrics based on some form of richness (see Table 3-3). Measurements of richness are sensitive to sampling effort and subsampling procedures (e.g., Larsen and Herlihy 1998, Barbour and Gerritsen 1996, Courtemanch 1996). We addressed these concerns by sampling a total of at least 2 m^2 of benthic habitat composited from a variety of riffle/run locations in each river and then processing the samples in a manner designed to minimize loss of rare taxa (see Methods). The inclusion of total taxa richness and EPT richness results in a degree of redundancy in the metrics included in the index. The percent dominant taxon also provides a measure of community diversity, but as a percent relative to the community as a whole. This redundancy in the index likely reflects the redundancy of natural benthic communities and should not necessarily be avoided (Karr 1993).

The two other metrics in the index are percent predators and percent Elmidae. The percent predators was the only functional feeding group included in the index and low values of this metric likely reflect a reduced abundance and/or diversity in types of invertebrate prey. The family Elmidae, or riffle beetles, are relatively unique among freshwater insects in that the adults are truly aquatic and long-lived, possibly living up to two years or more (Brown 1987). Elmidae occupy well-oxygenated riffle/run type habitats in swift-flowing streams and rivers. Impairment of these habitats likely will result in lowered abundance of these organisms (Brown 1981). Inclusion of the metric, percent Elmidae, indicates that the RMI should be sensitive to degradation of riffle habitats in large rivers.

The initial assessment of the RMI indicated a strong separation between reference and impaired sites (see Figure 3-3). The impaired sites sampled as part of the validation work; however, did not score as poorly as might be expected from an impaired site. There are three possible explanations for this discrepancy. First, the RMI might not be an accurate indicator of impaired conditions. This explanation is unlikely because the RMI was developed using some of the most degraded large-river sites in Idaho (see Royer and Minshall. 1996). It is expected that, with correct field-sampling, sites scored by the RMI as poor are, in fact, impaired in terms of ecological integrity. Second, sampling biases or errors might have created the high scores. This explanation fails because sampling errors result in lower scores, particularly for measures of diversity (Courtemanch 1996); it is unlikely that artificially high scores arose from sampling errors.

The third and most likely explanation is that the impaired sites chosen for validation were not in as degraded a condition as initially believed. For example, the South Fork of the Salmon River has received substantial inputs of inorganic sediment resulting in the loss of spawning habitat for anadromous salmonids (e.g., Megahan et al. 1992), but was scored by the RMI as in good condition (see Table 3-4). It is possible that the sediment inputs, although severely disrupting habitat for fish spawning, did not affect aquatic macroinvertebrates to the same degree. It also is possible that macroinvertebrates simply have recovered from the sediment inputs (inputs peaked in the 1960s), while fish habitat has remained impaired. These results suggest that a bioassessment protocol based on macroinvertebrates may not be sensitive to important habitat requirements of fish; whether the South Fork of the Salmon River is typical or unique in this regard is unknown.

The two other "degraded" sites used in the validation work were classified by the RMI as intermediate in condition (see Table 3-4). A score of intermediate indicates that additional information is required before the site can be accurately assessed. This appears to be the case for these particular locations on the Snake and Boise rivers. It is important to note that the RMI is a "rapid assessment" procedure for rivers. The RMI, as with any rapid bioassessment protocol, is not designed to provide a final and definitive answer to questions regarding the ecological integrity of a given site (Resh et al. 1995). Rather, rapid assessment protocols provide a means to separate those sites in good condition from those in poor or intermediate condition, thereby allowing resource managers to focus attention on sites requiring restoration or other management intervention. Towards this end, the RMI performed well as a rapid assessment protocol for large rivers in Idaho.

Reference Sites for Large Rivers

During the course of the research described here, several questions became evident regarding various topics within the field of aquatic bioassessment. Primary among these were questions regarding the selection of appropriate reference sites when examining large geographic regions (e.g., states). This question is particularly pertinent in the assessment of large rivers because (1) large rivers are limited in number, making statistical replication difficult or impossible; (2) large rivers often have been the foci for cultural and economic development, particularly in arid regions, resulting in few, if any, truly undisturbed large rivers; and (3) once impaired, the restoration of large rivers tends to be more difficult and expensive than for smaller streams, often making decisions about large rivers more politically controversial than similar decisions about small streams. For these reasons, among others, the selection of reference sites for large rivers is critical in the process of bioassessment.

Although the selection of reference sites is an important step in bioassessment, it also is highly constrained by at least two factors. First, large rivers are unique in that they transcend and integrate multiple terrestrial and aquatic ecosystems (e.g., Vannote et al. 1980). Although it is suggested that large rivers display some consistent, inherent properties, they also are influenced by local geomorphic and anthropomorphic effects and by large-scale patterns in land use (e.g., Schomberg et al. 1998). Second, large rivers are rare, relative to low order streams. The population of rivers from which to select reference sites is small, particularly in arid regions such as southern Idaho. The relative scarcity of large rivers, combined with the fact that few large rivers have remained undisturbed by humans, makes the selection of reference sites a difficult process.

As mentioned above, there are several problems associated with the selection of reference sites when examining large rivers. However, the reference-condition approach (Reynoldson et al. 1997) worked well for development of the RMI. The index presented here was successful at discriminating reference sites from sites known or believed to be impaired — the primary goal of rapid bioassessment. Bioassessment techniques are continually being refined and updated, and it should be expected that as resource managers collect additional data from larger river sites throughout Idaho, revision of the RMI from its current form may improve the accuracy of the index.

PART TWO: APPLICATION OF THE RMI TO MEDIUM-SIZED RIVERS

Introduction

The progression of a lotic ecosystem from headwater stream to large river occurs along a continuum rather than in discrete steps (Vannote et al. 1980). One result of this phenomenon is that size classifications, such as large, medium, or wadeable, invariably overlap to some degree. Furthermore, some sites can be legitimately classified in more than one size category. River sites that can be classified in more than one size category also potentially can be analyzed using more than one bioassessment index. Such is the case for medium-sized rivers in Idaho. Often, these medium-sized rivers can be sampled using techniques designed for wadeable streams, although the sites clearly resemble larger rivers. The goal of the analysis presented below is to examine the applicability of the RMI for bioassessment of medium-sized rivers.

Methods

From 1993 - 1997, DEQ personnel sampled macroinvertebrate assemblages at numerous sites throughout Idaho. Although sampled using techniques designed for wadeable streams, many of the sites could be considered medium-sized rivers. These water bodies still rated as “rivers” according to DEQ water body size criteria (see Chapter 2). To examine the applicability of the RMI, sites were classified as reference or test. The classification was performed by regional DEQ biologists familiar with the sites, using classification criteria based on the land use around and upstream of the sites and the ecological condition of the sites relative to other streams in the area (Table 3-5). The reference sites represented streams in least-disturbed conditions. Test sites were streams known to be impaired by one or more anthropogenic impacts. Sites that could not be readily classified as reference or test were not used in this analysis. The final data set included 58 reference sites and 68 test sites for which the Macroinvertebrate Biotic Index (MBI) and RMI scores were calculated. Figure 3-4 shows the distribution of the large- and medium-sized river sites sampled by ISU, large river sites sampled by DEQ, and sites that could be considered medium-sized rivers.

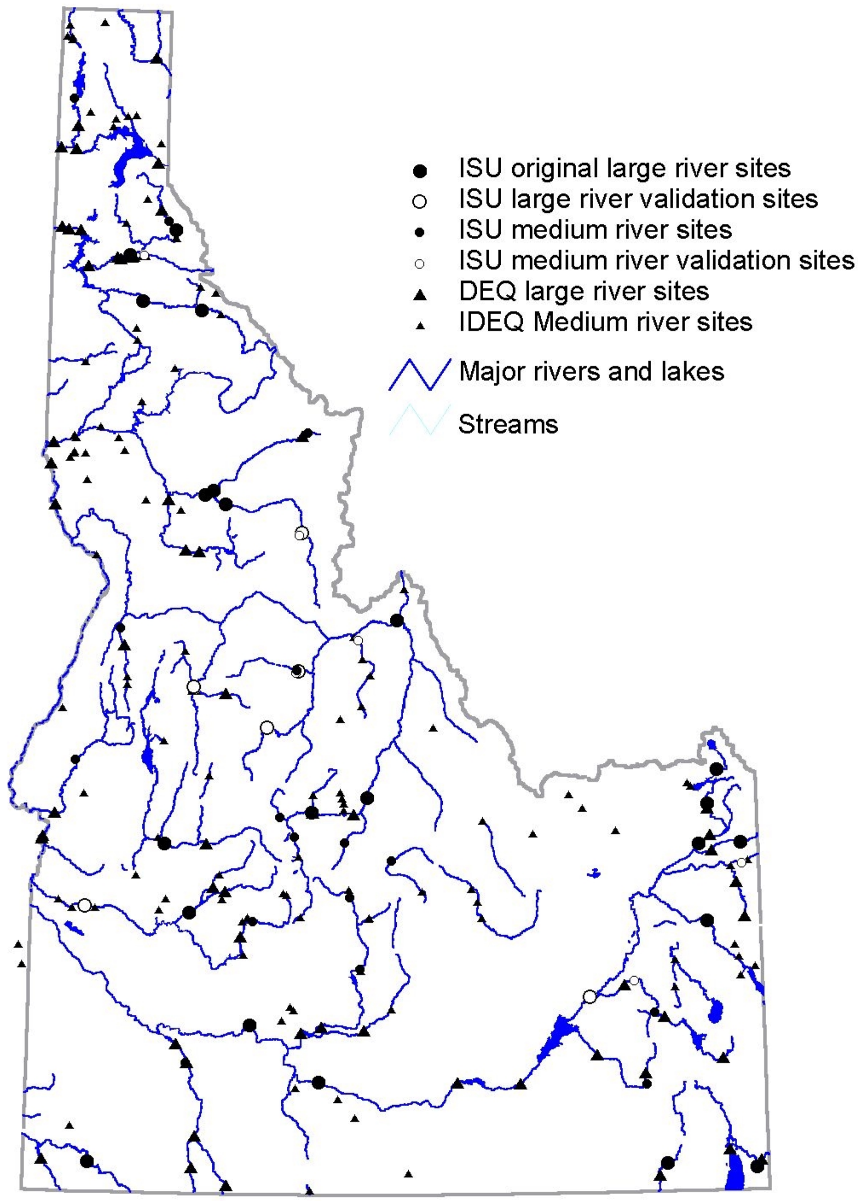

Figure 3-4. Map of the sites used to examine applicability of the RMI for bioassessment of medium-sized rivers.

Table 3-5. Factors considered in classifying medium-sized rivers as reference or test sites. (Mebane 1998, modified from Hughes [1995])

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.

Both mean values and interquartile ranges were calculated for the reference and test sites. Differences in mean values were examined using a Mann-Whitney U test (the non-parametric equivalent of a t-test). The interquartile ranges were examined using box-and-whisker plots in the manner outlined by Barbour et al. (1996).

Results and Discussion

The Mann-Whitney U tests indicated that the RMI was able to distinguish between the reference and test sites on medium-sized rivers ($p<0.005$). The mean RMI score for reference sites was 21.3 (+/- 2.4), whereas the mean for test sites was 15.8 (+/- 5.5). However, the box-and-whisker plots revealed a considerable amount of overlap between scores from the test sites and the "Good" classification (Figure 3-4). Indeed, the median value of the test sites was within the scoring range of streams considered to be in good ecological condition. This means that about 50 percent of the test sites could be considered free of water quality impairment, based on macroinvertebrate assemblages. The test sites likely included streams in a very degraded condition as well as streams suffering less intense impairment. This is reflected in the large range of scores seen among the test sites.

Among the reference sites, however, the range of scores was much narrower (Figure 3-4). This suggests that the RMI is measuring characteristics of the sites that are shared among geographically distant rivers (i.e., throughout Idaho). Medium-sized rivers ideally would be assessed using an index specific for that size class of rivers, but this may not be possible because lotic systems change gradually along a continuum rather than in discrete steps. Currently, the RMI appears to perform well for the rapid bioassessment of both large and medium-sized rivers in Idaho.

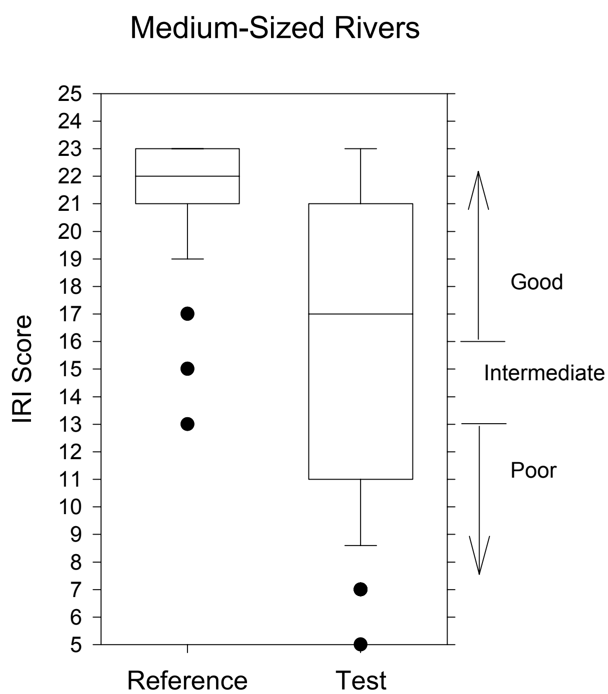

Figure 3-5. RMI scores calculated for reference and test sites on medium-sized rivers. Sample sizes are 58 for Reference Sites and 68 for Test Sites. The center horizontal bar is the median value, the upper horizontal bar is the 75th percentile the lower horizontal bar is the 25th percentile, and the "error bars" are the 10th and 90th percentiles. Solid circles are values (sites) outside the 10th or 90th percentiles.

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Chapter 4.
RIVER FISH INDEX

Christopher A. Mebane[7]

INTRODUCTION

The approach of measuring the biological integrity of rivers and streams using a quantitative index of biological integrity (IBI) based on fish assemblages was first described by Karr (1981). Since then the IBI approach has been widely applied by water resource managers and researchers to warm water streams and rivers in North America and elsewhere in the world. However, the application of the IBI to the cold water streams and rivers of the western U.S. has been limited (Simon 1999a). The purpose of this paper is to describe the development and testing of an IBI applicable to the large river basins of Idaho. We have called this specific IBI the River Fish Index, or RFI.

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, Karr 1991). In the development of quantitative indices, those components of biological integrity are measured and are intended to relate fish assemblages to other biotic and abiotic components of the ecosystem (Karr et al. 1986; Simon 1999a). Karr et al. (1986) developed the IBI for warm water (waters too warm to support salmonids) midwestern streams. Their original IBI consisted of 12 biometric values (metrics) that reflected fundamental ecological components of stream fish assemblages: taxonomic richness, habitat and trophic guild composition, and individual health and composition. Following this lead, fish IBIs have been developed and published for many regions of temperate North America (for example, Oregon, the Appalachians, the western Great Plains, and the Great Lakes region of the U.S. and Canada (Hughes et al. 1998, Miller et al. 1988, Angermeir et al. 2000, Bramblett and Fausch 1991, Steedman 1988, Minns et al. 1994, Lyons et al. 1996, Mundahl and Simon 1999) and elsewhere in the world (Harris and Silveira 1999, papers in Simon 1999a). As a result of all the iterations, the term "IBI" should be thought of as a family of related indices, rather than as a single index (Simon and Lyons 1995). Because of the substantial differences in fish faunas in areas outside the midwestern United States where the original IBI was developed, other investigators have substituted regional metrics for the original 12 metrics. Most have maintained the ecological structure of the original IBI. Until recently, the substituted metrics used in regional modifications of the IBI typically have been selected on the basis of expert judgment without showing empirical relations (Angermeier et al. 2000). Angermeier et al. (2000) also advised against building IBIs with only those metrics that exhibit strong empirical relations, because such indices may lack the ecological foundation needed to detect a broad range of human impacts. Our view is that both an ecological foundation and showing empirical relationships are needed in IBIs.

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Three significant factors complicate IBI development in cold water rivers. First, the cold water rivers 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 fish assemblages in the West. In contrast, the vast Mississippi River drainage served as a refuge for fish, which enablied them to avoid extinctions and possibly increased speciation. Least-disturbed western streams and rivers have a nearly universal cold water-adapted fish assemblage: salmonid (*Oncorhynchus/Salvelinus* sp.), sculpin (*Cottus* sp.), sucker (*Catostomus* sp.) and dace (*Rhinichthys* sp.). In contrast, streams in the Mississippi River 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 the numbers of native cold water fishes decline, making their habitats vulnerable to invasion by facultative cool water native species or nonindigenous 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 western cold water 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. State water quality standards and the national CWA explicitly call for protection of fish and fisheries. Direct assessment of the fish assemblage is more relevant to its management than are inferential approaches based on other assemblages or chemical and physical criteria alone. For these reasons, and despite the faunal limitations, an objective was to develop and test an IBI that would be generally applicable to the interior Columbia River Basin and its environs (parts of Idaho, Montana, Oregon, Washington, and Wyoming). The analysis was initiated and focused on Idaho rivers, but because data points in Idaho were insufficient, and because hydrology and biogeography do not heed political boundaries, the analysis was expanded to the U.S. portion of the interior Columbia River Basin and western Oregon. Metric selection and index construction in IBIs has often relied on expert application of stream ecology theory rather than testing empirical relationships. Here, we report on developing an index by empirically testing individual metrics and the overall index using different lines of evidence, rather than relying on ecological assumptions.

Desirably, an IBI should cover at least three major biological conditions (Figure 4-1). (1) nearly pristine waters where the natural assemblage structure and function are intact; (2) waters that support cold water adapted species even though biological integrity may have been impaired as a result of the displacement of indigenous salmonids by introduced salmonids. These introduced salmonids may fill a similar ecological niche and have habitat structure and water quality requirements similar to those of the native salmonids; and (3) waters with species composition, diversity, and functional organization dissimilar from natural habitats of the region. In this context, "habitat" includes chemical conditions, temperature, sediment and flow regime, and aquatic habitat structure. The overlapping categories in Figure 4-1 are intended to acknowledge that changes in biological condition occur along gradients, and that assessment tools have limited precision to delineate these groups.

A note on our usage of thermal terms: "cold water" rivers are those rivers where at least some of the fishes resident during the summer months would be classified as members of the temperate cold water thermal guild (Magnuson et al. 1979). These "cold water" rivers would often have a mixed assemblage of cold and cool water thermal guild members (e.g. Li et al. 1987). The classifications cold water, cool water, and warm water are equivalent to Hokanson's (1977) temperate stenotherms, mesotherms, and eurytherms.

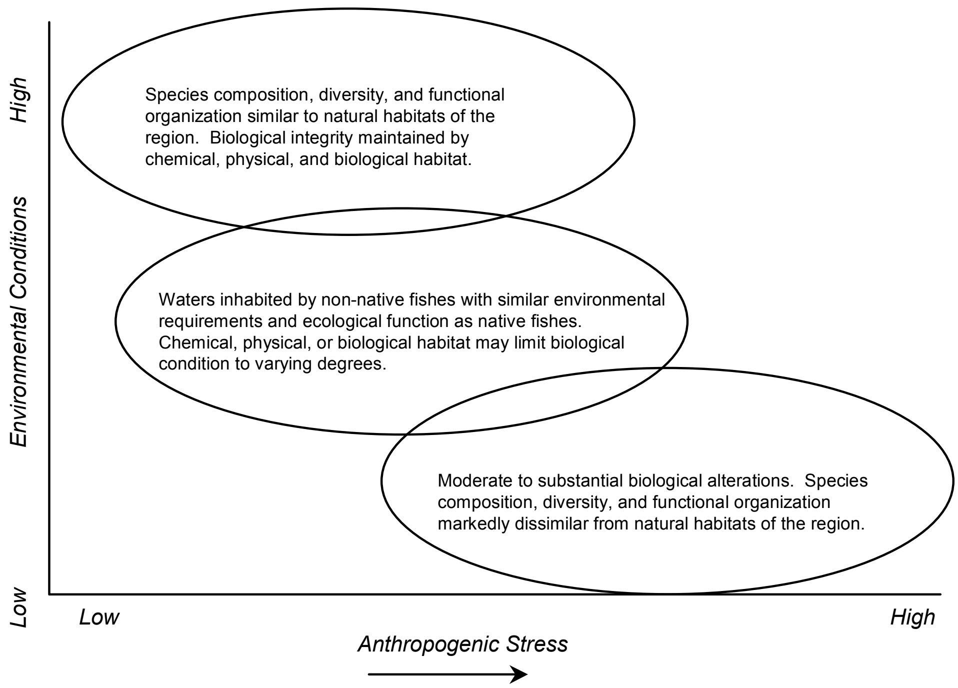


Figure 4-1. Conceptual relationship between river environmental conditions and biological integrity.

METHODS

A four-step process was used to construct the RFI: (1) Fish data sets were located for rivers, and potential metrics were derived from the IBI literature and other recommendations. Although in nature, there are no clear lines delineating when a “stream” becomes a “river,” for this paper Strahler 4th order and greater streams, determined at a scale of 1:100,000, were considered “rivers.” Wetted widths of greater than or equal to 4th order waters in the study area ranged from about 15 to 100m. (2) Reference conditions were estimated by considering historical reports and existing conditions at locations that were least influenced by human activities in the region.; (3) Candidate metrics with values that reflect the range of expected conditions, that distinguished between least-disturbed reference or disturbed test sites, and that were not functionally redundant, were scaled and added together to form a multimetric index. The metrics were standardized by scoring them continuously from 0 to 1 and then weighted to produce an IBI with scores ranging from a possible 0 to 100. (4) After an index was built, the index results were compared with site variables and land uses that have been correlated with anthropogenic disturbances. The index scores for separate data sets from different interior Columbia River Basins were then calculated to see whether the results matched our expectations. (5) Two reference rivers were sampled longitudinally to determine whether the RFI was sensitive to natural changes in the fish assemblages over a river continuum or whether it was reasonably stable across sizable distances on least disturbed reference rivers (up to 600 km). Because of the diversity of these steps, some methodological details are described with the respective results for easier association of the data with the procedures.

Data Sources

The primary data set used to develop the index was from the USGS-NAWQA - Upper Snake River Basin study unit (Maret 1997) and the cooperative USGS/DEQ statewide water quality trends monitoring program (O’Dell et al. 1998). These data sets have a number of desirable features for developing an index. The sampling and analysis procedures were rigorous and consistent, and the methods and data have been detailed (http://wwwidaho.wr.usgs.gov/nawqa/usnk_home.html). Additional Snake River Basin data from the IDFG, DEQ, ISU, and hydropower studies also were compiled and reviewed. Data that were comparable with the primary data set were used in the index development (i.e. included counts of the entire assemblage (rather than just game species), fish were identified to species, and a thorough sampling effort). The data sets encompassed a wide range of conditions: nearly pristine rivers in Yellowstone and Grand Teton National Parks; rivers representing least-disturbed reference conditions occurring outside of wilderness or park areas; rivers with some alteration of the watershed by agriculture; and the middle Snake River, which has had significant anthropogenic changes including extensive aquaculture, and irrigation diversions and return flows.

Principal out-of-sample data sources used to validate the index included the USGS Northern Rockies Intermontane Basins NAWQA project (http://montana.usgs.gov), the EPA

Environmental Monitoring and Assessment Project (EMAP) (Averill and Peck 1999), and data from the studies of Cuffney et al. (1997), Mullins (1997), and Munn and Gruber (1997).

Six sites were specifically sampled as part of this study to provide information on longitudinal profiles of reference rivers. Fish sampling procedures were consistent with Maret (1997) and followed methods described by Meador et al. (1993). Locations of samples used to develop and to validate the index are shown in Figure 4-2.

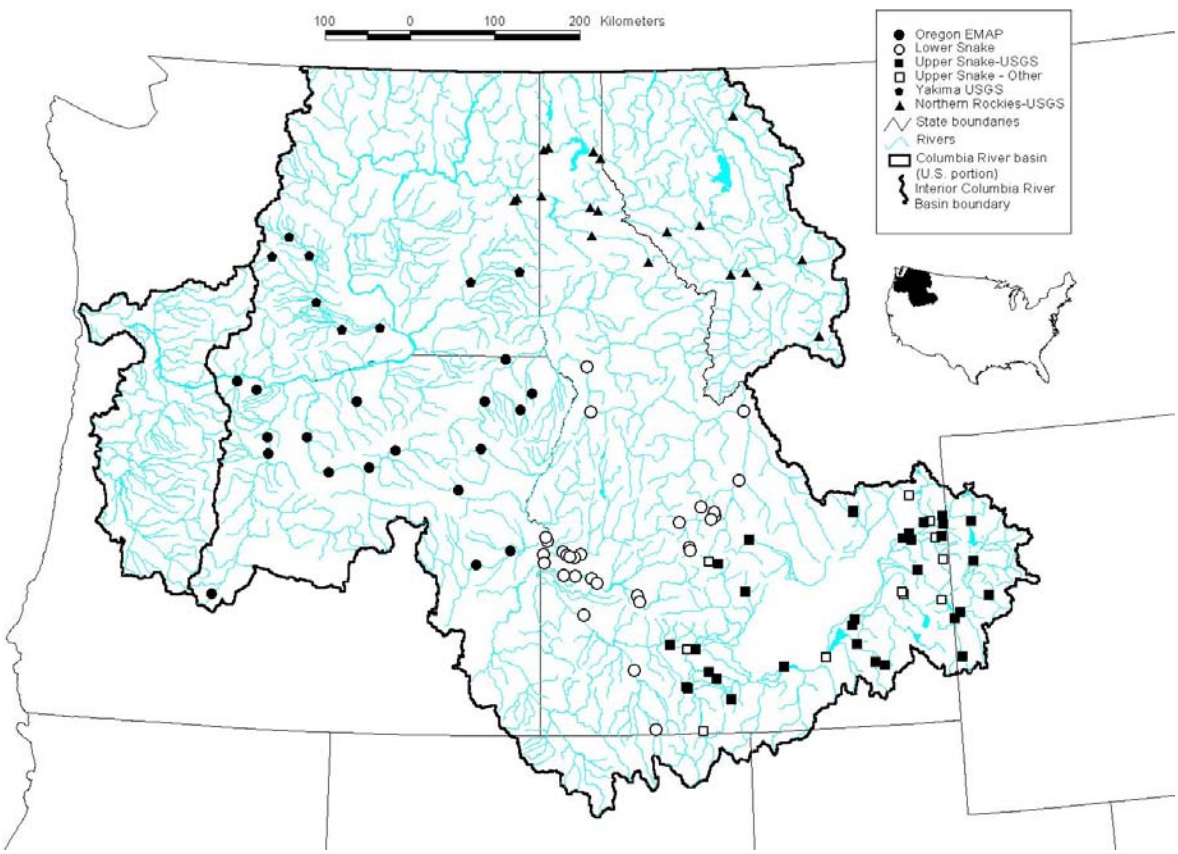


Figure 4-2. Locations of the sites used to develop and test the river fish index.

The Reference Condition

So that biometrics can be scaled appropriately, some estimate of the natural, or best-attainable condition (reference condition), needs to be made. This estimate can be made by describing least-disturbed existing river conditions or by describing historical natural conditions (Hughes 1995). In the mountainous West, many nearly pristine streams remain and the natural reference condition can be confidently described. The reference condition for rivers cannot be as readily described. Drainage basin size increases geometrically as stream size increases, and these large areas will never be completely free from anthropogenic disturbance. Rivers have been the foundation for the settlement and economic development throughout North America, especially in the arid West for transportation, irrigation storage and supply, and hydroelectric power. Thus, no large river remains in a truly natural condition to serve as a definitive standard against which to evaluate degrees of disturbance to other systems. Instead, describing the reference condition of rivers is necessarily an exercise that requires a measure of judgment. Describing reference conditions does not imply that these conditions are attainable in all cases. Instead, management goals need to be determined according to realistically attainable conditions and with the recognition that in some cases, pre-settlement conditions have been irreversibly altered.

The historical, natural condition of rivers in the interior Columbia River Basin was probably largely one of swiftly flowing rivers that supported cold and cool water fish species. Rivers located in montane areas where most of the drainage is in a nearly natural condition would be expected to support a fish assemblage that is similar to the historical reference condition. This assumption is supported by the conditions of many such rivers in wilderness areas that remain minimally disturbed. Further downstream, rivers would likely have had a mixed cold water and cool water-tolerant assemblage. This latter assumption is supported by observations from the late 1800s of abundant steelhead trout and Chinook salmon in the middle Snake River and its tributaries including the Owyhee River into northern Nevada and in the Boise River, and of sockeye salmon in Payette Lake. Bowler et al. (1993) noted accounts of early explorers who found the entire Snake River clear and abounding with wildlife resources. Archeological evidence from native American middens in the southern Snake River area showed that salmonids were a major part of the diet (Bowler et al. 1993). Collection records from Oregon rivers from 1900 to the mid-1940s showed that the river fauna was composed mostly of salmonids (39 to 50 percent) and cottids (20 to 30 percent) (Li et al. 1987). Since the shared species pool of Pacific Northwest fishes is substantial (Li et al 1987; Zaroban et al 1999), this composition is likely typical of other river systems in the Pacific Northwest. The current and historical distributions of native trout in the interior Columbia River Basin also support the concept of a historical cold water template for rivers in the basin (Behnke 1992).

The historical record describes a cold water template to define reference expectations but provides few details. So that metrics and an index can be selected and scaled, expectations of current regional conditions need to be established and compared with conditions at sites that are likely to be impacted by anthropogenic disturbance. Fish assemblage data collected from minimally disturbed larger stream and river sites in the upper Snake River Basin were used to evaluate the range of reference metric conditions, to contrast the ranges with those from locations with apparently compromised water quality, and to fit curves over this distribution.

Previous analyses have shown that the percentage of agricultural lands in the study area is strongly associated with negative biological or habitat changes. Relationships between fish assemblages, associated environmental variables, and land uses showed that the percentage of agricultural land in the watersheds was as important a factor in shaping fish assemblages in the upper Snake River Basin as were watershed size, discharge, elevation, or ecoregions (Maret 1997). Schomberg et al. (1998) reported that an entire taxa group (riffle beetles) of the invertebrate assemblage nearly disappeared in agricultural watersheds. Lee et al. (1997) reported that for streams in basins with different land uses and management goals, the percentages of riffles and pool tails covered with fine-grained sediment were highest in agricultural watersheds. For these reasons, watersheds with a large proportion of farmland (greater than 15 percent) were considered a reasonable predictor of potential water quality impacts that would allow fish data from different locations to be compared and contrasted. This oversimplifies actual conditions. Some farmers use progressive management practices that likely result in little impact to water quality. In other cases, watersheds with no farming are impacted by recreation, grazing, or logging. However, for this analysis, the percentage of agricultural land appeared to be a reasonable, broadscale indicator of substantive anthropogenic affects to fish assemblages. In less arid parts of North America 15 percent farmland might not be considered a large proportion of agricultural use in a watershed. However, in the upper Snake River Basin the need for irrigation results in agricultural use in watersheds being disproportionately distributed along rivers; the combination of irrigation water withdrawals and subsequent wastewater returns also increases the influence of agricultural use on water quality beyond what might be expected by simple proportion of watershed land use. The cumulative watershed area was estimated by delineating the subwatersheds (USGS 12-digit hydrologic cataloging units) upstream of the site and calculating land use percentages using 1:250,000 digital data.

Candidate Metrics

Candidate metrics were initially chosen for evaluation from those reported in previous IBI adaptation efforts (Table 4-1). The ecological concepts and evaluations behind them are described in Addendum 1. Common themes in previous cold water IBI development were efforts to overcome the problems of depauperate species in natural conditions and species enrichment in degraded waters by de-emphasizing the original IBI reliance on species richness, and instead, emphasizing the composition of salmonids or other cold water fishes. However, there have been conflicting interpretations of what these measures indicate. For example, the number of amphibian species, native fish species, and salmonid densities have been considered either positive or negative indicators of water quality in streams (Table 4-1).

Table 4-1. Metrics used for cold water streams and rivers in the northwestern US and metrics from the original IBI.
(-) or (+) indicates a metric for which a decreased or increased value, respectively, was supposed to indicate degraded water quality.

Original IBI (Karr et al. 1986)	Cold water stream of the upper Midwestern United States (Mundahl and Simon 1999)	Rivers and streams, Upper Snake River basin, Idaho and Wyoming (Maret 1997)
# fish species (-)	# fish species (+)	# native fish species (-)
# of sucker species (-)	# cold water fish species (-)	% introduced species (+)
# of darter species (-)	# minnow species (+)	% omnivores (+)
# of sunfish species (-)	# of benthic species (+)	% carp (+)
# of intolerant species (-)	# of tolerant species (+)	% salmonids (-)
% green sunfish (+)	% salmonids as brook trout (-)	% cold water species (-)
% omnivores (+)	% intolerant individuals (-)	
% insectivorous cyprinids (-)	% cold water individuals (-)	
% top carnivores (-)	% white suckers (+)	
% hybrids (+)	% top carnivores (-)	
abundance or catch per effort (CPUE) (-)	# of cold water individuals (-)	
% with anomalies (+)	Number of warm water individuals (+)	

Idaho large rivers (Royer and Minshall 1996)	Southern Idaho small streams (Robinson and Minshall 1992)	Northern and central Idaho erosional (e) or depositional (d) streams (Fisher 1989)
% insectivores (-)	# salmonid species (-)	# fish species (e -, d +)
# intolerant taxa (-)	# tolerant species (+)	# salmonid species (e -)
native cyprinid species (+)	% tolerant individuals (+)	# non-salmonid species (e -, d +)
% carp biomass (+)	% Salmonidae (-)	# introduced species (e -)
	salmonid biomass (-)	% salmonid individuals (e +)
	salmonid condition factor (-)	average salmonid length (e -)
		average salmonid weight (e -)
		salmonid density (e +, d -)
		# amphibian species (e +, d -)
		amphibian biomass (d +)
		# intolerant species (d -)
		% hybrid species (d +)
		salmonid biomass (d -)
		fish biomass (d -)
		macroinvertebrate density (d +)

Scoring and Index Construction

Many IBIs have followed Karr et al.'s (1986) method of normalizing and scoring metrics. A metric value that was similar to the investigators' expectations for reference conditions was given 5 points, a value that deviated slightly from expectations was given 3 points, and a value that deviated severely from expectations was given 1 point. In contrast, we decided that a continuous scoring system similar to those used by Minns et al. (1994) and Hughes et al. (1998) would be more appropriate for our data. Cumulative frequency distributions were used to characterize the distribution of candidate metric values and to identify minimum and maximum score values. Minimum scores were set at zero for positive metrics, and maximum scores were set at about the 90th percentile of scores occurring over the gradient of metric responses. Lines or simple curves were drawn between the ranges, depending if the cumulative frequency distributions of the metrics' values suggested a linear, threshold, or asymptotic response. Since the sample sites represented a wide gradient of anthropogenic disturbances, that gradient is reflected in cumulative distributions of metrics values. Equations describing the scoring curves were used to calculate metric and index scores.

Origins of and tolerances to generally degraded water quality were assigned to fish species by using ratings from Zaroban et al. (1999). Rainbow trout were considered a nonindigenous species above Shoshone Falls, a major zoogeographic barrier that limited of their historical distribution in the Columbia Basin (Simpson and Wallace 1982, Behnke 1992, Maret et al. 1997). Where they could be distinguished, hatchery individuals were excluded from all counts.

Validation

Efforts to independently validate the RFI included (1) comparing index scores to associated land uses and environmental variables; (2) statistically testing index scores from reference and potentially impaired groups; and (3) calculating index scores for independent data sets that were not used to develop the index, classifying these data into groups, and statistically testing those groups for differences; and (4) examining the stability of the index over longitudinal gradients for two reference rivers. Index responses to land uses and environmental variables were determined by using the cumulative percentages of major land-use classes in watersheds upstream from upper Snake River Basin study sites. The resulting land use percentages were correlated with physical variables measured at the sites and with the RFI. Analyses included graphical and statistical comparisons of individual metrics and the index results for the least disturbed reference and test sites in the upper Snake River Basin to determine whether the results were different. To evaluate whether the resulting index was applicable to river basins other than the one it was developed from, index results were calculated for fish data sets from other drainages encompassed by the U.S. portion of the interior Columbia River Basin. The river validation sites were grouped as "lower Snake" for sites in Idaho and Oregon drainages from downstream of Shoshone Falls to the Columbia River confluence, "middle Columbia" for those Oregon and Washington rivers that drain directly to the interior Columbia River (e.g. Yakima River), and "upper Columbia" for sites in the Pend Oreille and Spokane drainages of western Montana, northern Idaho, and eastern

Washington. We expect that a cold water-adapted fish assemblage likely occurs (or occurred) in these river basins as well. This assumption is supported by observations that the tributaries of the interior Columbia River traverse shared or similar ecoregions --areas of generally similar landforms, climate, and vegetation (Omernik and Gallant 1986). Also the shared species pool of Pacific Northwestern river species is substantial (Li et al. 1987, Zaroban et al. 1999).

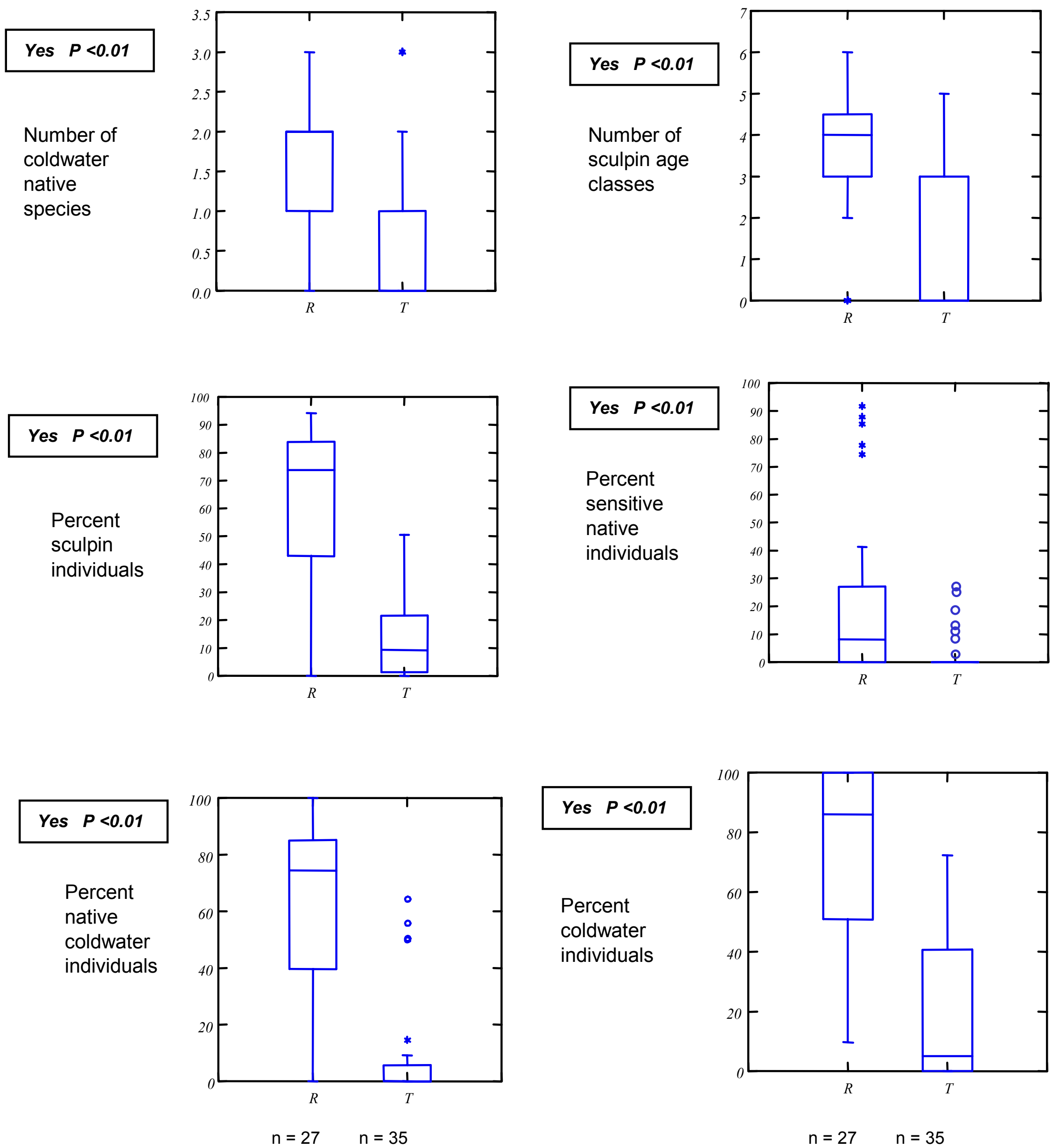
Unlike in the upper Snake River Basin, agriculture is not a major land use throughout these other basins. In parts of these areas, forestry, mining, and wilderness are predominant land uses. Rather than comparing index results to land uses that relate only to some of the areas, results from these other river basins were compared with the results of a landscape analysis that covers the entire area, albeit at a coarser scale than was available for the upper Snake River Basin. The "integrated scientific assessment for ecosystem management of the interior Columbia basin" linked landscape, aquatic, and terrestrial factors to derive ecological integrity ratings (Quigley et al. 1996). Much of this assessment was conducted at a subbasin scale (≈ 2,000-8,000 sq. km) which, depending on a site's location in a subbasin, may not always reflect the factors affecting the fish assemblage at an individual river sampling site. Despite this scale disparity, the objective assessment of landscape features and processes covering a large, geographically contiguous area, provides an objective and independent basis to compare the RFI results. The aquatic integrity subbasin ratings of Quigley et al. (1996) were used to group sites and compare RFI scores. Aquatic integrity was rated as high in systems characterized by a mosaic of well-connected, high-quality water and habitats that would support the full expression of life histories and dispersal mechanisms. Aquatic integrity was rated as moderate to low in systems characterized by increasing fragmentation and loss of the mosaic of habitats necessary for full life history patterns and dispersal among watersheds (Quigley et al. 1996). Because few sites were located in subbasins that were rated as having high aquatic integrity (zero and one in the lower Snake River Basin and Spokane-Pend Oreille Basins, respectively), the moderate and high groups were combined. Validation sites located in subbasins with moderate to high aquatic integrity were considered reference sites, and sites in subbasins with low aquatic integrity were considered test sites. In one area (the John Day River area of central Oregon), finer scale information was available that showed impaired aquatic habitat conditions (Li et al. 1994), and sites in that area were considered test sites instead of the broadscale rating of moderate aquatic integrity.

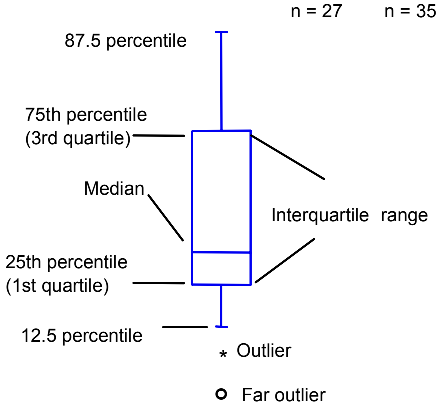
RESULTS AND DISCUSSION

Corroborating lines of evidence are fundamental to any investigation, and especially so with ecological risk assessments, bioassessment, or other field studies. However, independent corroboration needs to be distinguished from mere repetition of the same information. Inter-related, autocorrelated, or fully redundant metrics are undesirable in an index if they provide little biological information and only add weighting through repetition of the same information. For example because bigger, older, catchable trout are a subset of all age classes of trout, having several age classes of trout may address the ecological and social values of having large trout present (persistence and stability of adequate conditions, fishing opportunities). In contrast, "percent cold water individuals" and "percent sensitive native individuals" are also inter-related and correlated ($r = 0.50$, $P<0.01$), but do provide different information about the biological conditions. All sensitive natives are cold water species, but not all cold water fish are sensitive natives; a cutthroat trout is both, an introduced brook trout is only a cold water species. Although interrelated, the two metrics provide different information that can be used to distinguish high, moderate, and low biological condition. Thus, metrics were not selected or rejected solely based on correlations, or the lack thereof. Instead, the metric information, redundancy, and relative contribution of different metrics (weighting) need to be considered.

The Multimetric River Fish Index

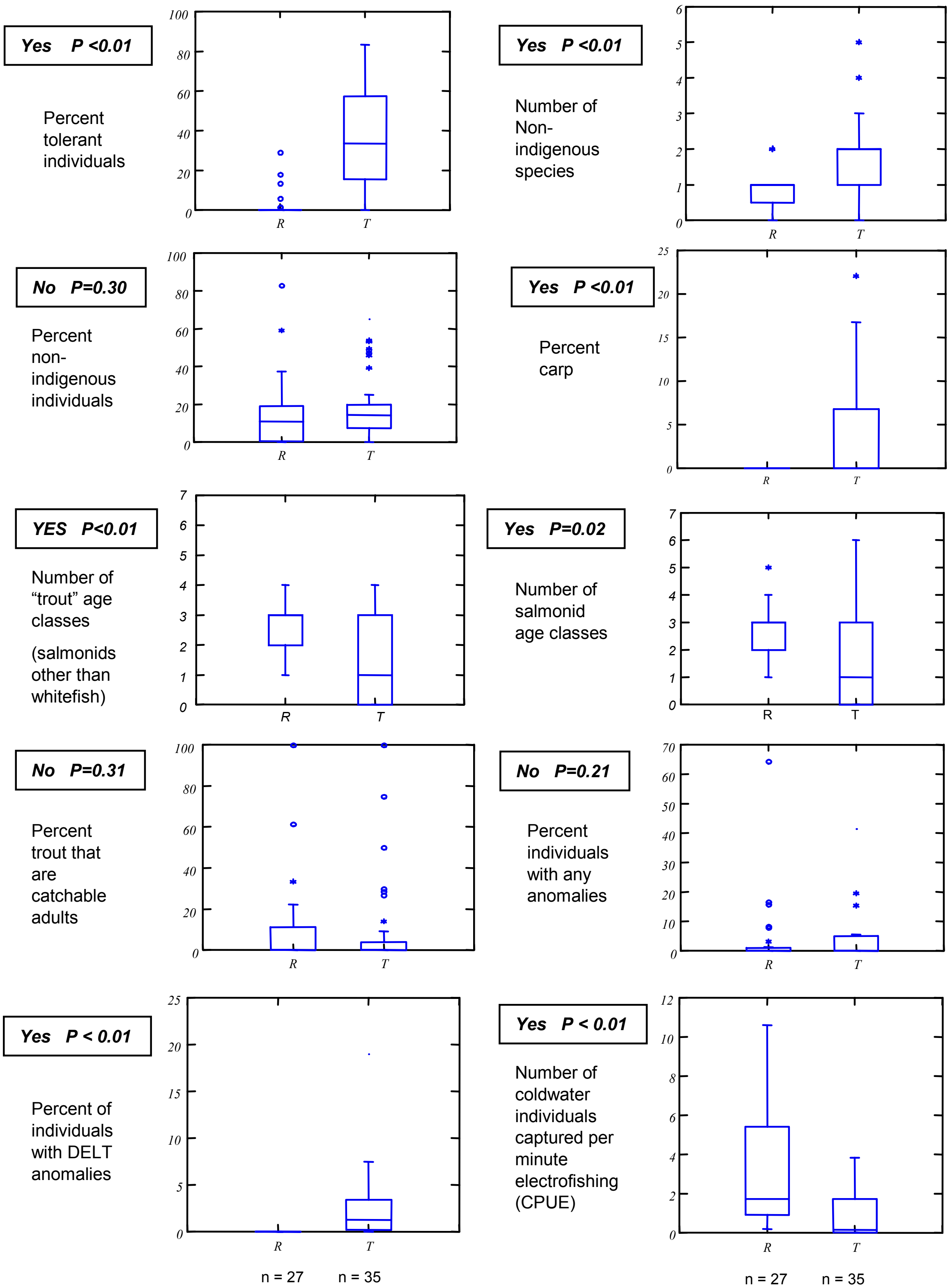
Of the 16 metrics tested, 13 discriminated between the reference and test sites (Figure 4-3). If the values from the reference and test groups were not statistically different, the metric was not considered further. Nondiscriminating metrics were percent nonindigenous individuals, percent trout that are catchable adults, and percent total anomalies. Ten functionally independent metrics that discriminated between reference and test groups were selected for the RFI. The carp metric was omitted from the upper Columbia river basin and the index was calculated with nine metrics. Simpson and Wallace (1982) reported that carp have not yet invaded these basins, which is probably still true since no carp were captured in the 48 sample sites from those basins.





Selected candidate fish metrics for reference sites (least-impacted by human disturbance) and potentially impacted test sites. "***YES***" or "***NO***" followed by a probability value indicates whether the metric values for the reference and test groups were statistically different using the Mann-Whitney procedure.

Figure 4-3. Selected candidate fish metrics for reference sites.



Candidate fish metrics for reference sites and potentially impacted test

Figure 4-3. *continued*

Cumulative frequency distributions (CFDs) were used to characterize the distribution of candidate metric values and to identify minimum and maximum score values. Minimum scores were set at zero for positive metrics, and maximum scores of one were set at about the 90th percentile of scores occurring over the gradient of metric responses. Lines or simple curves were drawn between the ranges, depending on whether the CFD of a metric's values suggested a linear, threshold, or asymptotic response (Figures 4-3 and 4-4). Since sites represented wide ranges of anthropogenic disturbance, those gradients were reflected in CFDs of metric values. Equations describing the scoring curves were used to calculate metric and index scores. We also ensured that scores could not eclipse one another or that a maximum score in one metric would not prevent other metrics from getting a maximum score when setting metric scoring ranges (Suter 1993). For example, 30 percent % *cool water* individuals occurred at many minimally-disturbed reference sites. Therefore, we set the top score of the percent *cold water* individuals metric at greater than or equal to 70 percent, otherwise it could not be achieved at many reference sites. Raw metric values for a sample site were standardized from 0 to 1.0 using these curve values. The final index scores were calculated by summing the 10 metric scores and multiplying the result by 10 to scale the scores from 0 to 100.

Sites at which fish were unusually sparse (greater than 20 individuals captured in a sample) were excluded from the results. Sites with very few fish probably indicate sampling problems or such degraded conditions that fish-assemblage-based indices provide little additional information. Fore et al. (1994) reported that, in Ohio streams, sites with less than 400 fish produced notably more variable IBI scores than did sites with more fish. However, the rivers and large streams in the upper Snake River Basin index development area were much less productive than were the Ohio streams. The average numbers of fish captured in the upper Snake River Basin data set for reference and potentially impacted sites were 96 and 131, respectively.

The different metric scores do not contribute uniformly to the overall index score. Minns et al. (1994) demonstrated that individual metrics differ in their contribution to the overall index scores in different ranges of IBI results (excellent to poor). Consequently, the relative sensitivity of index values to individual metrics was compared for the reference and test groups. The index sensitivity to each metric was examined by calculating a reduced index by sequentially removing one metric and calculating the percent difference between the reduced index of remaining metrics and the overall index. If all 10 metrics contributed uniformly, the differences would be 10 percent. Instead, among the reference sites the differences average from 5 percent to 16 percent, and among test sites from 1 percent to 19 percent (Table 4-2). The "percent sensitive natives" metric averages the least contribution to the overall index score. High scores with this metric were infrequent within the upper Snake River Basin for both reference and test sites. In contrast, no reference site had carp or was dominated by tolerant species; thus, all reference sites, and many test sites, received high scores for these metrics. Among test sites, the average scores of all metrics were lower than for reference sites, but the relative sensitivity to most metrics remained similar to the reference sites.

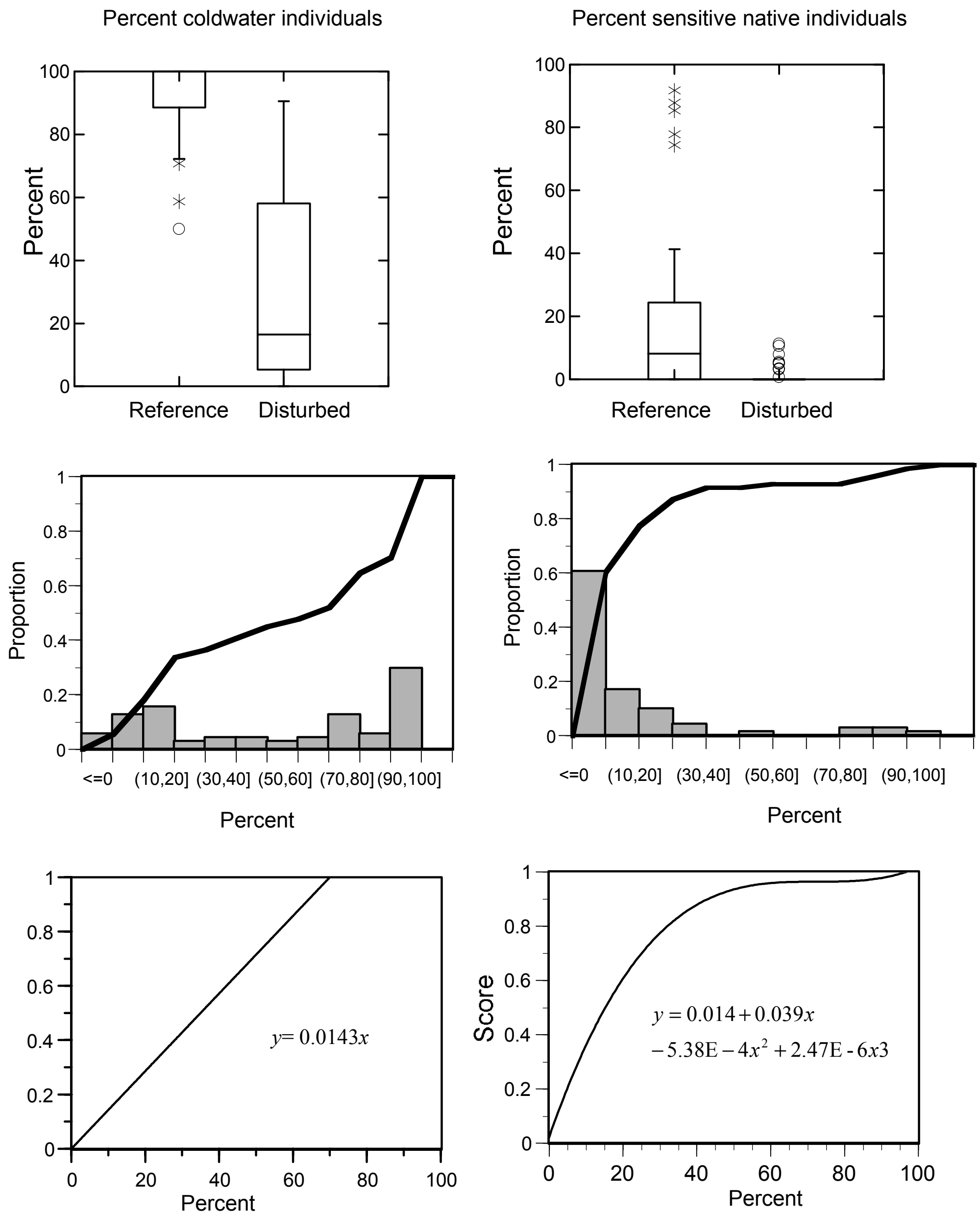


Figure 4-4. Metric scoring was set by considering the range of values at reference and impacted sites (top), and the pattern of metric responses over a range of pristine to highly disturbed conditions (middle).
A simple curve or line was selected that gave top scores to the main body of reference values and the slopes and shapes reflected the general pattern of values across the gradient of site conditions (bottom). For metrics which increased in response to degraded water quality (e.g., anomalies), the scoring curve is the inverse of the gradient of responses.

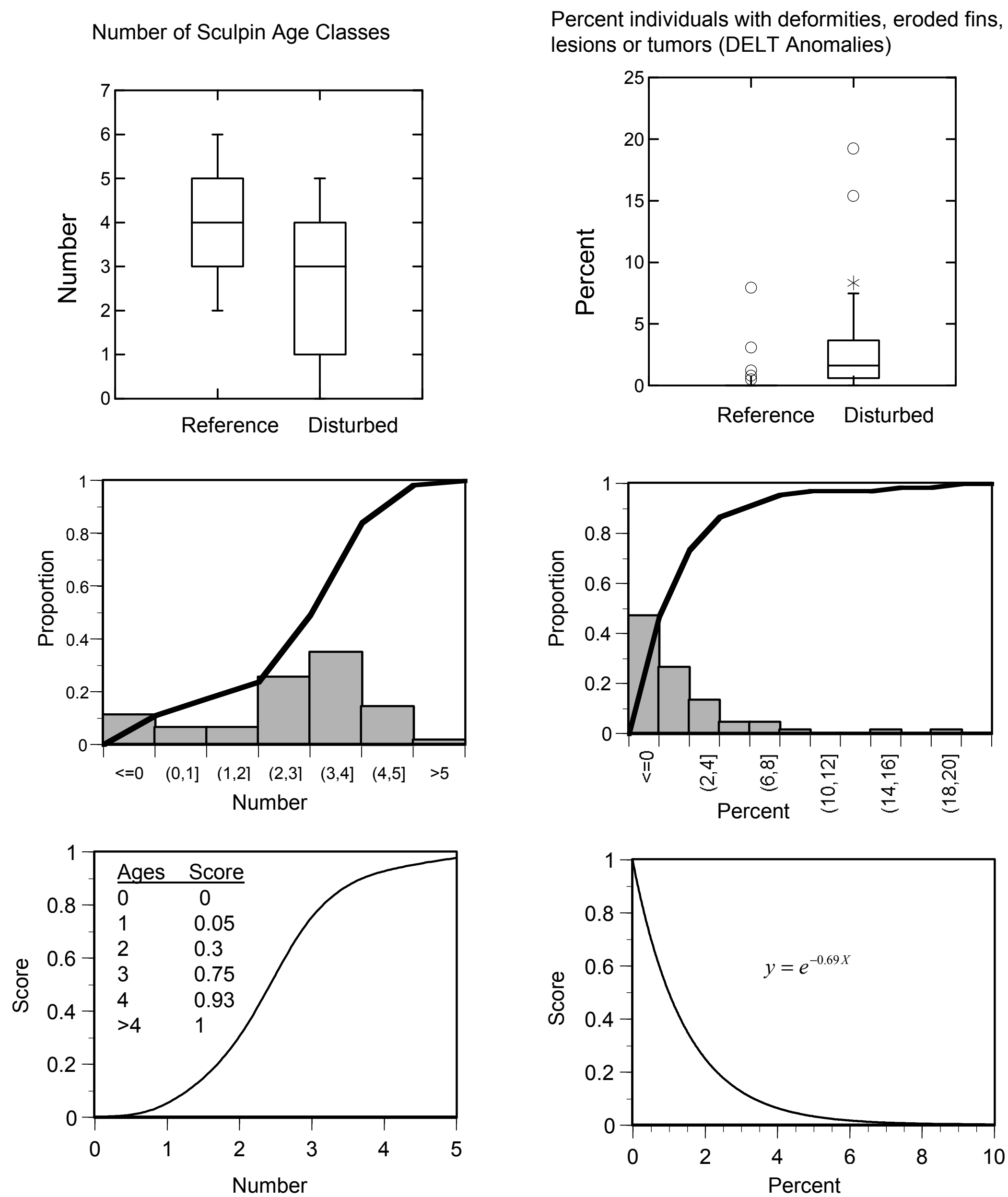


Figure 4-4. (continued)

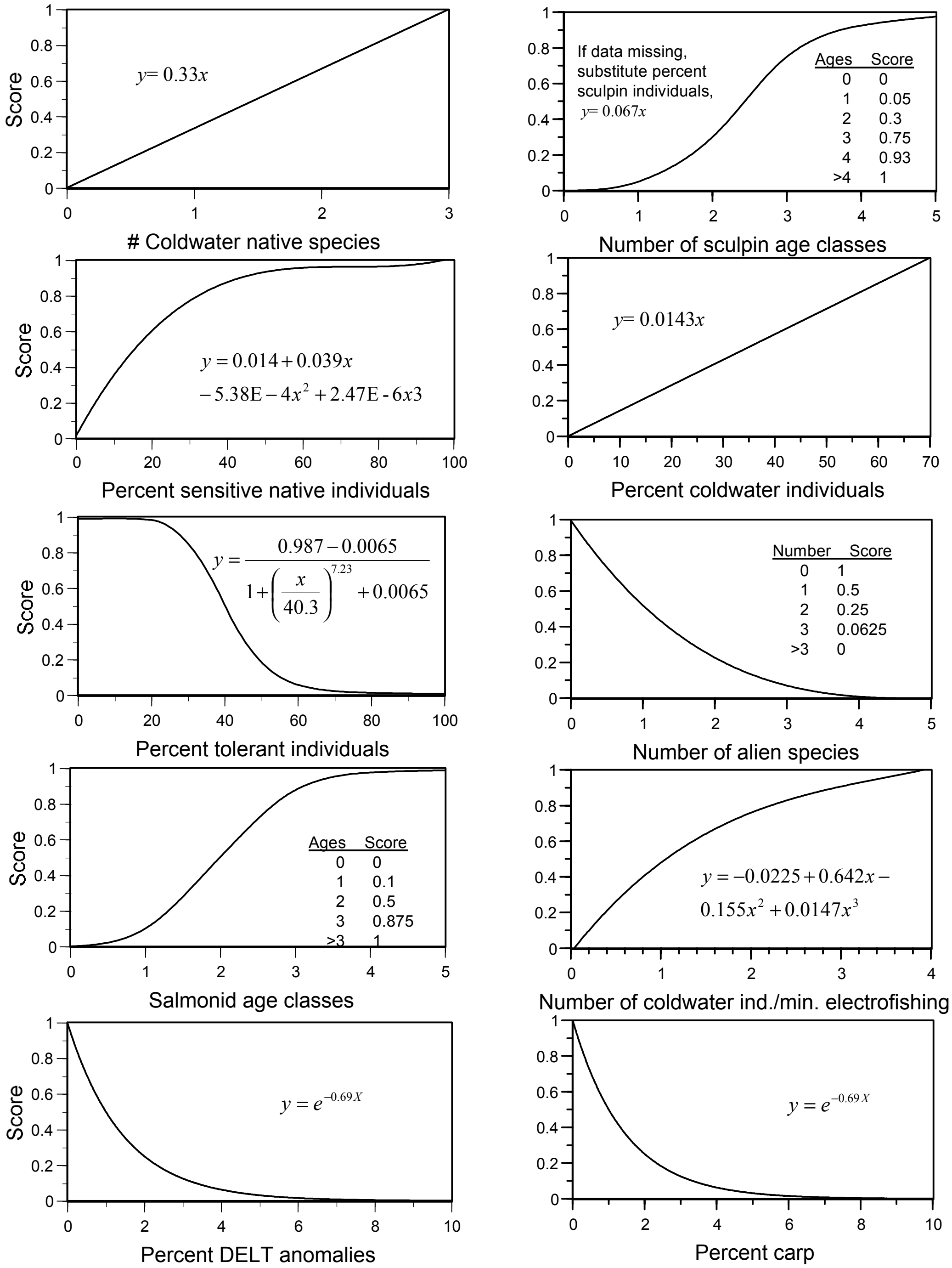


Figure 4-5. Scoring curves for metrics used in the RFI.

Table 4-2. Average scores, coefficients of variation, and relative contributions of the individual metrics to the overall index.

	CNS	SCU	SNS	COLD	TOL	NON	CARP	SAL	CPUE	DELT
Reference sites (n=29)										
Average score (1.0 maximum)	0.54	0.79	0.37	0.82	0.93	0.56	1.00	0.60	0.69	0.85
Average relative index contribution (%)	7.90	10.9	4.7	11.4	13.4	8.6	15.7	8.2	8.5	10.8
CV - raw values (%)	50	45	140	41	260	79	0	31	94	280
CV - scores (%)	50	42	110	37	26	48	0	49	42	39
Test sites (n=40)										
Average score (1.0 maximum)	0.22	0.25	0.04	0.28	0.42	0.35	0.54	0.29	0.31	0.41
Average relative index contribution (%)	8.1	7.8	1.2	6.8	14.4	18.6	14.7	6.5	5.6	16.5
CV - raw values (%)	150	100	240	220	64	68	140	100	140	150
CV - scores (%)	146	100	239	124	88	70	94	130	122	87
All replicated sites (n=35)										
S/N ratio	5.7	6.9	7.5	5.1	3.4	1.1	4.4	2.4	4.6	0.84

[a]CNS - #Cold water native species, SCU - Sculpin age classes, SNS - % Sensitive native individuals, COLD - % Cold water individuals , TOL - % Tolerant individuals, NON - #Non-indigenous species, CARP - Presence of carp, SAL - # Trout age classes, CPUE - #Cold water individuals/minute electrofishing, DELT - % DELT anomalies.

Variability

Metric and index variability was evaluated by examining the coefficients of variation (CV) and signal to noise (S/N) ratios. The CV is a measure of variability relative to the mean. A high coefficient among reference sites may mean a metric is too erratic to be relied upon for assessments; a low coefficient across a range of conditions indicates the metric is unresponsive to changes. Variability at impacted sites has been reported to be higher than at reference sites due to stress and unstable environmental conditions (Fore et al. 1994). Barbour et al. (1992) suggested that CVs greater than100 percent in macroinvertebrate metrics from reference sites were “high,” and were usually rejected by ANOVA as being unable to distinguish different types of streams. Although high variability in unimpacted systems does not preclude those metrics from being valuable differentiators between impacted and unimpacted streams, an understanding of variable metric results is important for proper interpretation (Barbour 1993).

Among reference sites, raw values for the percent tolerant and percent deformities, eroded fins, lesions and tumors (DELT anomalies) metrics had the highest average CVs (260 percent and 280 percent, Table 4-2). These metrics are highly variable because their mean values are very low, which results in division near zero. Therefore, scores for the few reference sites that have these metric responses present will result in high variability of the raw scores. Normalizing these metrics through the scoring curves greatly reduced the CVs of the most variable metrics. Normalizing raw values to unitless metric scores smoothes and reduces the high metric variability in a range of values that occurs in an asymptotic portion of a scoring curve. Yet, score variability is not smoothed to the point of creating metrics that are unresponsive to biological changes.

In addition to CVs, Kaufmann et al. (1999) described the precision of stream habitat measurements by the ratio of the variability of values between sites and the variability of values within replicated sites. They adapted the term "signal to noise ratio" (S/N) to refer to this among-site variance (signal) to within-site variance (noise) ratio. In statistical analyses of physical stream habitat metrics, those metrics with S/N ratios less than 2.0 severely limited analysis by regression or correlation. Metrics with S/N variance ratios greater than 10 provided insignificant error and distortion (Kaufmann et al. 1999). S/N variance ratios for individual metrics and the overall index were calculated from 35 sites which had been sampled at least twice. S/N variance ratios for individual raw metric values ranged from 0.8 to 7.5 (Table 4-2). Low S/N ratios for the number of nonindigenous species and percent DELT anomalies could be cause to reject these metrics because of low precision. However, we considered the establishment of nonindigenous species and the prevalence of anomalies to be ecologically significant enough to justify retaining these two metrics, despite their low precision. The S/N ratio for the overall RFI was about 8.0. The replicated sites in this paper include year-to year and seasonal sampling in addition to measurement variability. Thus, our noise also includes interannual changes in the fish assemblage; it is "noisier" than if it had included only single-season and site measurement error as described by Kaufmann et al. (1999). Another way to gage the index's precision is by considering the replication variability of the noise by itself. The pooled SD of the noise was 5.6, indicating that differences between RFI scores of less than 6 points are but noise and may be biologically insignificant.

If it is assumed that integrity did not change at sites from year to year, between sampling dates, or between different sampling crews, the variation in the RFI can be visualized as the deviation from a perfect 45° linear relationship in the plot of each RFI score against the mean RFI score for repeated visits (Figure 4-5). Differences at sites with high scores (greater than 70) were lower than sites with lower scores (SD of 3.5 vs. 8.6 respectively, different at P less than 0.01 using the Mann-Whitney test). Rock Creek, Idaho which had a mean score of 65, had an usually large point spread (25). Sampling crews could not confidently distinguish hatchery fish from naturally reproducing fish at this site (Maret 1997). Hatchery supplementations of young-of-year, juvenile, and catchable adults artificially inflate scores, which underscores the need for caution when interpreting fish assemblage data from highly "managed" waters. The most extreme difference in RFI scores (44 points) was at a site on the South Fork of the Coeur d'Alene River, Idaho which has been influenced by the combined effects of heavy metals contamination and associated habitat structure degradation from a legacy of mining and channel alterations. When sampled during September low flows, the fish assemblage was dominated by introduced Centrarchids and Ictalurids; only a few native cutthroat and introduced brook trout were present. When resampled the following June during higher, cooler flows, the fish assemblage consisted of native cutthroat and introduced brook trout only. In this case, the RFI score range of 20 to 64 likely does not reflect imprecision in the index, but the dramatic shift in the fish assemblage in this disturbed river as species move in and out of seasonally unsuitable conditions. Also noteworthy, the metals contaminated sampling sites were completely devoid of sculpin, although sculpin were abundant in all nearby uncontaminated areas.

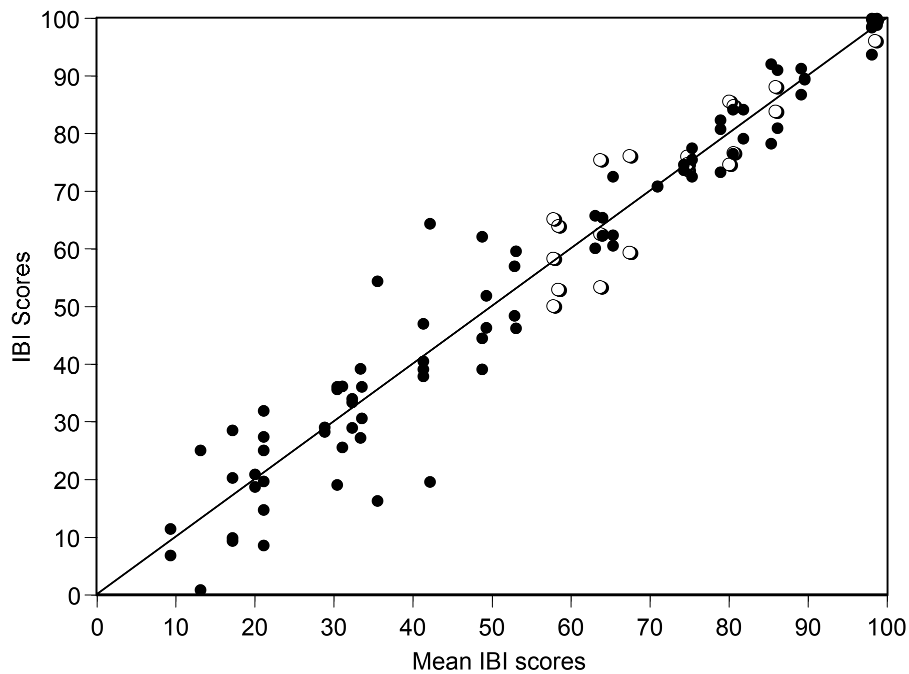


Figure 4-6. RFI scores vs. mean RFI scores for site sampled more than one time. Open circles indicate replicate reaches sampled during the same summer; closed circles indicate interannual replicates. Close proximity to a 1:1 slope indicate little interannual, reach, or measurement variance.

INDEX VALIDATION

Statistical comparisons of reference and potentially impaired sites

RFI scores from sites identified as reference sites were significantly higher ($P < 0.01$) than scores from potentially disturbed sites in the upper Snake River basin index-development data set as well as the independent data sets from the interior Columbia River basin (Figure 4-7). There was little overlap between the distributions of scores from the reference and impacted groups. All groups were statistically different at $P < 0.01$ using the Mann-Whitney test.

In the upper Snake River basin, the RFI scores were negatively correlated with the percentage of the watershed in agricultural use. Correlations with watershed areas in rangeland and forest lands were weaker and not statistically significant. The RFI scores were also negatively correlated with the percentage of river width covered by fine-grained sediments, which, in turn, was also significantly correlated with percentages of agricultural lands (Figure 4-7).

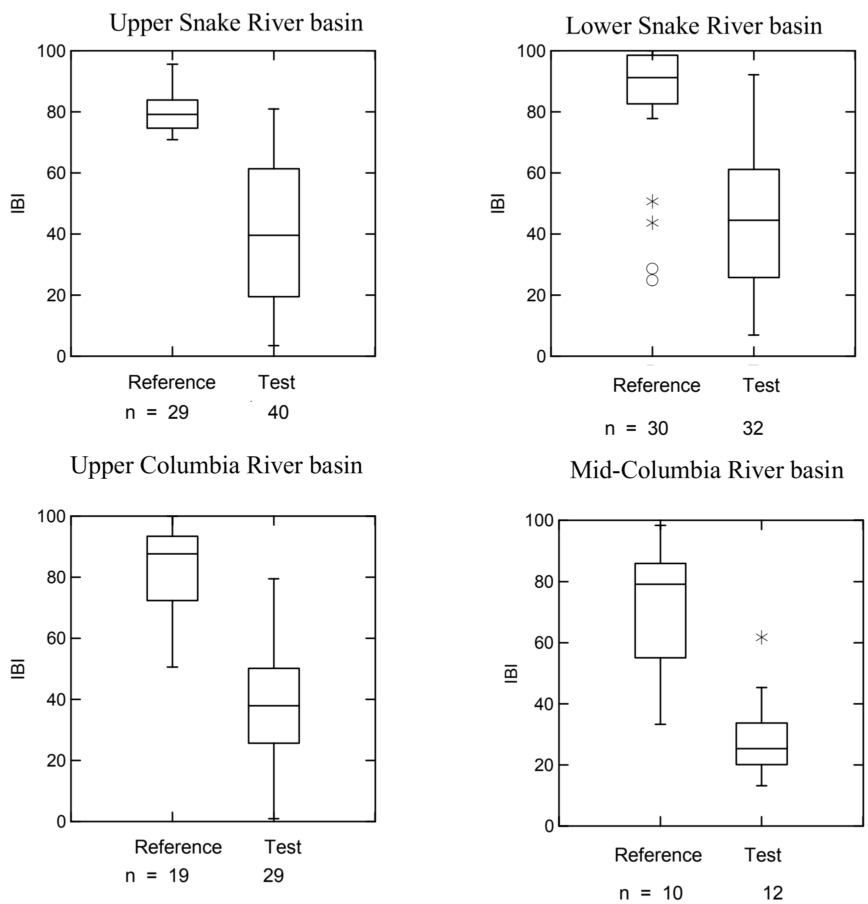


Figure 4-7. Ranges of RFI scores for reference and test sites used to develop the index (Upper Snake River Basin) and for the independent sites from other river basins in the Interior Columbia River Basin.

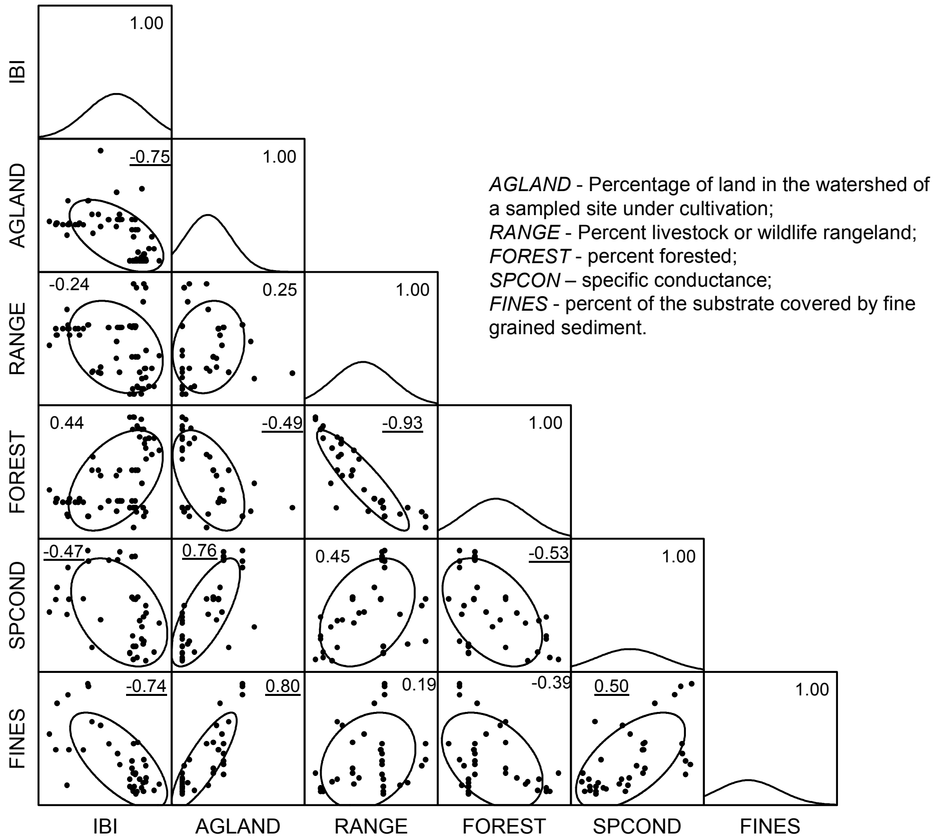


Figure 4-8. Correlation between fish index scores (RFI), land uses, fine sediments, and conductivity in the Upper Snake River basin.

LONGITUDINAL CHANGES IN RIVERINE FISH ASSEMBLAGES AND RFI SCORES

Ecological processes and natural aquatic communities in streams gradually change longitudinally as their size increases and gradient changes (Vannote et al. 1980, Li et al. 1987). In general, species are added to the system as gradient lessens and as water temperatures and stream size increase. As streams lose elevation, zonation occurs from a simple cold water trout-sculpin assemblage upstream into a more diverse, mesothermic and eurythermic assemblage downstream (Li et al. 1987, Rahel and Hubert 1991). Overlain on this ecological pattern is the pattern of settlement and development of arable lands, which depend upon rivers for irrigation or transportation. These patterns often mask one another. Anthropogenic disturbance of streams can shift the fish assemblage typical of downstream reaches farther upstream (Rahel and Hubert 1991). Teasing apart the downstream anthropogenic effects from the natural continuum is necessary to guide river management or restoration, because subtle degradation might not be noticed as a result of the natural longitudinal patterns and because misguided remediation efforts could attempt to create a trout stream where none previously existed.

One implication of natural longitudinal changes is that it limits how representative a particular set of metrics or an index is of the minimally disturbed reference condition. As previously discussed, historically, most interior Columbia River Basin rivers were likely predominantly erosional and inhabited by cold water species. Still, at some point between headwaters and the Pacific Ocean, the natural biological template was undoubtedly different from that described by our IBI. At some point in that continuum, a different assessment template than this IBI would be appropriate. Likewise, the fish assemblage model described here would not describe headwater streams, because of the theoretical reasons just given and because the IBI is an empirical model: headwater streams were not included in its development.

Opportunities to make comprehensive reference comparisons on rivers are, unfortunately, limited due to the extensive history of settlement and alteration. Fortunately, we were able to target additional sampling of longitudinal effects on two of the largest, relatively undisturbed river sections in the united States portion of the interior Columbia River Basin: the Salmon River in central Idaho and portions of the upper Snake River. The Salmon River descends from an elevation of about 2,500 to 300 m over 700 km. The rugged catchment and the relatively harsh climate (short growing season, limited precipitation) have restricted permanent human settlement and disturbance in the Salmon River Basin. Also, most of the basin is in public ownership, which results in reasonably sound, long-term land management practices but also results in some irrigation, grazing, and logging effects (Minshall et al. 1992). Much of the basin is managed as wilderness. The Salmon is one of the few rivers of its size in the conterminous United States with no impoundments on it or on any of its tributaries. The upper 300 km of the Snake River has been similarly protected by a harsh climate and much of its basin is protected through management as wilderness and national parks, although two reservoirs are located between the three sample sites.

The RFI results were fairly stable over a longitudinal gradient for these two reference rivers (Figure 4-9, Table 4-3). Scores from sites about 300 km apart on the Snake River ranged from 72 to 84. Scores from five sites on the Salmon River ranged only from 82 to 95 over 500 km, despite marked changes in the fish assemblages along the river continuum. Over the first 100 km downstream from the Salmon River headwaters, the fish assemblage consisted almost entirely of invertivorous cottids and salmonids, by 190 km, piscivorous cyprinids (northern pikeminnow) and herbivorous catostomids were added to the assemblage. At our lowest Salmon River site, located at Whitebird Creek, 600 km downstream from the headwaters and 80 km upstream from the confluence with the lower Snake River, the fish assemblage was influenced by the downstream slackwater fishery. Nonindigenous-smallmouth bass and common carp were present, and sensitive native species were present but scarce, which resulted in a lower RFI score (Figure 4-9). There were no significant anthropogenic influences between the sites at 526 km and 595 km downstream from the headwaters. Rather, the principal differences between the sites were a more open canyon, which probably caused some higher water temperatures, and proximity to the downstream Snake River impoundments. Because the scoring criteria for the metrics in the index account for much of the range of reference conditions, the effect on the RFI of this natural longitudinal zonation and species additions is dampened, yet seems not to be dampened to the point of missing significant unnatural longitudinal zonation. Ranges of RFI scores were greater over longitudinal gradients in rivers with more extensive anthropogenic alteration, 13 to 55 for the John Day River in Oregon, 21 to 87 for the Yakima River in Washington, 7 to 92 for the Boise River in southern Idaho, and 1 to 100 for the Spokane River system in northern Idaho and Washington.

Table 4-3. Longitudinal downstream changes in selected metrics at least-disturbed reference river sites.

Site	km below head-waters	Elev. (m)	Total species	Native species	# CNS	% Cold	% Tol	CPUE	# Sal. ages	RFI
Salmon @ Alturas Cr	5	2384	2	1	1	100	0	6.5	4	NA
Salmon @ Camp Cr	10	2300	2	1	1	100	0	4.0	4	87
Salmon @ Slate Cr	98	1750	6	6	5	97	0	4.5	2	95
Salmon @ Pahsimeroi R	189	1430	11	11	5	77	13	5.6	3	93
Salmon @ North Fork	297	1125	15	15	6	40	33	3.2	3	85
Salmon @ Little Salmon	526	670	11	10	5	53	7	1.8	2	82
Salmon @ Whitebird	595	430	11	9	3	19	51	0.8	2	51
Snake @ Yellowstone National Park boundary, WY	50	2073	10	8	3	30	1	3.0	3	73 to 82
Snake @ Moose, Grand Teton National Park, WY	130	1960	9	9	4	53	18	1.9	3	84
Snake @ Heise, ID	280	1528	9	6	3	80	2	3.3	4	83

a CPUE:

b RFI: River Fish Index.

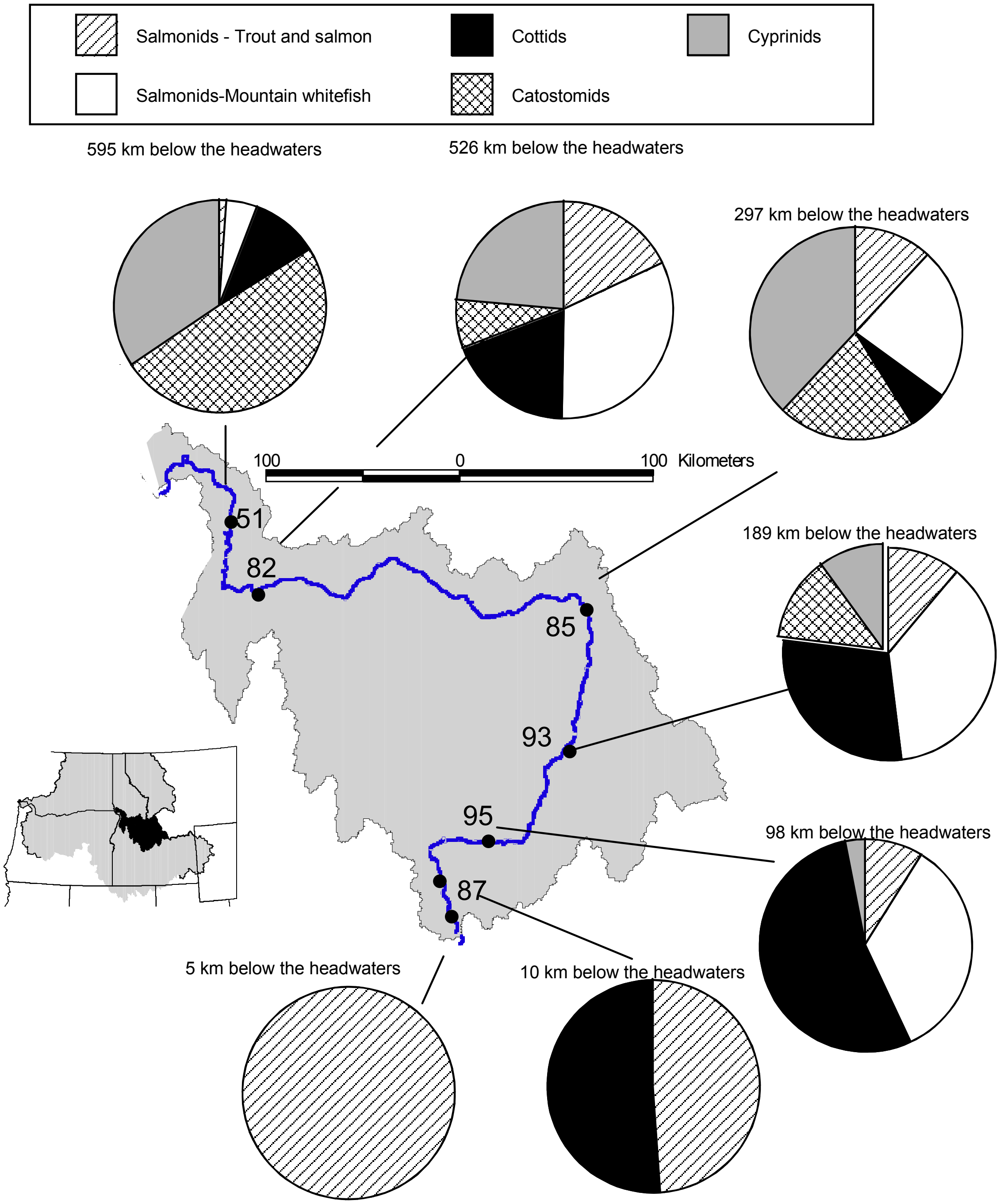


Figure 4-9. Longitudinal changes in fish assemblage composition and corresponding RFI scores along a 7th order reference stream, the Salmon River in Idaho.
RFI scores are shown next to the sampling sites. No RFI score was calculated for the site nearest the headwaters, for there the Salmon River is a "river" in name only.

Conclusion

The index of biotic integrity (IBI) has been commonly used as a measure of relative aquatic ecosystem health, however, the application over large geographic areas in cold water systems with low natural species richness has been limited. A four-step process was used to construct an IBI applicable to fish assemblages in cold water rivers of the U.S. portion of the interior Columbia River Basin (parts of Idaho, Montana, Oregon, Washington, and Wyoming): (1) fish data from the region sets were compiled and candidate metrics were selected from previous studies; (2) data were separated by major river basins, and data from the upper Snake River Basin were used to test metrics and develop the index, (3) metrics were standardized by scoring them continuously from 0 to 10 to produce an IBI with scores ranging from a possible 0 to 100; and (4) the IBI responses were tested with data sets from the interior Columbia River area other than the upper Snake River Basin. The resulting index called the River Fish Index (RFI) comprised 10 metrics: number of cold water native species, number of sculpin age classes, percent sensitive native individuals, percent cold water individuals, percent tolerant individuals, number of nonindigenous species, percent carp individuals, number of selected salmonid age classes, number of cold water individuals/minute electrofishing, and percent selected anomalies. Scores from least disturbed reference rivers were evaluated for longitudinal gradients along the river continuum. The RFI was responsive to environmental disturbances and was generally spatially and temporally stable. The results support the feasibility of using a quantitative index over a large geographic area to describe relative biological conditions of rivers with low natural species richness.

The RFI appears to be a useful tool for interpreting, comparing, and communicating the biological integrity of cold water rivers in the inland Pacific Northwest. The component metrics and the overall index results responded to different biological conditions in the test and validation fish data sets. The scoring criteria were developed over a wide gradient of actual conditions. Results of testing the responses to independent site and land use data, and with data that was not used to develop the index, were favorable. As hoped, the index appears to delineate three classes of sites: 1) those waters with the highest biological integrity, where a diverse and abundant assemblage of predominately native species is supported; 2) those waters where native species may have been displaced by nonindigenous species that may be deemed socially desirable, and still reflect cold, clean water quality conditions; and 3) those waters where cold water species are rare or absent, and species that tolerate turbid, warm water predominate (Table 4-4). Over broad areas (up to 500 river km), RFI scores changed more in response to anthropogenic effects than to natural longitudinal changes. These results support using this RFI as a quantitative measure of fish assemblage assessment.

Table 4-4. RFI scoring ranges and species occurrence.
Species are listed in order of frequency of occurrence within each scoring group (10 most frequently occurring). [a]

RFI Range	Common Name	*Scientific Name*	Origin	Thermal Guild	Tolerance
75-100	Rainbow Trout	*Oncorhynchus mykiss*	N/I	Cold	S
	Mountain whitefish	*Prosopium williamsoni*	N	Cold	I
	Cutthroat trout	*O. clarki*	N	Cold	S
	Shorthead sculpin	*Cottus confusus*	N	Cold	S
	Speckled dace	*Rhinichthys osculus*	N	Cool	I
	Longnose dace	*R. cataractae*	N	Cool	I
	Mottled sculpin	*C. bairdi*	N	Cold	I
	Paiute Sculpin	*C. beldingi*	N	Cold	I
	Chinook salmon	*O. tshawytscha*	N	Cold	S
	Largescale sucker	*Catostomus macrocheilus*	N	Cool	T
50 - 75	Rainbow Trout	*O. mykiss*	N/I	Cold	S
	Redside shiner	*Richardsonius balteatus*	N	Cool	I
	Largescale sucker	*Catostomus macrocheilus*	N	Cool	T
	Mountain whitefish	*P. williamsoni*	N	Cold	I
	Longnose dace	*R. cataractae*	N	Cool	I
	Northern pikeminnow	*Ptychocheilus oregonensis*	N	Cool	T
	Speckled dace	*R. osculus*	N	Cool	I
	Bridgelip sucker	*Catostomus columbianus*	N	Cool	T
	Brown trout	*Salmo trutta*	I	Cold	I
	Cutthroat trout	*O. clarki*	N	Cold	S
< 50	Largescale sucker	*Catostomus macrocheilus*	N	Cool	T
	Redside shiner	*Richardsonius balteatus*	N	Cool	I
	Northern pikeminnow	*Ptychocheilus oregonensis*	N	Cool	T
	Common carp	*Cyprinus carpio*	I	Warm	T
	Chiselmouth	*Acrocheilus alutaceus*	N	Cool	I
	Speckled dace	*R. osculus*	N	Cool	I
	Mountain whitefish	*P. williamsoni*	N	Cold	I
	Bridgelip sucker	*Catostomus columbianus*	N	Cool	T
	Smallmouth bass	*Micropterus dolomieui*	I	Cool	I
	Rainbow Trout	*O. mykiss*	N/I	Cold	S

[a] Origin: N – Native, I – Introduced; Overall pollution tolerance: S- sensitive, I – intermediate, T – tolerant. See Addendum A for definitions.

ADDENDUM 1: ECOLOGICAL CONCEPTS AND EVALUATIONS OF CANDIDATE METRICS

The theoretical basis of the IBI framework was initially established for warm water streams in midwestern North America (Karr et al. 1986). In extrapolating that framework to northwestern rivers in the U.S., we have substantially modified the metrics of the original IBI. Here we describe ecological concepts of candidate metrics, their expected change with environmental degradation, and reasons for using or not using candidate metrics.

Assemblage richness and composition metrics

Number of cold water native species. – Species richness frequently changes in response to environmental stress. The metric is limited to native cold water species to exclude confounding introduced or tolerant native species. As habitats shift from cold to cool water, total species richness may increase as cool water and warm water species expand their ranges. The metric responses matched expectations across the upper Snake River Basin. A maximum of three cold water native species was collected at any single sample site. Individuals were assumed native if they were collected within the historical distribution for that species.

Cold water adapted species were classified according to Zaroban et al.'s (1999) listing of 132 freshwater species found in the Pacific Northwest, with the exception of the mottled sculpin, *Cottus bairdi*. Zaroban et al (1999) classified mottled sculpin as a cool water species on the basis of their broad range across North America but generally cautioned that there were significant biogeographic limitations in applying their classifications, and modifications might be needed for some applications. Here we consider mottled sculpin a cold water species on the basis of the following factors. (1) Bond (1963) and Wydoski and Whitney (1979) observed that mottled sculpin occupied somewhat colder waters than the Paiute sculpin *Cottus beldingi,* which is a cold water-classified species. (2) Hendricks (1997) reported that mottled sculpin in Montana were found in greatest abundance in summer water temperatures of 13 to 19º C. (3) Mottled and Paiute sculpin occurred at similar temperatures and elevations in small streams in central Idaho (C. Mebane, unpublished data). (4) Li et al's (1987) classification of both Paiute and mottled sculpin as temperate stenotherms. In addition to the bioassessment problem of how to classify and score species' attributes, further practical significance of this mesotherm-stenotherm distinction is that the mottled sculpin can be very hard to distinguish from the cold water shorthead sculpin *Cottus confusus*, and that they are sympatric in some rivers of the interior Columbia basin. Mottled and shorthead sculpin were considered conspecific until the early 1960s (Bond 1963). The two species are often difficult to segregate because each species is variable in morphology, and the morphological traits of the two species are quite similar (Hendricks 1997).

Percent cold water individuals – This metric reflects widespread, permanent establishment of nonindigenous trout populations in the study area. Introduced trout may displace native trout but still require high quality habitat, and a low representation of cold water species may indicate degraded habitat conditions. Cold water individuals were dominant in least-disturbed areas and were uncommon or absent in highly altered areas. Because of the widespread introduction of nonindigenous trout, the metric provides responses in more areas than the metric percent native cold water individuals does.

Indicator species metrics

Percent sensitive native individuals – General tolerances to environmental stress have been listed for basin 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 as systems become more turbid or warmer. Some sensitive native fishes were present at most reference sites in the upper Snake River Basin data set used to develop the index. Where they were present, sensitive natives seldom made up more than 40 percent of the sample assemblage.

Percent tolerant individuals – The proportion of fish that thrive in or tolerate poor- quality habitat is likely to be high in rivers with degraded conditions. Some native cyprinids and catostomids, as well as many nonindigenous species, were considered tolerant following the listings by Zaroban et al. (1999). Percent tolerant individuals in the data used to develop the index was highest at locations known to have degraded conditions (e.g. sections of the Snake, Portneuf, and Bear Rivers). Native tolerant species were present at the least-disturbed reference sites but were never dominant.

Number of nonindigenous species– This metric reflects the severity of biological pollution of invading or introduced nonindigenous species and is measured by how many species have become established, rather than by numerical dominance by individuals of nonindigenous species (percent). We considered presence of a nonindigenous species as usually permanent and less variable than percent nonindigenous individuals. Prevalence of impoundments may increase the vulnerability of rivers to invasion by introduced reservoir fisheries such as centrarchids, ictalurids, and percids (Meffe 1991). Nonindigenous species occurred more frequently at impacted test sites than at reference sites (Figure 4-3), although the number of nonindigenous species was high (three) at both otherwise least disturbed locations with introduced trout species (Yellowstone National Park) and at highly altered sites (Middle-Snake River). Within species' historical ranges, it may be difficult to tell whether a population is indigenous or introduced (for example, rainbow trout).

Percent carp (Cyprinus carpio) – Carp are omnivorous fish that are exceptionally tolerant of warm, turbid, silty conditions. In the interior Columbia River Basin, we consider their prevalence to be a strong indicator of degraded conditions. Even a small percentage of carp in the assemblage may make up the majority of the fish biomass at a site (Royer and Minshall 1996, Maret 1997). Carp were collected at only 20 percent of sites in the index development data set, all of which also had other indications of impairment.

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 in areas where fine-grained substrate or highly embedded cobble substrate predominate. Larvae of these species and some adults burrow into the interstitices of cobble substrate for refuge (Bond 1963; Finger 1982; Haro and Brusven 1994). Some freshwater sculpin species are tolerant of fine sediments and low dissolved oxygen but do not occur in most parts of the study area (Zaroban et al. 1999). The physiological needs of many sculpin species are generally are similar to those of many salmonids, but their relatively sessile habits make sculpins excellent water quality indicators (Bond 1963). Gagen et al. (1993) reported that mottled and slimy sculpin were better indicators of acidic episodes than were brook trout, although in laboratory exposures the sculpin showed similar or less sensitive responses than the trout. McCormick et al. (1994) reported that sculpin were absent from streams in Colorado with elevated metals concentrations, although trout were present. Mullins (1997) reported that mottled sculpin were absent downstream of municipal treated-sewage discharges, although they were the most abundant species immediately upstream; salmonids showed no such trends. In our data, sculpins were absent or scarce at apparently impacted sites and present at all least-impacted river sites. At more than 30 to 40 percent of the assemblage, further increases in domination by sculpins probably no longer reflects water quality but may reflect habitat limitations for salmonids or perhaps interactions with other fishes. Sculpin diets overlap with those of trout, and when sculpins are abundant may reduce food consumption and production of salmonids (Johnson 1985, Brocksen et al. 1968). Sculpin representation in longitudinal sampling of the least-disturbed Salmon River ranged from 6 –to 80 percent. Sculpin age classes ranged from 3 to 5. Percent sculpin and sculpin age class metrics provide similar information; age class is used as a primary metric because of its smaller variability. Percent sculpin is used as an alternate to the sculpin age class metric if no length-frequency data, from which the number of age classes can be estimated, are reported.

REPRODUCTIVE FUNCTION METRICS

Number of selected salmonid age classes – This metric reflects suitability and stability of conditions in a surveyed location for salmonid spawning, juvenile rearing, and adult salmonids. Shifts in age class distribution are a frequent response to different stressors such as exploitation, recruitment failure, food limitation or niche shifts (Munnkittrick and Dixon 1989). The spawning success of trout, char, and salmon may be limited by excessive siltation because fines embedded in gravels reduce interstitial spaces between the gravel particles, in turn reducing intergravel dissolved oxygen necessary for egg and alevin survival (Chapman 1988, Maret et al. 1993). Salmonid age classes declined with increasing proportions of fine sediments in mountain streams in central Idaho (Mebane 2001).

Mountain whitefish (*Prosopium williamsoni*) were abundant and multiple age classes were present at apparently degraded sites at which other salmonids were absent or rare, and thus may be more resilient than other salmonids are to warm temperatures or low intergravel dissolved oxygen. We included only the redd-building, gravel-spawning salmonid species (trout, char, and salmon) in the metric. Mountain whitefish spawn by broadcasting eggs and milt over gravelly areas, no redd is built nonguarding open substratum, lithopelagophils) (Simon 1999b). Neither whitefish embyros nor larvae appear to utilize intergravel spaces; development occurs in quiescent river backwaters (Northcote and Ennis 1994; Thompson and Davies, 1976). Trout, char, and salmon bury their eggs in redds in gravelly areas (nonguarding brood hiding lithophils) (Simon 1999b). The spawning success of these salmonids may be more sensitive to siltation than is the spawning success of 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.

Numbers of age classes in a sample were estimated from size classes using length-frequency data and average length at age relationships (Table 4-A1).

Table 4-A1. Average (ranges) lengths at age in mm used to estimate salmonid and sculpin age class metrics. Table length at age relationships were compiled primarily from Bond (1963), Gagen et al. (1981), MacPhee (1966), Scott and Crossman (1998), Wydoski and Whitney (1979), and unpublished Idaho Department of Fish and Game records.

		Average length-at-age				
Species (*n* studies)	Species name	1	2	3	4	5
Salmonids						
Brook trout (12)	*Salvelinus fontinalis*	122 (88-164)	195 (142-262)	264 (181-360)	349 (228-400)	
Brown trout (10)	*Salmo trutta*	115 (84-139)	194 (155-216)	269 (228-287)	331 (277-353)	395 (333-391)
Bull trout (11)	*Salvelinus confluentus*	89 (48–165)	149 (97-235)	225 (174-350)	318 (217-404)	404 (320-497)
Cutthroat trout (11)	*Oncorhynchus clarki*	101 (46-160)	189 (129-295)	266 (170-369)	327 (201-430)	390 (254-462)
O. mykiss (24)[a]	*O. mykiss*	106 (74-155)	180 (139-305)	240 (196-432)	311 (198-467)	384 (223-493)
Cottids[b]						
Mottled sculpin (3)	*Cottus bairdi*	43 (36-53)	66 (46-84)	81 (56-109)	97 (71-119)	112 (94-130)
Paiute sculpin	*Cottus beldingi*	33	48	58	71	No estimate
Shorthead sculpin (3)	*Cottus confusus*	43 (25-77)	54 (49-85)	69	82	95
Slimy sculpin	*Cottus cognatus*	41	53	71	84	No estimate
Torrent sculpin (2)	*Cottus rhotheus*	43 (35-50)	67 (58-76)	80 (71-90)	84	100

[a] No differentiation was attempted between the three subspecies of *O. mykiss* occurring in the study area (introduced coastal rainbow trout, native redband trout, and native steelhead trout).
[b] Mottled sculpin values were used to estimate age classes for the following sculpin species which were collected in the study area and for which no length-at-age estimates were located (Wood River sculpin, *C. leiopomus;* and Shoshone sculpin, *C. greenei*)

Number of sculpin age classes – This metric reflects the availability of unembedded cobble substrate required for cavity nesters and for refuge. Sedentary life histories of some sculpin species may result in adult home ranges of only less than 50 to 150 m (Hendricks 1997). These low dispersal distances result in the presence of sculpin likely reflecting site conditions over the previous few years. Sculpin age classes tended to decline with increasing proportions of fine sediments in mountain streams in central Idaho (Mebane 2001). Erman (1986) found that sculpin age class distributions were relatively stable during long term monitoring of a mountain stream, whereas abundances were more variable due to flow patterns. Most of the features of the percent sculpin metric are relevant to this metric also.

Number of cold water individuals per minute of electrofishing (catch per unit effort, CPUE) – This metrics presumes cold water fish should be more abundant at locations with favorable conditions for cold water adapted fishes. Relative abundance needs to be normalized to compare different size habitats, different fishing efforts, and so on. We chose electrofishing time over area or distance to normalize catch, since the latter are difficult to quantitatively estimate in larger waters. Limiting the metric to cold water-adapted individuals appears to avoid the problem where overall fish abundances may increase in response to some types of degraded habitat conditions such as nutrient enrichment (the paradox of enrichment).

The values for this metric should be considered carefully since electrofishing efficiency declines in larger, deeper rivers. Depending upon study objectives, it may be appropriate to exclude the metric if data from waters of markedly different sizes are being compared. If different gear combinations were to be used, the metric would need to be excluded or modified. Populations of salmonids and sculpin have been reported to have large fluctuations, unrelated to physical habitat or water quality changes (Erman 1986, Platts and Nelson 1988). These reports notwithstanding, in most cases in the present test data set, this metric provided useful information about the fish assemblage.

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. The metric excludes protozoan or other parasitic infestations, which are often unrelated to water quality.

Numerous field and laboratory studies on fish have shown that the liver is the most frequent site of neoplasms that were correlated with chemical contamination. While less common, neoplasms of the skin or other epithelial tissues, have been linked to environmental contamination. Etiology of gross external pathological anomalies other than neoplasms are inconsistent and have not been closely linked to chemical contamination (Harshbarger and Clark 1990; Horness et al. 1998). In the data used to develop our IBI, DELT anomalies were about twice as common at sites with significant agricultural development than at reference sites. Also, Sanders et al. (1999) qualitatively associated occurrence of DELT anomalies to pollution sources in Ohio rivers.

DELT anomalies may be a crude measure, however they can be an indication of a serious problem to the aquatic ecosystem. We think the desirability of identifying areas with elevated incidences of cancer or other abnormalities in wild fish outweighs the limitations.

Candidate metrics not used in the RFI

Percent cold water native individuals – The concept is that cold water native fishes will make up a large component of Idaho river systems with high biological integrity; a low representation of cold water species may indicate degraded conditions. However, the information provided and pattern of responses across the upper Snake River Basin was similar to, and thus redundant with the number of native cold water species metric. The latter metric was preferred because fish assemblages are likely more stable in terms of species' presence and absence, than in terms of abundance (Rahel 1990).

Percent nonindigenous individuals – This candidate metric was to reflect the severity of biological pollution of invading or introduced nonindigenous species. However, the sites with highest percentage of nonindigenous individuals (60 to 80 percent) were otherwise little disturbed locations where managers had introduced "desirable" species (Snake River at Yellowstone National Park, Wyoming). The metric was nondiscriminatory in statistical testing between reference and test sites.

Percent catchable trout ("lunker" metric) – The presence of relatively old individuals of a generally intolerant species group could be an indication that satisfactory habitat had persisted over the previous 3 to5 years. This candidate metric also reflects the "fishable" goals of federal and state water quality policies (Hughes and Gammon 1987, Simon and Lyons 1995, Hughes et al. 1998). However, in the data set used to develop our index, the highest percentages (100 percent) occurred at a degraded site (lower Portneuf River). The metric's concept is contrary to aquatic toxicology principles where larger individuals may be less sensitive to chemicals and low dissolved oxygen than juveniles are (Sprague 1995); this metric would also "reward" recruitment failure. Further, the salmonid age class metric in part functionally addresses this concept. The metric was nondiscriminatory in statistical testing between reference and test sites.

Percent fish with total anomalies – The concept of this metric is the same as for DELT anomalies, but is less restrictive. It assumes fish are more likely to develop deformities, tumors, lesions, infections, or parasite burdens in areas with degraded conditions. However, in our data sets, we did not find empirical support for increased parasite burdens in degraded conditions. The highest occurrences of total anomalies (blackspot disease - 65 percent) consistently occurred at a reference site (Snake River at the Yellowstone National Park boundary). The metric was nondiscriminatory in statistical testing between reference and test sites.

ADDENDUM 2. SCORING EQUATIONS OF THE SCORING CURVES

Equations were generated by plotting several points over the expected response ranges and then fitting curves to the points. Curves that could not be accurately described with linear or exponential equations were fitted through repeated polynomial regression or sigmoid logistical functions. (Zar 1984, DeltaPoint 1995).

Trout and sculpin age classes, and the number of non-indigenous species, were scored by discrete values rather than by curves. The curve equations are used in spreadsheet and predefined database queries in order to efficiently score sites.

Metric (x)	**f(x) Metric score**						
Cold water native species	f(x) = 3.333333E-1*x						
Percent sculpin	f(x) = 6.666667E-2*x						
# Sculpin age classes	# Ages	0	1	2	3	4	>4
	Score	0	0.05	0.3	0.75	0.925	1
Percent cold water	f(x) = 1.428571E-2*x						
Percent sensitive native individuals	f(x) = 2.475072E-6*x^3 + -5.387238E-4*x^2 + 3.911333E-2*x + 1.423585E-2						
Percent tolerant individuals	f(x) =(9.877495E-1-6.500219E-3)/(1+(x/4.026224E+1)^7.230386E+0)+ 6.5E-3						
# Non-indigenous species	# Species	0	1	2	3	4	>4
	Score	1	0.5	0.25	0.0625	0.004	0
# Cold water fish captured per minute of electrofishing	f(x) = 1.476804E-2*x^3 + -1.551539E-1*x^2 + 6.421866E-1*x + -2.253135E-2						
Anomalies	f(x) = 1 * exp(-6.907755E-1*x)						
# Trout age classes	# Ages	0	1	2	3	4	>4
	Score	0	0.1	0.5	0.875	1	1
Presence of carp	f(x) = exp(-6.907755E-1*x)						

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Chapter 5.
RIVER DIATOM INDEX

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INTRODUCTION

Although much is known about diatom responses to human-induced degradation, relatively little work has been done, compared to fish and invertebrates, to formalize this knowledge in terms of a monitoring tool for biological assessment of lotic waters, (Rosen 1995, Whitton and Kelly 1995, Davis et al.1996, Hill et al. 2000). This situation is changing rapidly as European countries develop indexes to monitor eutrophication (Kelly and Whitton, 1998) and US monitoring programs incorporate algal sampling into their routine assessments (Rosen 1995, Charles 1996).

The importance of algae to riverine ecology is easily appreciated when one considers their role as primary producers that transform solar energy into food for many invertebrates (Lamberti 1996). In addition, algae transform inorganic nutrients, such as atmospheric nitrogen, into organic forms, such as ammonia and amino acids, that can be used by other organisms (Mulholland 1996). Structurally, algae stabilize the substrate and create mats that form habitat for fish and invertebrates. Some invertebrates use algae to construct cases (Bott 1996).

Algal monitoring has evolved from the early indexes of saprobity (Reid et al. 1995, Lowe and Pan 1996) developed for European streams into a variety of tolerance indexes related to specific stressors (Prygiel and Coste 1993, Kelly and Whitton 1998, Stevenson and Pan 1999). Many studies have linked changes in algal assemblages, particularly diatoms, to changes in water chemistry such as pH, phosphorus, and nitrogen (Carrick, Lowe, and Rotenberry 1988, Pan et al. 1996, Winter and Duthie 2000). Water chemistry variables are meaningful proxy measures for human disturbance in some cases, for example, when nutrient enrichment results from agriculture (McCormick and O'Dell 1996, Pan et al. 1996). For other types of disturbances, chemistry may fail to capture changes associated with loss of instream or riparian vegetation, increased sunlight, or alteration of the flow regime (Barbour, Stribling, and Karr 1995, Karr, Allan and Benke in press). Consequently, other studies have taken a broader view of human influence and tested algal response to more direct measures of human disturbance such as catchment land cover, land use and riparian disturbance (Kutka and Richards 1996, Chessman et al. 1999, Pan et al. 1999, Hill et al. 2000).

The purpose of this study was to determine which attributes of the diatom assemblage were consistently associated with human disturbance, either at the site or catchment scale. We selected diatoms because they dominate algal assemblages in Idaho, are relatively easy to

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identify to species and because much is known about their natural history (Van Dam, Mertens and Sinkeldam 1994, Stevenson and Pan 1999). Our goal was to develop a multimetric index (Karr et al. 1986, Stevenson and Bahls 1999) for diatoms to use alongside similar indexes for fish and invertebrates to assess the biological condition of Idaho rivers under the CWAct (Karr 1991, Ransel 1995, Mebane, 2000).

METHODS

We followed four steps in developing and testing a multimetric index (RDI) for Idaho rivers. First, we defined three geographic regions based on physical features and types of human disturbance. Second, we either ranked sites according to the intensity of human disturbance (southern sites) or we grouped sites according to the type of disturbance (northern sites). Third, we tested metrics in each region and selected metrics that were not redundant to be included in a multimetric index. Last, we evaluated the index in terms of its statistical precision and association with disturbance.

Periphyton Collection and Identification

Periphyton were collected from 49 river sites on 23 rivers from mid-August through late October (typically baseflow period) in 1997 and 1998 (Figure 5-1). In 1999, eight sites were selected for repeat sampling and were sampled twice on the same day in September and once again one month later.

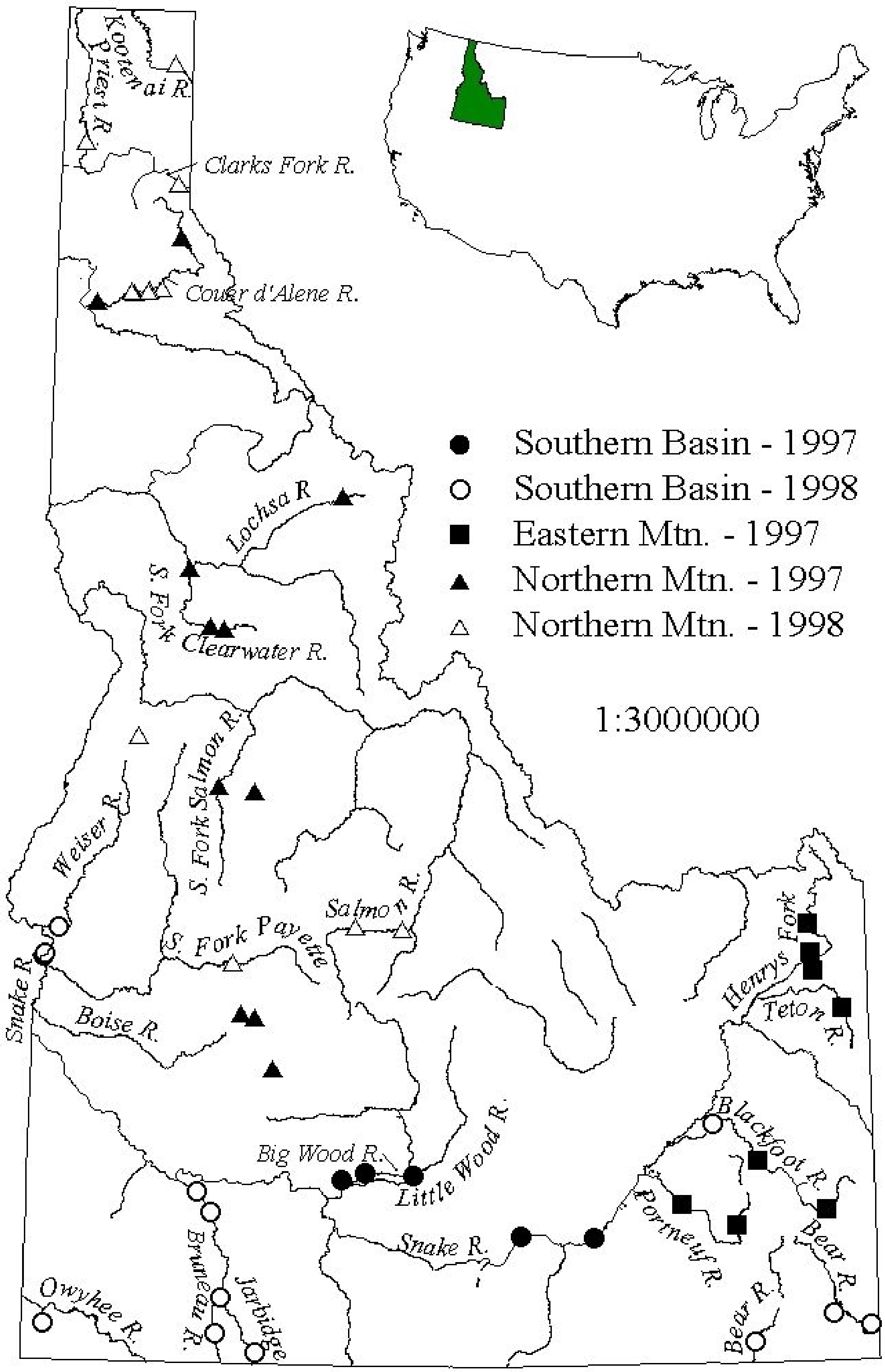

Figure 5-1. River sampling sites, year sampled and geographic region.

Field crews collected periphyton from riffle habitat at three transects located 200 to 300 m apart depending on channel width. Three rocks were collected from each transect at the right, left and center of each transect, for a total of nine rocks. For very deep sites, rocks were collected closer to the river bank. For same-day samples, crew members sampled from the same transect locations, but selected rocks separately. Periphyton were sampled with a brush and syringe from each of the nine rocks and combined for a total sample area of approximately 28 cm^2 (Porter et al. 1993). Samples were preserved with two percent formalin.

In the laboratory, samples were cleaned using nitric acid digestion and a microwave apparatus before slide mounting with Naphrax™. A minimum of 800 valves were counted at 1000x magnification and identified to the level of species where possible. Soft algae were identified in 1997 and 1999 to the level of genus.

Geographic Classification of Sites

We classified sites according to landscape features because human activities followed topography (Omernik and Gallant 1986). We grouped sites from similar ecoregions (Omernik 1995) into three geographic regions: southern basins (18 sites), eastern mountains (eight sites), and northern mountains (23 sites). Southern basins (SB) included 14 sites from the Snake River Basin/High Desert, two from the Wyoming Basin, and two from the Northern Basin and Range. Eastern mountains (EM) and northern mountains (NM) sites were all located in the Northern Rockies ecoregion except for one site in the Middle Rockies. We split this ecoregion into two groups because of the differences in latitude, land cover, and land use. Compared to SB and EM sites, NM sites had less urbanization and agriculture, higher forest cover, and lower temperatures. EM sites had to higher forest cover and higher elevation than SB sites, although intensities of agriculture and urbanization were similar.

Quantifying Human Disturbance

Human disturbance was measured at three spatial scales: the sample reach, 10 km upstream from the site, and the catchment. Measurements at the stream reach included percent erosion; percent fines; and, for riparian vegetation, extensiveness, condition, and predominant type of vegetation on each bank. Chemical variables included temperature, dissolved oxygen, conductivity, and pH. We used principal components analysis to reduce these 12 related measures to a single measure of site condition (PC1-HAB). At a larger scale, field crews noted the types of human activities in an approximate 10 km radius upstream. They also contacted regional land managers to confirm their observations and identify other important activities they might have missed. Activities including forestry, mining, agriculture, grazing, urbanization, channel alteration, and recreation and were noted near the site and further upstream. We summed the number of activities observed as a measure of the intensity of human disturbance.

Satellite data were used to estimate the percent of the catchment area upstream of each site classified as agricultural, developed for urban use, forested, or rangeland. These large river sites had potentially huge land areas in their upstream catchments; therefore, we based calculations on the 4th level hydrologic unit as defined by the USGS (Seaber et al. 1987) rather than the entire upstream catchment. If a site was near the unit boundary, the next upstream unit was also included. The average area upstream used for calculation was approximately 2300 km^2. Although grazing is associated with rangeland, the area of the catchment defined as range was not an indication of grazing intensity. Livestock grazing is an important activity in Idaho and can be very destructive to water resources (Fleischner 1994), but could not be quantified for this study. Similarly, forested area only measured vegetation cover and did not distinguish forest type based on stand age or crown cover.

Identifying Candidate Diatom Metrics

For this study, we distinguished between the terms attribute, candidate metric, and metric. Attribute refers to any feature of the algal assemblage (e.g., diatoms) that is tolerant of polysaprobic conditions. Candidate metric refers to the way in which an attribute is measured (e.g., percent relative abundance of polysaprobic valves). Metrics are promoted from candidacy if they demonstrate a significant correlation with human disturbance. Most attributes could be expressed in more than one way, for example, as taxa richness or percent relative abundance. Percents (e.g., percent motile valves), were calculated as the number of valves in the group of interest, divided by the total number of valves identified. In addition, some candidate metrics were tested for both species and genus-level identification. Thus, 26 attributes were selected from the literature, 55 candidate metrics were tested, and 12 metrics were selected for possible inclusion in the final index.

We tested attributes related to tolerance and intolerance, autecological guild, community structure, morphological guild, and individual condition (Table 5-1).

Table 5-1. Diatom attributes, their predicted response to human disturbance, results of five tests for association with disturbance and level of taxonomic identification used to calculate.
For autecological guild, only the general attribute is listed because significance for number of taxa and percent of valves were typically similar. Metrics considered for inclusion in RDI are underlined. We used Spearman's *r* to test EM and 1998 SB sites; for 1997 SB sites, "agree" indicates $r > 0.6$; and we used the Mann-Whitney U-test for NM sites. (All tests were one-sided; * $P < 0.05$; * $P < 0.025$. Significant results in the *opposite* direction of prediction are marked with an '*X*'.)

Diatom attribute	Predicted response	EM 1997 n=8	SB 1998 n=13	SB 1997 n=5	NM Dist n=10, 6	NM Mining n=10, 7	Level of ID
Tolerance and Intolerance							
Pollution tolerance index [1, 2]	Decrease	* *				* *	Species
% Sensitive individuals [1, 2]	Decrease	* *	*			* *	Species
		*	* *				Genus
No. of sensitive species [1, 2]	Decrease	*				* *	Species
% Tolerant individuals[1, 2]	Increase	* *	*			* *	Species
No. of tolerant species [1, 2]	Increase	*	*				Species
% Very tolerant individuals[1]	Increase	* *	* *	*agree*		* *	Species

Diatom attribute	Predicted response	EM 1997 n=8	SB 1998 n=13	SB 1997 n=5	NM Dist n=10, 6	NM Mining n=10, 7	Level of ID
No. of very tolerant species[1]	Increase		* *	*agree*		* *	Species
Salinity tolerance [3]	Increase	*				*X*	Species
Autecological Guild							
Eutrophic [3, 4]	Increase	*	* *	*agree*	*		Species
	Increase		* *	*agree*		*X*	Genus
Oligotrophic [3]	Decrease					*X*	Species
Nitrogen fixers [5]	Decrease					* *	Genus
Nitrogen heterotrophs [3]	Increase	*	* *	*agree*		*	Species
			*	*agree*			Genus
Polysaprobic [3]	Increase	* *	* *	*agree*	*	* *	Species
Oligosaprobic [3]	Decrease	*				* *	Species
Alkaliphilic [3]	Increase		* *	*agree*	*	*X*	Species
			* *	*agree*			Genus
Require high oxygen [3]	Decrease	*	* *	*agree*	*X*		Species
		* *	*				Genus
Tolerate low oxygen [3]	Increase	* *	*	*agree*		* *	Species
Community Structure							
Total taxa richness [2]	Decrease		*X*	*X*		* *	Species
Diversity index [2]	Decrease					* *	Species
% Dominance (1-5 taxa) [2, 4]	Increase		*X*			* *	Species
Percent *Ach. minutissima* [2]	Increase					* *	Species
Morphological Guilds							
% Motile [1]	Increase	* *	* *	*agree*			Genus
% Moderately motile [6]	Increase	*					Genus
% Very motile [6]	Increase	*	* *	*agree*	*		Genus
% Prostrate [6]	Increase		* *				Genus
% Erect [6]	Decrease			*X*		*X*	Genus
% Stalked [6]	Decrease		* *			* *	Genus
% Unattached [6]	Increase						Genus
Individual condition							
% Deformed cells	Increase					* *	None

Tolerance and intolerance

Species were categorized as sensitive, tolerant or very tolerant according to Bahls (1993), who modified initial assignments by Lange-Bertalot (1979) and Lowe (1974) to reflect diatom responses to disturbance in Montana. Diatom species were defined as generally tolerant to high nutrients (eutrophic), organics (polysaprobic), temperature (euthermal), salts (euhalobus), toxics, suspended solids, or unstable substrate (Bahls 1993).

The pollution tolerance index (PTI) was calculated as the sum over all taxa of the number of valves within each species multiplied by that species' tolerance value. This format is typical for many algae indexes used in Europe (Whitton and Kelly 1995).

Autecological Guilds

Diatom samples from Idaho rivers included taxa listed as tolerant to salt by Van Dam et al. (1994). Evaporation of irrigation water from agricultural fields can leave salt or alkaline residue that is washed into the river by precipitation or irrigation return. We predicted salt tolerant species and relative abundance of salt tolerant valves would increase with agriculture and livestock grazing.

A trophic state refers to the presence of inorganic nutrients such as nitrogen, phosphorus, silica, and carbon; in contrast, saprobity refers to the presence of biodegradable organic matter and high oxygen concentrations (Van Dam et al. 1994). We expected eutrophic and polysaprobic diatoms to increase if inorganic or organic nutrients were present in large amounts. Fertilizer from irrigated fields is one potential source of inorganic nutrient enrichment; livestock excrement and wastewater return are sources of organic waste. In contrast, oligotrophic and oligosaprobic diatoms should decline with disturbances that increase nutrient levels. Although Van Dam et al. (1994) originally classified species as tolerant or intolerant of high or low oxygen levels in the context of organic waste decomposition, this attribute may be applicable for Idaho rivers where dams create stagnate water that is poorly oxygenated.

Diatoms in the genera *Epithemia* and *Rhopalodia* are called nitrogen fixers because they harbor cyanobacteria as endosymbionts that allow them to convert atmospheric nitrogen into more biologically useful forms such as ammonia (Mulholland 1996). Diatoms classified as nitrogen heterotrophs can use amino acids created by other organisms as sources of carbon and nitrogen (Tuchman 1996). Thus, nitrogen fixers should decline and nitrogen heterotrophs should increase with disturbances that increase organic nitrogen.

Many diatoms are known to be specifically sensitive to acidic or alkaline conditions. In southern basins, agriculture on alkaline soils can cause erosion which may increase alkalinity of rivers. Irrigation and fertilization can also increase alkalinity of soils. For this type of disturbance, we expected alkaliphilic diatoms to increase. Overall, Idaho river sites tended toward alkalinity, pH values ranged from 6.5 to 9.1, and only two sites were below neutral (7.0). Consequently, acidophilic taxa may not be common in these rivers. This attribute was included for testing because of its potential sensitivity to acid mine waste.

Community Structure

Human activities that increase silt and sediment often reduce habitat complexity which can lead to a decline in biodiversity and dominance by a few tolerant taxa. Dominance was calculated as the percent relative abundance of the single most abundant species; dominance was also calculated as the sum of the two through five most abundant species present in the sample. *Achnanthes minutissima* is a common diatom associated with scouring. A high relative abundance of this species may indicate recent disturbance by extreme flows such as those caused by a dam release or excessive run-off from developed areas (Stevenson and Bahls 1999).

Morphological Structure Guilds

Motile diatoms include species that can move across unstable substrate without being buried; thus, they are somewhat tolerant of silt. We expected them to increase as sediment increased. We tested percent motile diatoms in three ways, all calculated at the genus level. We tested very motile genera (*Cymatopleura*, *Gyrosigma, Hantzschia, Nitzschia, Stenopterobia,* and *Surirella*), moderately motile genera (all genera with a raphe, excluding very motile genera), andgenera listed in Bahls' (1993) siltation tolerant index (*Navicula, Nitzschia* and *Surirella*).

Algal mats are hypothesized to follow a pattern of succession (McCormick 1996, Peterson 1996) that may begin with high spring flows carrying sediment that scour the substrate. The first algae that attach to the scoured surface attach along their length (prostrate); they are followed by algae that attach apically (adnate). Next are algae that attach perpendicular to the substrate (erect); last are the stalked and filamentous algae that are typically taller and cannot tolerate fast current (Kutka and Richards 1996). Diatom genera were assigned to morphological guilds based on how cells attach to the substrate and each other (Round et al. 1990, Stevenson 2000). Morphological attributes were only tested as percents because the physical structure of the assemblage depends more on the percent of valves of each type than the presence of a particular taxon.

Individual Condition

Cell deformities have been associated with contamination by heavy metals and should increase with this type of disturbance (McFarland, Hill, Willingham 1997). This attribute was only calculated for 1998 and 1999 samples.

Criteria for Metric Selection

Metrics selected for RDI satisfied three criteria: (1) they were significantly associated with disturbance in at least two geographic regions, (2) they responded to disturbance in the predicted direction, and (3) they were not redundant with other metrics.

For SB and EM sites, we tested for significant correlation (Spearman's r) of candidate metrics against a gradient of human disturbance measured as the total number of human activities (NUM_ACT) near the site. We selected this measures for two reasons. First, it was significantly correlated (Spearman's r, $p < 0.05$) with measures of disturbance made at the reach scale (PC1-HAB) and the catchment scale (percent agriculture, forested, and urban land cover). Second, NUM_ACT represented a compromise between site scale and catchment scale measures of human influence.

For NM sites, a gradient could not be defined for testing because the range of disturbance was not as broad as it was for SB and EM sites. Instead, we defined three site groups based on the type and intensity of disturbance and tested for significant differences between groups (Mann-Whitney U-test). The first group was made of ten sites with low, or minimal, disturbance that were influenced by timber harvest and a small amount (less than 0.4 percent) of urbanization in the catchment. The second group was moderately disturbed and included four sites with agriculture or urbanization greater than 0.4 percent, one site with very high levels of timber harvest, and one with a large hydropower facility that severely altered daily peak flows. The third group included seven sites with a history of silver mining upstream that are still contaminated by heavy metals, particularly zinc (Farag et al. 1999). Six of the seven mining sites were on the Coeur d'Alene River; therefore, the data were not independent. Consequently, significant differences should not be generalized to other rivers without additional testing.

We tested candidate metrics for their association with disturbance using five independent tests including two tests for the SB region (1997 and 1998), one test for the EM region, and two tests for the NM region (low vs. moderate disturbance and low vs. mining disturbance). We used multiple tests because some significant correlations are expected due to chance when testing a large number of hypotheses; the percent of significant results expected by chance is equal to the alpha-level of the test. Multiple, independent tests insure that observed patterns are broadly applicable and are not unique to the data set in hand. In this case, five percent of 55 tests (the number of candidate metrics tested) is approximately three, or one-quarter of the 12 metrics ultimately selected. By restricting our selection to those candidate metrics that satisfied two independent tests of significance, significance due to chance alone declines to 0.25 percent of 55, or much less than one.

We used one-sided tests in all cases because we were testing specific predictions about how diatom attributes should change in response to human disturbance. One-sided tests increased the power of the test to detect differences.

Some pairs of metrics were redundant either because they measured the same attribute or they were based on the same taxa. In each case, we selected the metric that was significant for the most tests and did not include the other metric in the index.

Constructing a Multimetric Index

Metrics were combined into an overall multimetric index, the RDI. Metrics were rescaled using scoring criteria because each metric had a different range of potential values. Scoring criteria were based on the cumulative distribution plots of metric values. We assumed that rivers sampled for this data set were evenly spread across a gradient of human disturbance and defined scoring breaks to follow the percentiles of the distributions of metric values. Our assumption may not be correct and scoring criteria should be reevaluated as more data are collected.

We scored metrics using two different sets of scoring criteria, based on three and 10 scoring categories. We compared the two versions of the RDI to determine whether the scoring method affected the precision of the index. For both versions of the RDI, larger values indicated better biological conditions.

Evaluating the Statistical Properties of the Index

Eight sites were sampled three times in 1999 and once in a previous year. For both versions of the RDI and for eight of its nine component metrics, we used an Anova model to estimate the proportion of the total variance associated with site differences, transect location within sites, and time of sampling.

Using the estimates for mean squared error from the preceding Anova models, we also estimated the number of categories of biological condition that the RDI could reliably detect based on the minimum detectable difference, or MDD (Zar 1984). We used a simple statistical model, a two-sample *t*-test with three replicates, and commonly accepted values for alpha of 0.05 and power (1 – beta) of 0.80 (Peterman 1990, Carlisle and Clements 1999). This model answers the question, "How large a difference between RDI values do we have an 80 percent chance of detecting with a *p*-value < 0.05?" We divided the possible range of the RDI by the MDD to obtain the number of distinct categories of biological condition the RDI could detect (Fore et al. 1994, Fore et al. in press).

RESULTS

We developed a multimetric index for periphyton based on diatoms because they dominated the field samples. We selected nine metrics for the RDI that showed a consistent association with disturbance in different regions and used species level rather than genus level identification where possible. We scored metrics based on three rather than 10 scoring categories because it was simpler and did not affect the precision of the RDI. Measurement error of the RDI and its component metrics was higher for differences associated with time rather than location of sampling. The RDI could reliably detect three levels of biological conditions based on annual sampling and may be more precise if sampling were restricted to the same month each year.

Algae Sampling

Periphyton sampling yielded 350 diatom species in 46 genera. The most abundant species, *Achnanthes minutissima*, was found at every site. Many species were rare; only a single valve was found for 11 percent of the species. For soft algae, 27 genera were identified in 1997 with *Calothrix sp*. present at the most sites. We did not test attributes based on soft algae because very few genera were collected at each site (2.7 on average) and many sites had none. Samples collected in eastern Washington showed a similar pattern where 77 to 97 percent of the taxa collected were diatoms (Cuffney et al. 1997).

Averaging across sites, about 10 species per sample, or 15 percent of the individual valves, were not listed by Van Dam et al. (1994). We did not have autecological information for these species. For SB and EM sites, neither the number of unassigned species nor the percent of unassigned valves was correlated with human disturbance. In contrast, for the NM region, significantly more unidentified species were found at less disturbed sites.

Metric Response to Disturbance

Of the 26 attributes tested, 12 were consistently associated with human disturbance across the state (see Table 5-1). Eight metrics were associated with disturbance in all three regions:

percent sensitive valves, percent tolerant valves, percent very tolerant valves, number of eutrophic species, percent nitrogen heterotrophs, percent polysaprobic valves, number of low oxygen species, and percent very motile valves. Three metrics were significantly in two regions (usually SB and EM): number of alkaliphilic species, percent high oxygen valves, and percent motile valves. For percent deformed cells, only mining sites had higher values in the NM region.

Results of testing in the EM region and for two years in the SB region tended to agree for most candidate metrics, probably because similar types of human disturbance were common in both regions. Percent sensitive and high oxygen valves declined with increasing disturbance; percent very tolerant, polysaprobic, nitrogen heterotroph, and very motile valves, and the number of alkaliphilic and eutrophic species increased with disturbance (Figure 5-2).

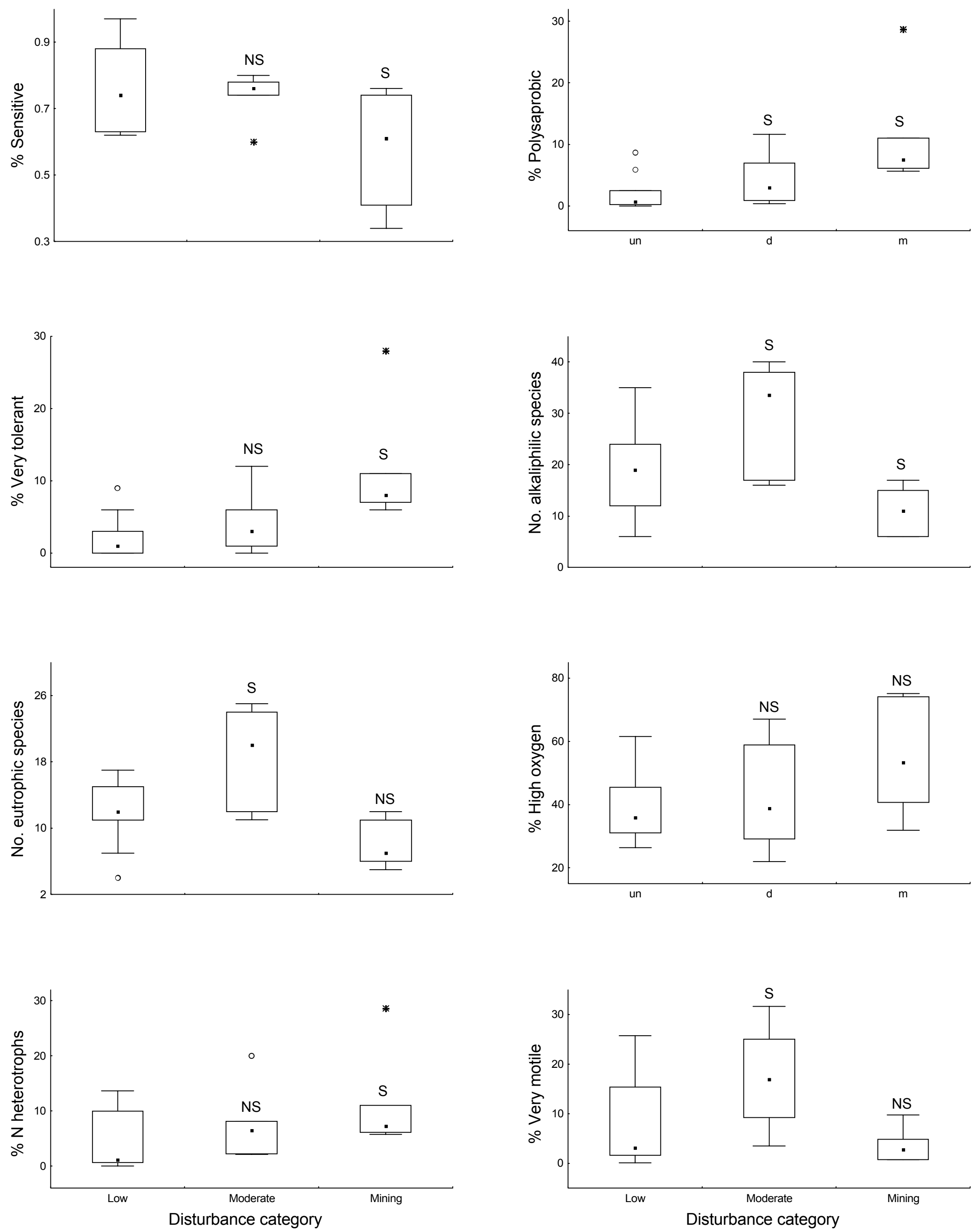

Figure 5-2. Eight diatom metrics associated with human disturbance.
Eight diatom metrics were significantly associated with human disturbance measured as the number of human activities within 10 km of the site. Least-squares regression lines drawn separately for SB (open circles) and EM (solid triangles) sites. For three metrics in the SB region, regression lines differed by year and are drawn separately for each year.

In the NM region, somewhat fewer candidate metrics were significantly associated with disturbance and those that were tended to be significantly associated with either moderate disturbance or mining disturbance, but not both (Figure 5-3). Percent sensitive valves were significantly lower, and percent polysaprobic, very tolerant, and nitrogen heterotroph valves were higher at mining sites. For moderately disturbed sites, percent polysaprobic and very motile valves and number of eutrophic species increased with disturbance. The number of alkaliphilic species was significantly higher for moderately disturbed sites (as predicted), but significantly lower for mining sites, probably due to acidic mine waste.

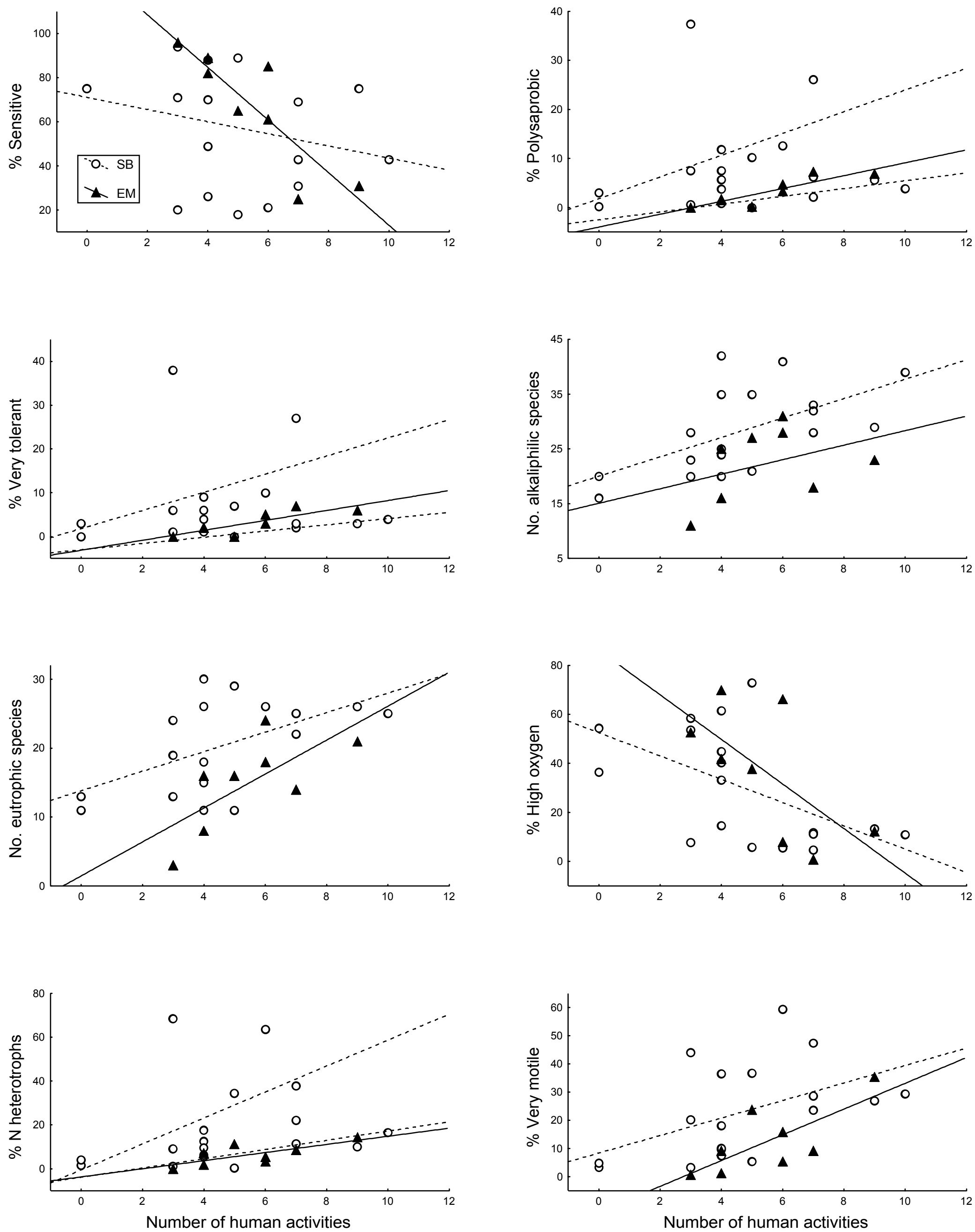

Figure 5-3. Comparison of eight metrics for groups of sites classified as low human disturbance, moderate disturbance and mining disturbance in the NM region.
The outlier in the mining group for percent very tolerant, nitrogen heterotrophs and polysaprobic was a site just downstream of a wastewater treatment plant. Boxes marked with an "S" were significantly different from the low disturbance groups; "NS" means not significantly different (Mann-Whitney U-test).

When sites from all regions were combined, metrics were significantly associated with measures of human disturbance made at the reach scale, 10 km upstream, and at the catchment scale (Table 5-2). Of the site scale measures, metrics were most frequently associated with percent fines and the derived variable, PC1-HAB. At a larger scale, metrics tended to associate more closely with urbanization and agriculture than forested areas. Number of eutrophic species and percent very motile were significantly correlated with the greatest number of measures of human disturbance.

Table 5-2. Diatom metrics correlated with measures of disturbance.
Diatom metrics were correlated (Speaman's *r*) with measures of disturbance made at the reach (temperature, conductivity, percent fines and PC1-HAB), 10 km upstream (number of human activities), and the catchment (percent urban, agriculture and forested land cover) for 49 river sites. (* $P < 0.05$; ** $P < 0.01$.)

Metric	**Temp**	**Cond**	**pH**	**%Fines**	**PC1-Hab**	**Num_Act**	**% Urb**	**% Ag**	**% For**
% Sensitive				-0.35 *	-0.44 **	-0.40 **			
% V. Tolerant	0.43 **			0.39 **	0.49 **				
Eutrophic species		0.41 **	0.38 **	0.33 *	0.38 **	0.33 *	0.29 *	0.56 **	-0.39 **
% N heterotrophs				0.40 **	0.40 **	0.37 **	0.38 **	0.35 *	
% Polysaprobic	0.40 **			0.38 **	0.51 **		0.31 *		
Alkaliphilic species		0.29 *	0.43 **					0.51 **	-0.37 **
% High oxygen			-0.31 *		-0.32 *	-0.28 *		-0.40 **	
% V. motile			0.29 *	0.33 *	0.34 *	0.35 **	0.34 *	0.57 **	-0.29 *
RDI		-0.38 **		-0.39 **	-0.50 **	-0.38 **	-0.38 **	-0.40 **	

Metric Selection for the RDI

Of the 12 metrics, three pairs were redundant. Most of the species that were tolerant of low oxygen were also polysaprobic. We chose the polysaprobic metric because it was significantly associated with disturbance in more regions. Two other pairs of metrics, percent tolerant and percent very tolerant, and percent motile and percent very motile were redundant conceptually. For these metrics, the more specific version was chosen. Some of the remaining metrics were significantly correlated with each other but were retained for the index because they were each derived from a different set of species.

Although metrics based on identification to genus may be easier to calculate (Hill et al. in press, Chessman et al. 1999), we selected species level versions of the metrics where possible because they tended to have more significant associations with disturbance. For some attributes, genus level assignments could not be made because too few species within large genera defined the attribute (e.g., percent very tolerant and high oxygen individuals). Only percent very motile was calculated at the genus level.

We selected nine metrics for RDI representing biological information related to tolerance and intolerance, autecological guild, morphological guild, and individual condition. No metrics related to community structure were selected because they were only associated with disturbance related to mining in the NM region.

Index performance

A reliable multimetric index should be influenced more by site differences than by sampling location or time of sampling at the site. We used components of variance analysis to compare the relative influence of site differences, time of sampling, and location of sampling on the variability of the RDI (Figure 5-4). Site differences contributed by far the largest component (73 percent) to the overall variability of the RDI indicating that the RDI was sensitive to differences in site conditions that it was designed to measure. Variability associated with sampling location within the reach was very small (1 percent of the total variance). Variability associated with specific months (i.e., September versus October) was also very small (1 percent); however, variability associated with the interaction of month with site was relatively large (25 percent). The small relative variance associated with specific months means that there was no systematic change in the RDI associated with season; in other words, the RDI was not consistently higher in October. The larger interaction effect means that sites varied in different ways across the sampling season; specifically, the RDI improved for later samples collected at sites with large agricultural areas in their upstream catchments (five out of eight sites). For same-day samples, the RDI differed by one point on average, or three percent of its potential range from 9 to 45.

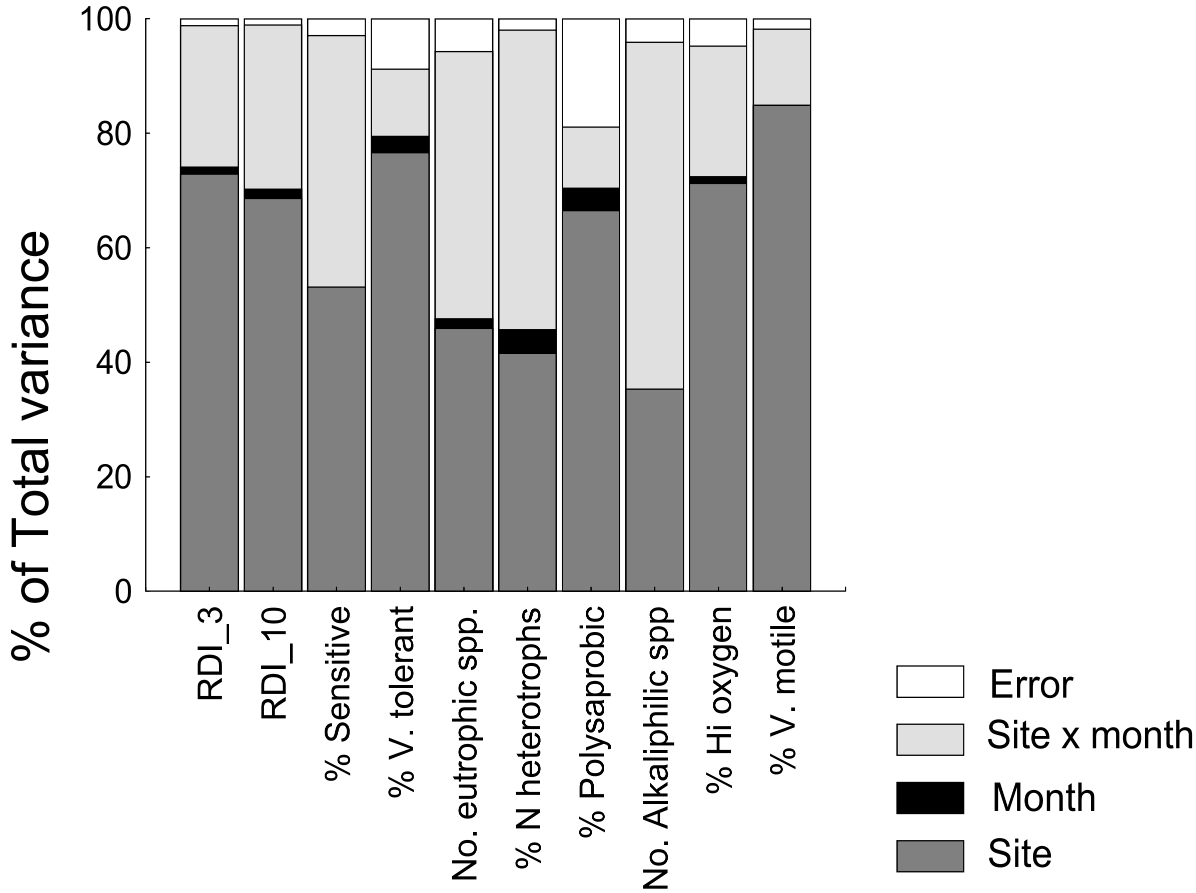

Figure 5-4. Components of variance for two versions of the river diatom index. Based on three (RDI_3) or ten (RDI_10) scoring categories and nine component metrics. Variability associated with site differences, e.g., human disturbance, was highest for RDI and five of the metrics. Samples taken during different months varied more by site (interaction of site and month) than according to time of year (month). Measurement error associated with samples taken on the same day was very low for all measures.

At one site, a thick algal mat was observed only on the second sampling occasion, yet the RDI score changed by only two points. Another site was influenced by a high flow event (dam release) between sampling occasions, but the RDI score differed again by only two points. These observations provide anecdotal evidence that the RDI score was not much affected by unusual events of short duration.

For the component metrics, site differences and the interaction of site and month contributed much more to the overall variability than did transect location or specific month. Compared to its component metrics, the RDI was more precise. This is typical of multimetric indexes because they function mathematically like averages (Fore et al. 1994).

Measurement error was very similar for the two versions of RDI based on three and 10 scoring categories. For the sake of simplicity, we selected the more traditional version (Karr, 1981) based on three categories (Table 5-3).

Table 5-3. Biological metrics for the river diatom index, RDI, response to human disturbance and scoring criteria used to re-scale metric values.

		Scoring criteria		
Metric	**Response**	**1**	**3**	**5**
Tolerance and intolerance				
% Sensitive	Decrease	< 60	(60, 80)	> 80
% Very tolerant	Increase	> 15	(3, 15)	< 3
Autecological guild				
Eutrophic species richness	Increase	> 20	(12, 20)	< 12
% Nitrogen heterotrophs	Increase	> 20	(7, 20)	< 7
% Polysaprobic	Increase	> 10	(5, 10)	< 5
Alkaliphilic species richness	Increase	> 30	(18, 30)	< 18
% High oxygen	Decrease	< 25	(25, 55)	> 55
Morphometric guild				
% Very motile	Increase	> 25	(7, 25)	< 7
Individual condition				
% Deformed cells	Increase	> 1	(0, 1)	0

We calculated the number of distinct categories of biological condition that the RDI could reliably detect for three different sampling scenarios. Each scenario used 16 values for the RDI (eight sites x two repeat visits); but in each case, repeat visits were defined differently. For the first scenario, we used same-day samples to estimate mean squared error. For the second scenario, we averaged the RDI scores from September same-day samples to obtain a single RDI value for September and used October samples as repeat visits. The third scenario used one RDI value from the previous year and averaged the three values from 1999.

Results

RDI could reliably detect 11.9 categories of biological condition when repeat samples collected on the same day were used as replicates (Table 5-4). When monthly repeat visits were used as replicates (with same-day samples averaged), RDI was much less precise and could detect 2.5 categories of biological condition (Figure 5-5). When annual repeat visits were used as replicates (with same-year samples averaged), the results were similar and RDI could detect 2.7 categories. Based on these results we defined the following three categories of biological condition for diatom assemblages:

<22 Poor
22-34 Moderate
34-45 Good

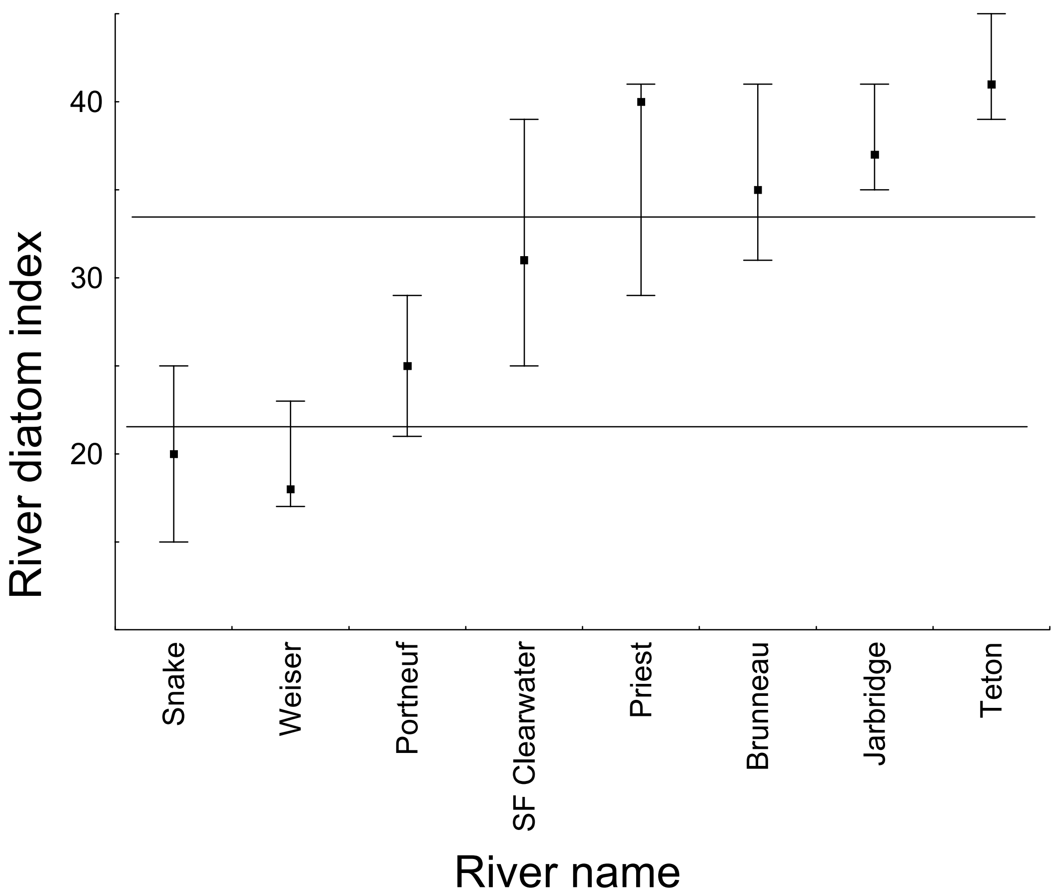

Figure 5-5. Range of values for RDI for eight sites sampled three times in 1999 and once in a previous year.
Horizontal lines indicate categories of biological condition (good, fair and poor) that RDI can reliably detect for comparisons across years. (For comparisons within years, see text.)

Table 5-4. Measurement error of RDI.
This was calculated for three types of repeat visits collected on the same day, during different months and during different years. Index variability was summarized as mean squared error from Anova, percent error relative to variability associated with site differences, and in terms of the number of distinct categories the RDI could detect. For all comparisons, n = 16.

Type of repeat samples	**Mean squared error**	**Percent error**	**Categories**
Same day	1.0	1.0	11.9
Different months	22.8	29.2	2.5
Different years	19.2	22.3	2.7

The RDI was only significantly correlated with measures of natural variability if the measure was also correlated with human disturbance (Table 5-5). The RDI was not correlated with latitude, elevation, channel width, temperature, or pH. The RDI was significantly correlated with stream order, channel slope, and channel depth; but these measures were also significantly correlated with the number of human activities, and in most cases, with each other.

Table 5-5. Correlation of RDI and number of human activities.
Correlation (Spearman's *r*) of RDI and number of human activities with geographic features (latitude and elevation); channel features (order, channel slope, depth and width); and water chemistry (temperature and pH) for 49 river sites. (* $P < 0.05$; ** $P < 0.01$.)

	Lat.	**Elev.**	**Order**	**Slope**	**Depth**	**Width**	**Temp.**	**pH**
RDI			-0.53 **	0.44 **	-0.36 **			
No. of activities	-0.28 *		0.34 **	-0.36 **	0.45 **		-0.35 **	

At the catchment scale, the RDI was most closely associated with agricultural land use in the SB region and with forested area in the EM region (Figure 5-6). For the NM region, catchment scale measures of disturbance varied little and could not be used to evaluate the RDI. Instead, we used the disturbance categories used initially to test the metrics and found that the RDI was lower for both moderately- and mining-disturbed sites.

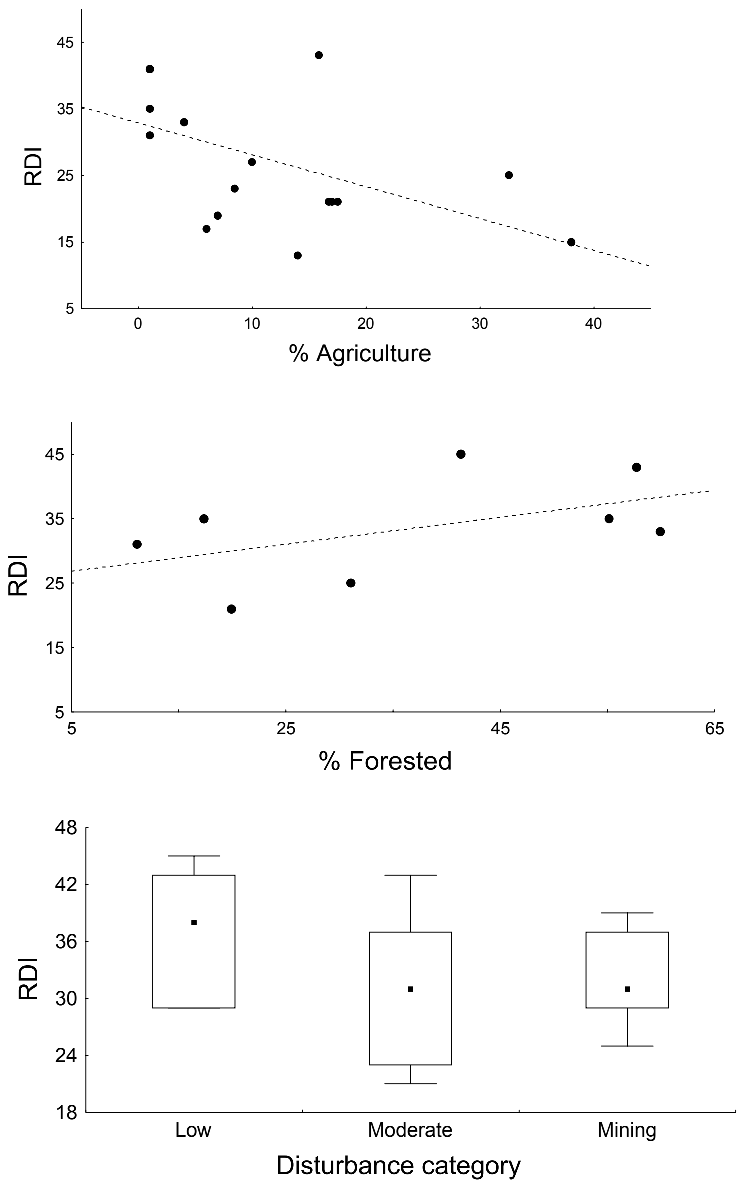

Figure 5-6. Decline and increase of RDI values.
For SB sites, RDI values declined as agricultural area in the catchment increased (upper panel). For EM sites, RDI values increased with forested area (middle panel). Lines are least-squares approximations. For NM sites, RDI was lower for both moderately disturbed and mining disturbed sites.

DISCUSSION

For Idaho rivers, changes in the diatom assemblage were strongly associated with human land use, measured at both the reach and the catchment scale. Diatoms noted as sensitive or tolerant to disturbance in other regions (Lange-Bertalot 1979, Bahls 1993) showed similar responses in Idaho. Several attributes related to autecological guild also shifted at disturbed sites where more eutrophic and alkaliphilic species, more nitrogen heterotrophs, and more polysaprobic valves were found. Shifts in the diatom assemblage related to agriculture (Leland 1995, McCormick and O'Dell 1996, Cuffney et al. 1997, Pan et al. 1999), alkalinity (Chessman et al. 1999) and organic pollution (Kelly, Penny, and Whitton 1995, Rott, Duthie, and Pipp 1998) have been documented by other studies as well. As predicted by others (Bahls 1993, Kutka and Richards 1996), an increase in silt and sediment was reflected by an increase in motile diatoms that can move across the substrate and avoid being buried by shifting sand. Total taxon richness declined at mining sites similar to other studies (Genter and Lehman 2000, Verb and Vis 2000), but was not significantly associated with other disturbances; therefore, we did not include it in the RDI. Inconsistent response to disturbance in other studies has been reviewed by Hill et al. (in press). Our results support the idea that total taxa richness only declines at intense levels of disturbance (Chessman et al. 1999).

The structure of the RDI differs from many other diatom indexes because it includes multiple measures of biological condition based on general tolerance, autecological guild, morphological guild, and individual condition. Other indexes typically summarize the sensitivity of each taxon to a single type of biological change such as eutrophication or saprobity (Prygiel and Costa 1993, Kelly et al. 1995). Multimetric indexes include measures from different levels of biological organization in order to be responsive to many types of disturbance and to be regionally applicable. In contrast, the component metrics can respond independently to different types of disturbance and suites of metrics and may define a "signature" for a particular type of disturbance (Yoder and Rankin 1995). In our study, mining sites had fewer sensitive valves, fewer eutrophic and alkaliphilic species, and more deformed valves than sites with other types of disturbance. Pan and Stevenson (1996) made a similar distinction between wetland sites affected by mining and agriculture. Though not included as metrics, an increase in the number of oligotrophic and oligosaprobic species at mining sites further supports the idea that metals, such as zinc, affect diatoms differently by interfering with the uptake of phosphorus (Kuwabara 1985).

Although polysaprobic and eutrophic diatoms are both influenced by enrichment, different taxa may distinguish between different sources. Our land use information was not sufficient to test this idea; but other studies have used diatoms to distinguish between organic and inorganic effluent (Kelly 1998, Rott et al. 1998). These distinctions are useful when regulating and managing human use.

In a regulatory context, changes in the biological assemblage related to human activities must be clearly distinguished from changes associated with natural variability (Howlin, Hughes, and Kaufmann in press). We used multiple, independent tests in three geographic regions to insure that the selected metrics were robust indicators of the various types of disturbance common in Idaho. Across regions, the same attributes tended to correlate with disturbance, indicating that the selected metrics were not greatly influenced by geographic differences. Pan et al. (2000) also found that human disturbance was more important in structuring diatom assemblages than ecoregional differences. Furthermore, the RDI was not correlated with latitude, elevation, channel width, temperature, or pH. The RDI were, however, significantly lower at higher order sites that were deeper and had lower gradients; but these sites also tended to have more intense disturbance. We conclude for our data that the RDI was only associated with natural features when they in turn influenced patterns of human land use; otherwise, the RDI was not associated with measures of natural variability.

Sampling and Analysis Protocol for Diatoms

A robust monitoring tool should be sensitive to site differences associated with human disturbance but not much affected by small differences in location or time of sampling (Fore et al. 1994, Barbour et al. 1999, Kaufmann et al. 1999). RDI values for same-day samples differed by only three percent indicating that the current sampling protocol yields precise measures of the diatom assemblage and that neither the number of valves nor the area sampled needs to be increased. In addition, replicate same-day samples are not necessary. On the other hand, variability associated with time of sampling was much higher (22 to 29 percent). In comparison, a multimetric index for stream invertebrates showed the opposite pattern, with about 10 percent of the variability in index values associated with different sampling locations within the same reach and zero percent of the variability associated with time of sampling (Fore et al. in press). These differences are probably due to the greater mobility and longer life cycles of invertebrates.

Our sample size was too small (eight sites) to determine whether changes in RDI through time stemmed from natural seasonal shifts in the diatom assemblage or from changes in human activity. Agriculture took place in the upstream catchment of five of the eight sites and RDI increased for all five from September to October. At that time of year, irrigation, fertilization and herbicide application all cease while crops are harvested; thus, diatom assemblages may well reflect real changes in human land use. It would be more accurate to use only reference sites to estimate the influence of seasonality on RDI values, but large river sites with little or no human influence are difficult to find.

Quantifying Human Disturbance

The method used to quantify human disturbance is necessarily specific to the geographic region of interest because physical processes and features determine what types of human activities are possible (e.g., farming in river valleys and timber harvest on mountain slopes) (Omernick and Gallant 1986). The number of human activities was a reasonable measure of human influence in southern Idaho because different types of human activities tended to cluster together. Strong correlation between urban and agricultural land cover supported the idea that much of the economy in southern Idaho is based on agriculture. In northern Idaho, human activities were not as strongly clustered geographically.

For this study, our measures of disturbance were approximate at best. We evaluated the association of diatom metrics with multiple measures of human disturbance because human activities degrade catchments and surface waters in diverse ways: by altering or destroying the natural habit, disrupting energy cycles, modifying flow regimes, releasing chemicals, and propagating alien species (Karr et al. 2000). In the course of relating diatom attributes to human disturbance, we could estimate the measurement error associated with the biological metrics and index; but on the other side of the equation, the error associated with measures of disturbance could not be quantified or mitigated.

At the catchment level, livestock grazing was common and pervasive, but could not be quantified for this study. Livestock grazing can be very damaging to river ecosystems by causing erosion, loss of riparian cover, nutrient enrichment from excrement, and loss of instream habitat (Armour, Duff, Elmore 1994, Fleischner 1994). The influence of disturbance in the catchment area further upstream may also be important but was not considered for these rivers because of their large size. At the reach scale, water chemistry information was not available and we could not assess the relative influence of nitrogen, phosphorus, or heavy metals. Sorting out the relative influence of different human activities (Richards, Johnson, and Host 1996, Roth, Allan, and Erickson 1996) may be more easily accomplished for smaller streams where different activities are isolated within catchments.

Statistical Considerations

Diatom samples used in statistical testing were not necessarily independent because more than one sample site was located on some rivers. Statistical testing assumes independence because correlation and significance can be inflated when values are similar due to physical proximity rather than the independent factors being tested (Hurlbert 1984, Dunham and Vinyard 1997). The average range in RDI values for different sites on the same river system was 11 (out of a possible 36) points, indicating that sites located on the same river could have quite different RDI values; in one case, two sites differed by 32 points. This does not prove independence, but supports the idea that biological condition was not constrained by upstream conditions and could vary in response to human activities near the site. We elected to include all the sites in the statistical tests for two reasons. First, sites were at least 2 km apart and often much farther (greater than 50 km). Second, a sufficiently large sample size is difficult to obtain for rivers of this size.

Lack of independence was much more of a concern for mining sites in the NM region because six of the seven sites were located along an approximately 40 km section of the Coeur d'Alene River. We reported the results for three reasons: the data set was adequate to characterize the changes in the diatom assemblage if not provide a specific test, the differences associated with these sites were dramatic and suggest that diatoms may be very robust indicators of metal contamination, and biological endpoints are in great demand for assessing the remediation of abandoned mine sites (Clements et al. 2000).

Diatoms as Indicators

Fish, invertebrates, and diatoms represent different trophic levels and integrate environmental conditions over different temporal and spatial scales. Therefore, we expect them to be affected differently by different types of disturbance (Allen et al. 1999). For example, physical barriers such as dams are probably more disruptive to fish populations than to diatoms. On the other hand, heavy metal concentrations that eliminate many diatoms may be tolerated by fish that can travel further to refugia. For rivers in Idaho, diatoms may represent a biological alternative to fish when sites are too deep to effectively sample fish or when endangered and protected species prohibit sampling entirely. In contrast with longer-lived organisms, the quick response of diatoms to riverine conditions makes them an excellent tool for evaluating and comparing management practices within a year or season. Finally, in cases where chemical and biological information disagree about site condition, diatoms may provide clues for resolving the conflict because of their sensitivity to water chemistry and their nature as living organisms.

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Chapter 6.
RIVER PHYSIOCHEMICAL INDEX

Darren Brandt[10]

INTRODUCTION

Water quality indexes were developed in the 1970s and used through the 1980s to interpret conventional physiochemical water data (EPA-STORET WQI, Peterson 1980; OWQI, Dunnette 2000, 1980 NFS WQI McClelland 1974, DEQ 1989). For instance, DEQ used the WQI (EPA STORET data) for the 1988 and 1992 305(b) reports (DEQ 1989,1992). DEQ discontinued using the WQI when the BURP program was developed. At the time, bioassessment information was considered a better indicator of water quality than limited chemical data. This assumption has worked well for small wadeable streams; however, as the team began to assess large and medium rivers it became apparent that water chemistry data could be very valuable as a supplemental data source to biological data.

Therefore, the large river assessment team investigated various WQIs that might be applicable to Idaho streams. After investigating several different indices, the team decided to use the Oregon Water Quality Index (OWQI) as an interim index until Idaho could develop a WQI that was tailored to Idaho streams. The River Physicochemical Index (RPI) is based on the OWQI[11]. This index has been tested and used extensively in Oregon to assess water quality conditions (Cude 1998).

METHODS AND RESULTS

Oregon Water Quality Index

The OWQI uses eight water quality parameters to determine the condition of a water body (Table 6-1). The sub-index scores for each of the variables are calculated using complex regressions for data that falls within a set range for each of the variables and threshold scores for data outside of that range. The range of potential values for each sub-index is from 10 to 100. The regression for each of these parameters can be found in Appendix F (Cude 1998).

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[11] Since the working definition of "water quality" has been expanded through the 1990s to include biological conditions, the term "River Physiochemical Index" (RPI) more accurately describes this index and is used in favor of the original term "water quality index."

Table 6-1. Water quality parameters used in the OWQI

Temperature	Total solids
Dissolved oxygen	Ammonia + nitrate nitrogen
Biochemical oxygen demand	Total phosphorus
pH	Fecal coliform

The individual sub-indexes are then averaged to give a single index value. There are several methods of calculating central tendency. The most common methods are used to determine the arithmetic mean and the geometric mean. The geometric mean is usually used where there is a large amount of between-sample variability. The geometric mean will always return a mean score lower than the arithmetic mean. For samples with even greater variability or where it is important for rare but important low values to have more weight, one can calculate either the harmonic mean or the harmonic square mean. Of these two methods, the harmonic square mean is the most sensitve to low values in the data set. The OWQI uses the harmonic square mean method for determining central tendency. The harmonic square mean is similar to the calculation of a harmonic mean except that a step is added in the calulation process that squares individual values before summing them. The product is then back transformed to derive the harmonic square mean. The equations for the harmonic mean and the harmonic square mean are as follows.

$$\textit{Harmonic Mean} = \frac{n}{\sum_{i=1}^{n} \frac{1}{SI}} \qquad \textit{Harmonic Square Mean} = \sqrt{\frac{n}{\sum_{i=1}^{n} \frac{1}{SI_i^2}}}$$

Where SI is the individual sub-index scores.

Both the harmonic mean and harmonic square mean methods are designed to give a greater response to changes in a single variable than other methods of calculating means. The OWQI uses the harmonic square mean rather than other measures of central tendency to insure that a single poor sub-index score carries more weight in the calculation than high scores. This insures that final scores are weighted in favor of environmental protection. An illustration of the effect of using different procedures for calculating central tendency can be seen in Table 6-2. As you can see, the harmonic square mean is much more conservative and responsive to a single low value than any of the other methods considered.

Table 6-2. Procedures for calculating central tendency.
The mean of the following data series using four different methods to calculate central tendency (10, 90, 90, 90, 90, 90, 90, 90).

Arithmetic Mean	Geometric Mean	Harmonic Mean	Harmonic Square Mean
80	68	45	27

Index Testing on Idaho Rivers

Prior to using the OWQI, we determined that it was necessary to test the index on Idaho rivers. The OWQI as described by Cude (1998) uses several different sub-index curves for total solids. DEQ decided to test the OWQI using a common total solids equation without regard to location within the state. Additional testing may be conducted to derive total solid equations for different regions within Idaho; however, due to time and data constraints we felt that for testing purposes a single total solids equation was appropriate. The revised OWQI will be called the RPI to ensure that the reader is aware that the testing was not done using the OWQI as written. DEQ used the total solids equation developed for the John Day, Umatilla, and Grande Ronde Basins and the Crooked subbasin in Oregon.

The data set used to test the RPI was from USGS trend monitoring stations. To determine the overall condition of a water body from several sampling runs, we calculated the harmonic mean of individual RPI scores from all dates. Once again this was done to insure that sampling runs with the worst water quality conditions would be weighed more heavily. Since the USGS trend monitoring stations were not established with the RPI in mind, not all of the parameters were collected. Biochemical Oxygen Demand (BOD) was not collected at any time; and therefore all testing will be based on a composite RPI score from seven not eight parameters. Occasionally, an additional parameter was not collected or the sample was discarded. For these individual runs, it was determined that a minimum of six of the eight parameters must be reported prior to calculating a RPI score.

The average RPI scores by station calculated using the harmonic mean function can be found in Appendix G.

<u>RPI versus RMI and RFI</u>

Other chapters in this document discuss using diatoms and macroinvertebrates to determine water quality conditions in large rivers. Prior to inclusion of the RPI into the large river assessment process we wanted to test how it responded relative to the other indexes proposed. Unfortunately, only five sites had data sufficient for RPI calculations and biological data in the form of diatoms and macroinvertebrates. Because of the low paired sample sites, the result of the testing will not be as powerful as we would like; however, the results thus far are very encouraging.

A simple regression analysis was done on the five paired sites to determine if the RPI scores responded to environmental stressors in a similar fashion as the RFI and RDI. A significant linear regression exists between the RDI and the RPI (Figure 6-1). The R^2 for this regression was 0.85 and this was significant at the 0.05 level. The regression was also positive indicating that the RPI and the RMI responded in a similar manner. The regression analysis done between the RPI and the RMI was not significant at the 0.05 level; however, this is most likely due to small sample size (Figure 6-2). The RPI and RFI appear to respond in a similar manner even though there is not a significant regression. DEQ will continue to collect water chemistry data necessary to calculate the RPI and macroinvertebrates at the same locations. We expect that as the data set increases we will find that the RPI is correlated to the RFI.

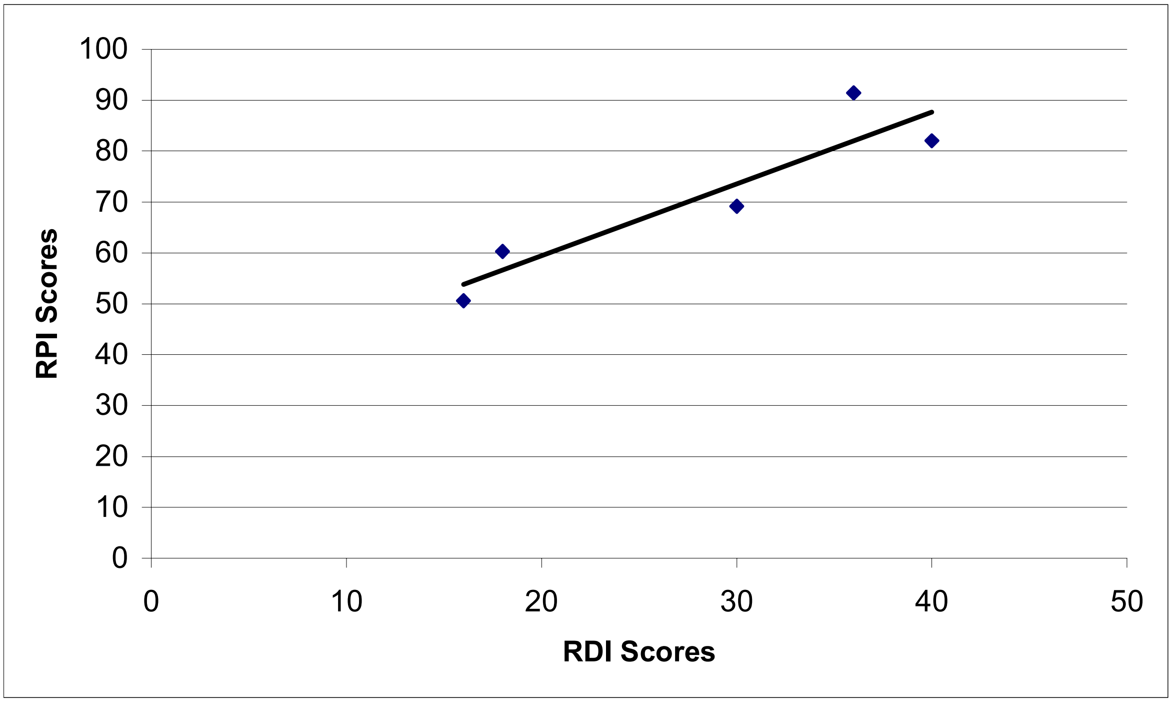

Figure 6-1. RPI scores versus Idaho's RDI. (R^2=0.85 $p<0.05$)

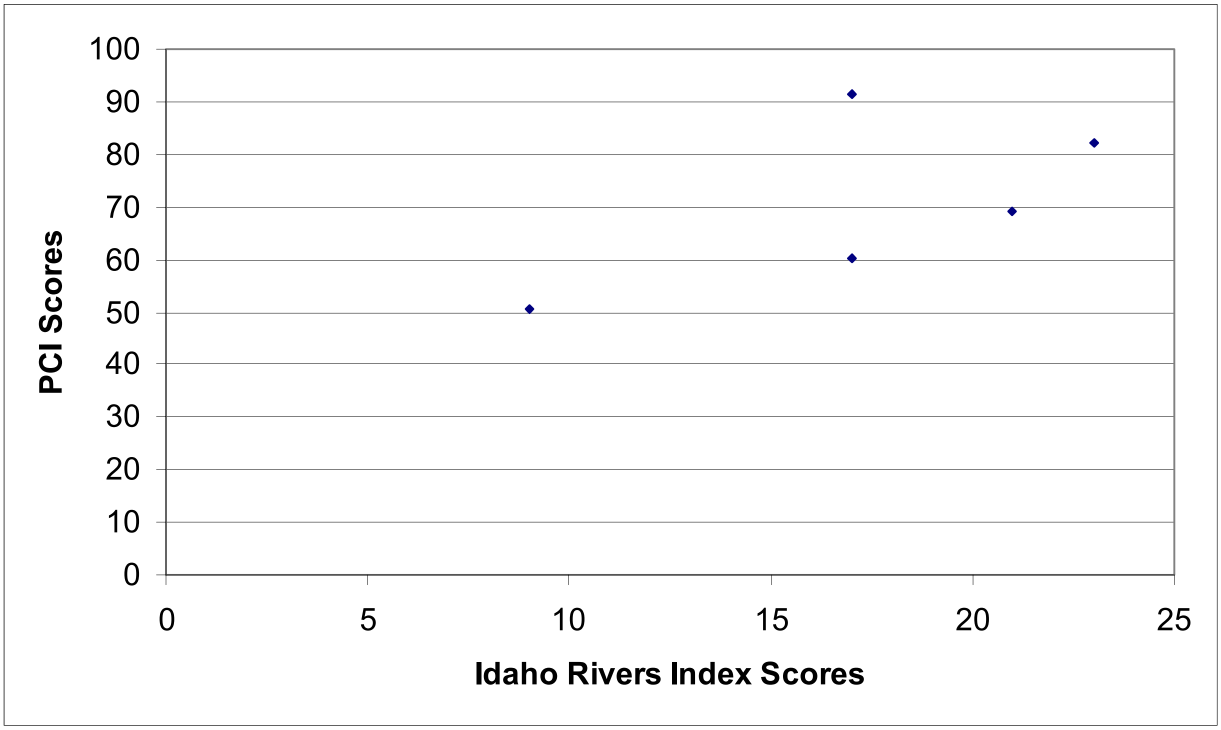

Figure 6-2. RPI scores versus Idaho's RMI.

RPI versus Indications of Human Disturbance

Land use percentages of the 5th field HUC in which the station was used as a surrogate for human disturbance. Land uses within the 5th field HUCs included: percent forest, percent dryland agriculture, percent gravity-irrigated agriculture, percent sprinkler-irrigated agriculture, percent rangeland, percent urban, and percent riparian. The percentage of each land use within each 5th field HUC was determined through the use of GIS and the Idaho Department of Water Resources Land use coverage and hydrologic delination.

The first analysis performed was a simple regression analysis of RPI versus all of the individual land use types. For this analysis the three categories of agricultural land use were combined into one land use category called total agriculture.

For the watersheds that had percent forest as a land use there was a significant positive regression with percent forest and RPI scores (Figure 6-3).

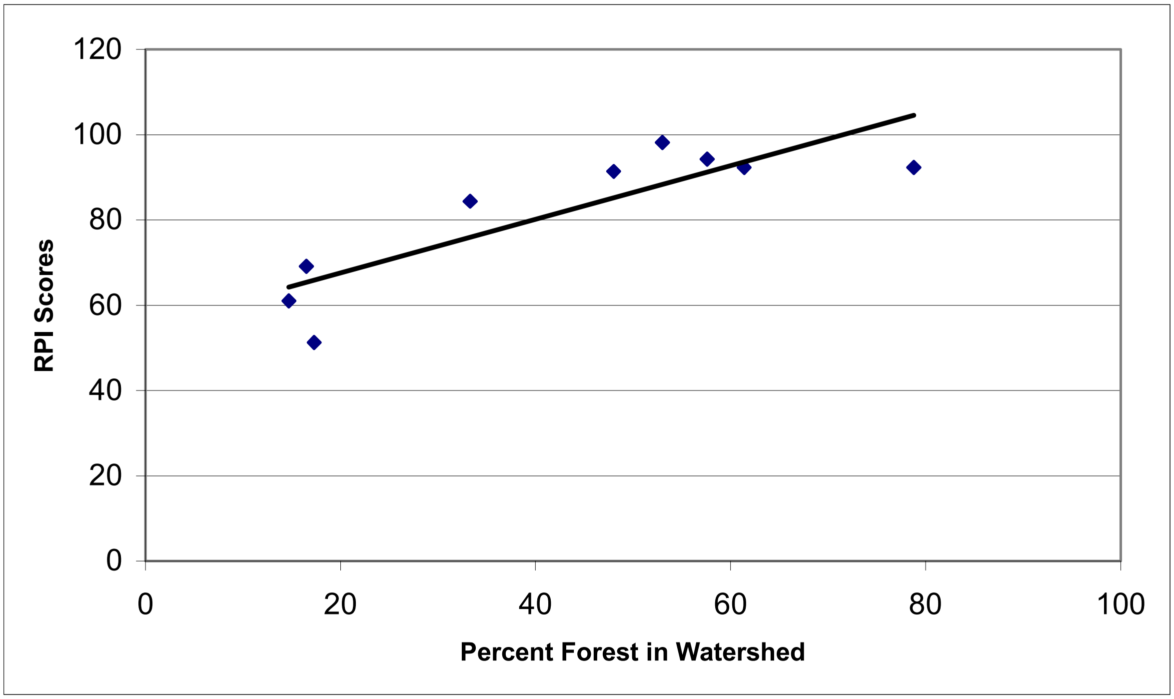

Figure 6-3. RPI Scores versus percent forest in 5th field watersheds where forest lands were a described land use. (R^2=0.75 $p<0.05$)

Another significant regression was a negative regression between RPI scores and percent agriculture in the watershed (Figure 6-4). Although the R^2 is not as high as the regression with percent forest, it is still highly significant.

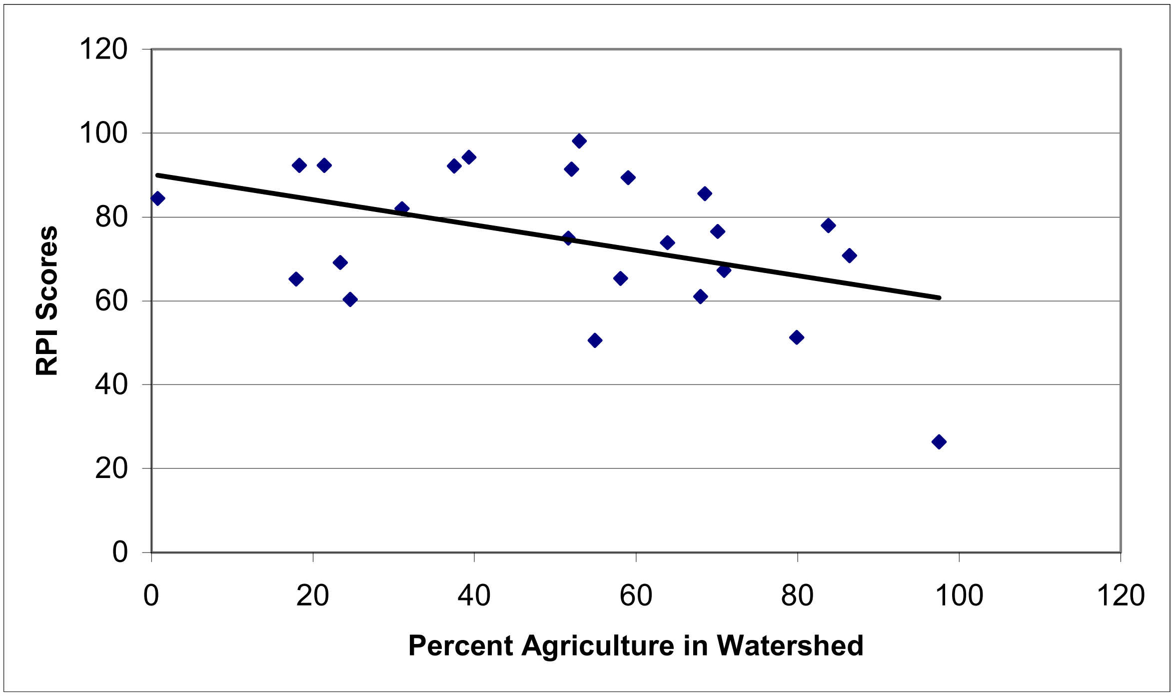

Figure 6-4. RPI Scores versus percent agriculture in 5th field watersheds where agriculture was a described landuse. (R^2=0.22, $p<0.05$)

Also of significance is the slope of the regressions. Both of the regressions respond in ways one would expect. As percent forest increases, so does the RPI score and as percent agriculture increases, the RPI score goes down. We also ran a forward step-wise regression which indicated that percent forest, percent dryland agriculture, and percent-furrow irrigated agriculture predicted approximately 50percent of the variablility in RPI scores (R^2=0.499 $p<0.05$). These characteristices would seem to indicate that the RPI does respond to changes in land use and could be a useful tool to predict water quality support status.

RPI versus Professional Expectations

We also wanted to determine if the RPI agreed with water quality professionals' opinions in regards to the rivers status. We asked DEQ employees who have experience in collecting and assessing water quality data to rate selected rivers on a scale of 1 to 3. They were asked to score rivers that were impaired as a 1. Rivers that were in good condition were to receive a 3 and rivers that had some degree of degradation were to receive a score of 2. The RPI scores were plotted against the expectations of DEQ employees for a visual examination of the data (Figure 6-5). Streams that were scored as either a 1 or 2 had a fair amount variability; however, streams that were determined to be in good condition had little variability. This trend is fairly common in this type of testing. People are very confident that streams or rivers that are in good condition, but the confidence and differences in expectations results in increasing variability as water bodies become more degraded. The results are encouraging because of the complete lack of overlap of RPI scores for rivers people considered in good condition and scores of rivers people considered degraded. The results from this analysis also tends to support the use of the RPI for determining the status of large rivers.

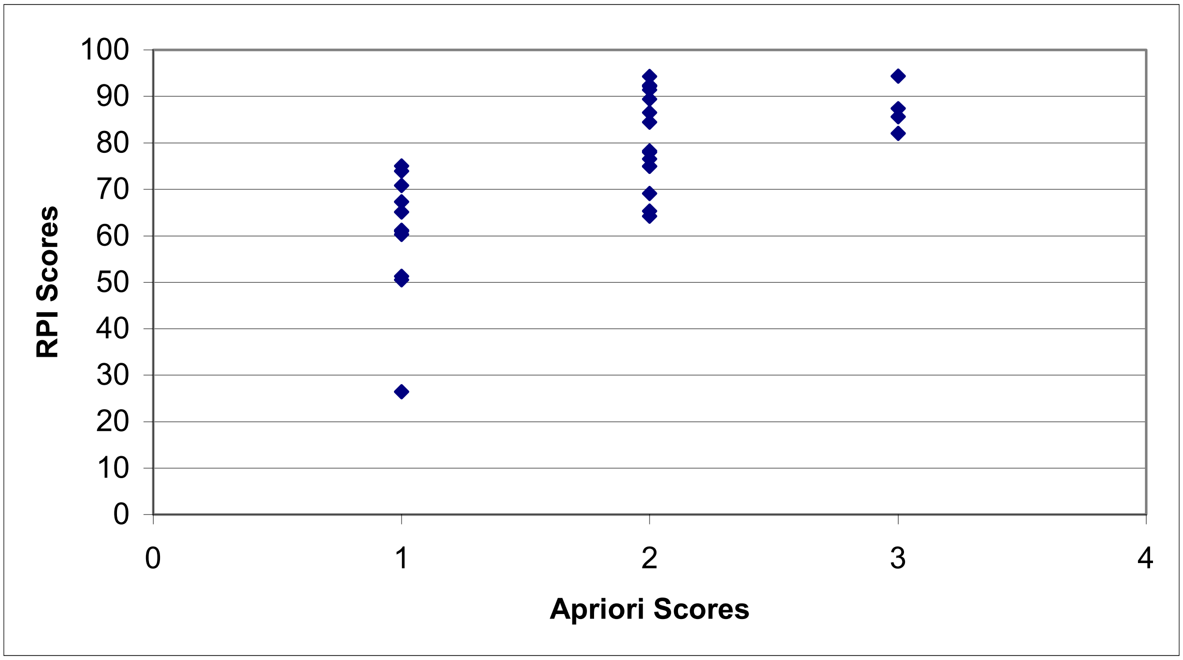

Figure 6-5. RPI Scores versus Apriori Scores.

This analysis was also used to help determine the four condition categories that will be used in the assessment process. It was apparent that water bodies with scores in excess of 80 were considered to be in good condition. It was also apperent that streams with scores less than 70 were significantly different from what would be expected of the them if they were in pristine condition. Therefore, it was determined that DEQ would use the following classifications for determining river condition using the RPI (Table 6-3).

Table 6-3. Proposed categories for the RPI.

Threshold Value	Signficant Deviation from Expected Condition	Moderate Deviation from Expected Condition	Similar to Expected Condition
<40	40-70	70-80	>80

Based on the analysis described above, DEQ believes that the RPI can be a valuable tool in determinating support status for large rivers. Eventhough the data sets were limited and the RPI needs additional testing, all tests performed on the RPI support its ability to descriminate between rivers that are in good condition and rivers that are degraded.

Sampling Requirements

In an effort to make sure that condition statements are made with as much rigor as possible, we set out to determine the minimum number of samples necessary for DEQ to use the RPI with reasonable assurity that differences in RPI scores of 10 points were statistically different. Therefore we ran a power analysis to determine the minimum number of samples needed to evaluate water quality conditions. We determined that a reasonable goal was to determine the number of samples necessary to assure that a 10 point difference in a score was significant to the 0.10 level 80 percent of the time. The average standard deviation from our test data set was nine points. The power analysis results indicated that a total of 10 data points were needed to determine if a 10 point difference was significant 80 percent of the time. A minimum of four samples would be needed if we only wanted to determine a 15 point difference 80 percent of the time. Any status calls made using less than 10 samples should be made with caution due to the increased possibility of making an incorrect status call. The data can and should still be used; however, it may be prudent for the assessor to be more cautious of the resulting scores.

CONCLUSIONS

The RPI is consistent with the RDI and the RFI. The RPI appears to correlate with measures of human disturbance, particularly agriculture and forest percentages within a watershed. The RPI also corresponds with professional opinion regarding the status of river conditions.

The test data set used had a large percentage of sites from southern Idaho. Future testing should be done to confirm that the index works for the entire state. Although there were relatively few sites from northern Idaho the assumptions made in the RPI should hold true for northern Idaho as well as southern Idaho and the preliminary analysis does not indicate that northern Idaho rivers respond any differently than southern Idaho rivers in regards to the RPI. Therefore, the RPI should be used as an interpretive tool with the caveat that future testing will need to be done to confirm the reliability of the index for northern Idaho. Users should not try to apply the RPI for rivers known to be impaired by toxics such as pesticides or heavy metals. These pollutants were not intended to be assessed using the RPI and the results of the RPI would not be indicative of the status of rivers impacted by these other pollutants. Given the results of these analysis, the RPI can be a valuable interpretive tool in assessing large river conditions in Idaho.

ACKNOWLEDGEMENT

I would like to thank Curtis Cude for his valuable insight, Mike Ingham for his review and assistance and all the DEQ personnel that provided data for testing the RPI.

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Chapter 7.
DATA ASSESSMENT AND REPORTING OF ASSEMBLAGES

Cynthia S. Grafe[12], Darren Brandt[13], and Christopher A. Mebane[14]

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. The challenge is how to interpret and report all the results from different indexes, particularly when the results disagree.

Both numeric criteria evaluations and multimetric index results are used to evaluate cold water biota in rivers. For the RMI, RFI, and RDI, DEQ rates different categories of conditions 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 7-1 illustrates the process of applying this approach.

METHODS

River Index Scoring

DEQ uses BURP-compatible data to calculate the River Macroinvertebrate Index (RMI), River Fish Index (RFI), and River Diatom Index (RDI). The results from these indexes are used to evaluate support use of cold water aquatic life in rivers. 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 RMI, RFI, and RDI are direct biological measures of cold water aquatic life. The details of index development and supporting analyses may be found in Royer and Mebane (Chapter 3), Mebane (Chapter 4), Fore and Grafe (Chapter 5), and Brandt (Chapter 6).

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

Scoring methods used for the river biological indexes differ according to the techniques used to develop the indexes. The RMI and RFI used reference condition approaches similar to those methods used in the development of the SMI and SFI. The developers of the RMI and RDI did not adjust index scores to a 100-point scale. Therefore, the maximum scores of these indexes are the highest scores of the individual metrics comprising the indexes. However, the RFI is based on a 100-point scale.

Both the RMI and RFI base condition categories on the 25th percentile of reference condition, which is considered adequately conservative in identifying sites in good condition (Jessup and Gerritsen 2000). DEQ applies the authors' recommendations when identifying additional condition categories. For the RFI, DEQ uses the median and 5th percentiles; below the 5th percentile is distinguished as a minimum. For the RMI, Royer and Minshall (1996) recommended the minimum score of the reference condition to distinguish additional condition categories. DEQ evaluated the range in each condition category of the RMI and then linearly extended the range to identify a minimum threshold.

The development of the RDI scores were based upon the distribution of the entire data set rather than just reference sites, due to the limited number of reference sites. Fore and Grafe recommend scores assigned to the different index categories based on the 75th, 50th, and 25th percentiles. Fore and Grafe did not have supporting analysis to recommend a minimum threshold.

Although the RPI is not used in the river data integration process, the index results may still be used in water quality interpretations and decisions other than 303(d). The RPI uses a scoring classification approach based on the development methods of the Oregon Water Quality Index (Cude, 2001), the index on which the RPI is based. Standard deviation was used to identify the different index categories of expected condition.

Each condition category is assigned a rating of 1, 2, or 3 to allow effective integration of multiple index results into one score. The final score derived from these multiple data sets is then used to determine use support. Table 6-4 summarizes the scoring and rating categories for the RMI, RDI, RFI, and RPI. It should be noted that the RPI scoring criteria is provided for information purposes only. This index is not directly used in the river data integration process. However, the RPI results may be used to supplement water quality interpretations.

Table 7-1. RMI, RDI, RFI, and RPI Scoring and Rating Categories

Index	Minimum Threshold	1	2	3
RMI	<11	11 – 13	14 – 16	>16
RDI	NA[1]	<22	22 – 33	>34
RFI	<54	54-69	70-75	>75
RPI	<40	40 – 70	70 – 80	>80

[1]Fore and Grafe (2000) did not identify a minimum threshold category.

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 7-1 illustrates the process of applying this approach.

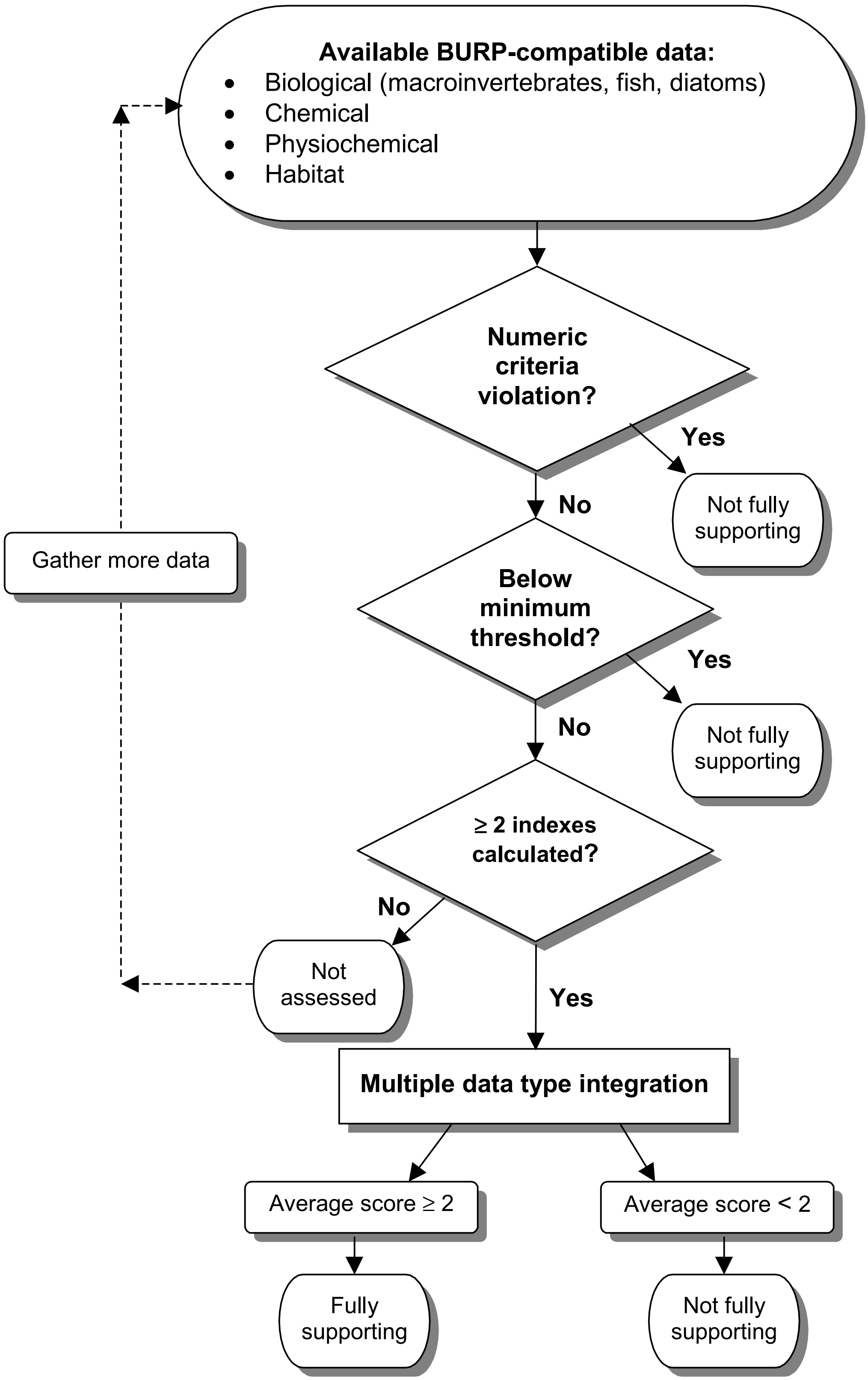

Figure 7-1. River cold water aquatic life use support determination.

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.

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).

Examples of the River Ecological Assessment Approach[15]

Lower Payette River

The lower Payette River is located in the southwestern portion of Idaho (Figure 7-2). The river flows westerly to join the Snake River near Payette, Idaho. The sampling location is in Payette, Idaho downstream from the wastewater treatment plant. Sources of pollutants include both point sources and non-point sources. Agriculture is the dominant land use with approximately 100,000 acres under some form of irrigation. Uplands are mainly used for open grazing of cattle and sheep. Other non-point sources are associated with urban land use. Point sources are limited mainly to municipal treatment plants and confined animal feeding operations.

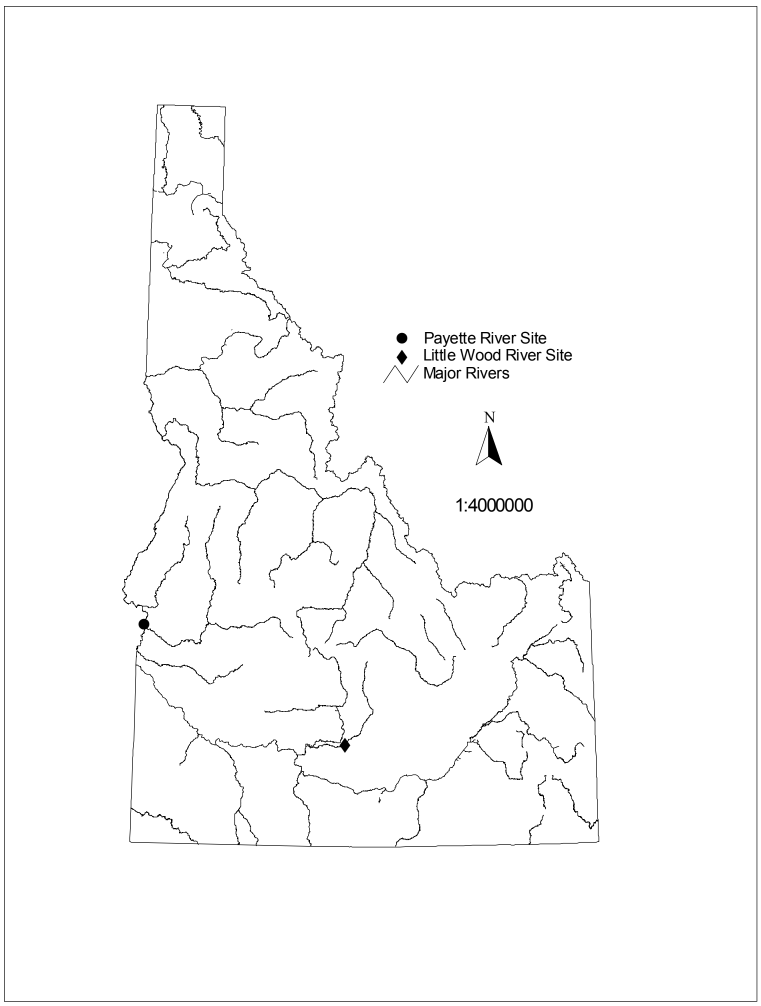

Figure 7-2. Sample locations of example rivers.

[15] These examples are intended to illustrate the index integration approach only and are not intended as a DEQ finding of beneficial use support status for the listed examples.

Little Wood River

The Little Wood River originates in the Pioneer Mountains in south central Idaho (Figure 7-2). From its headwaters, the river flows through forested areas and then enters into the Little Wood Reservoir, an irrigation supply reservoir. After leaving the Little Wood Reservoir, the Little Wood River flows through sagebrush steppe where it is used heavily for irrigation water as it approaches the town of Richfield. The Little Wood River joins the Big Wood River just west of the town of Gooding. The sampling location on the Little Wood River is near Carey, Idaho. This sampling location is upstream of the most heavily used sections of the Little Wood River.

ALUS Quantitative Assessment

- **Collect existing and readily available data.** In these examples, IDFG data was available to calculate the RFI scores for both sites. Also, DEQ collected macroinvertebrate and periphyton data at both sites. USGS data was collected at the lower Payette River site.

- **Identify numeric criteria exceedances.** For purposes of this example to illustrate the multiple data integration approach, it is assumed there are no numeric criteria exceedances. If there were any exceedances, then the determination would be not fully supporting.

- **Calculate indexes.** Table 7-2 shows the index results. The RPI is not used in the index integration, but may be used as additional information.

Table 7-2. River index score results (preliminary).

Site	RMI[16]	RDI	RFI
Payette (near wastewater treatment plant)	15	8	14
Little Wood River near Carey, Idaho	21	38	82

- **Classify index scores.** The assessor assigns a 1, 2, or 3 score to each index. Table 7-3 shows the assignment of scores according to the information provided in Table 7-1.

Table 7-3. River condition rating assignments.

Site	RMI	RDI	RFI
Payette (near wastewater treatment plant)	2	1	Below Minimum Threshold
Little Wood River near Carey, Idaho	3	3	3

- **Identify threshold exceedances**. As seen in Table 7-3, the assessor identifies that the RFI is below the minimum threshold for the Payette River site and consequently, determines this site as not fully supporting. The Little Wood River site does not have index scores below any minimum thresholds.

[16] RMI calculations based on 1996 DEQ macroinvertebrate taxa list.

Table 7-4. River ecological assessment results.

Site	Numeric Criteria Exceedance?	Below Minimum Threshold?	Average Index Score	ALUS Determination
Payette (near wastewater treatment plant)	No	Yes	1.5	Not Fully Supporting. RFI score below minimum threshold and average index score less than 2.
Little Wood River near Carey, Idaho	No	No	3	Fully Supporting. Average index score greater than 2.

- **Determine support status.** As seen in Table 7-4, the support status for the segment of the Payette River sampled is not fully supporting cold water aquatic life for two reasons. First, there is a violation of the minimum threshold for the RFI and second, the average index score is <2. The Little Wood River site is determined fully supporting cold water aquatic life since there were no numeric criteria exceedances, no index scores below minimum thresholds, and the average index score was greater than 2.

The assessor would review these preliminary, quantitative results to ensure that they met logical expectations and data requirements. If not, the assessor would re-evaluate the data and provide sound justification to change the preliminary support status. In the above examples, the support status determination seems reasonable due to the level of human disturbance in the watershed and the summary descriptions provided earlier.

The benefits of this integrative approach is that one composite index score indicates aquatic life use status. However, if an individual assemblage's index score is extremely low, then the use of minimum thresholds result in a conclusion that aquatic life is not fully supported. Also, the calculation of the individual and overall scores can be easily performed using spreadsheet or database calculations.

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Appendix A.
1997-98 RIVER BURP SITES

1997 RIVER BURP SITES

Water Body	Date Sampled	HUC[1]	Boundaries	Site I.D.
Boise RO				
Middle Fork Boise River	9-4-97	17050111	Headwaters to Arrowrock Reservoir (site above Roaring River)	1997RSWIROQ001
North Fork Boise River	9-5-97	17050111	Headwaters to MF Boise River (4 miles upstream from Rabbit Creek)	1997RSWIROQ002
South Fork Boise River	9-8-97	17050113	Headwaters to Anderson Ranch Reservoir (site near Pine, Idaho)	1997RSWIROQ003
South Fork Salmon River	9-10-97	17060208	Headwaters to mouth, 0.1 miles upstream from Krassel Gage Site	1997RSWIROQ004
East Fork of South Fork Salmon River	9-10-97	17060208	Sugar Creek to Johnson Creek	1997RSWIROQ005
Total Sites = 5				
Lewiston RO				
South Fork Clearwater River (L)[2]	9-16-97	17060305	Mill Creek to Clearwater River	1997RNCIROQ001
South Fork Clearwater River (M)[3]	9-16-97	17060305	Mill Creek to Clearwater River	1997RNCIROQ002
South Fork Clearwater River (U)[4]	9-17-97	17060305	American River to Mill Creek	1997RNCIROQ003
Lochsa River	9-18-97	17060303	Headwaters to Lowell	1997RNCIROQ004
Total Sites=4				
Coeur d'Alene RO 09/24/97 - 09/30/97				
North Fork Coeur d'Alene River	9-24-97	17010301	Yellowdog Creek to Coeur d'Alene River, SF	1997RNIRO0Q001
Pend Oreille River	9-25-97	17010214	Lake to State Border	1997RNIRO0Q002
Pack River	9-27-97	17010214	Hwy 95 to Lake	1997RNIRO0Q003

Water Body	Date Sampled	HUC[1]	Boundaries	Site I.D.
St. Maries River	9-28-97	17010304	Mashburn to St. Joe River	1997RNIRO0Q004
Coeur d'Alene (Harrison)	9-29-97	17010303	Thompson Lake to Lake Coeur d'Alene	1997RNIRO0Q005
Coeur d'Alene River (Rose Lake)	9-29-97	17010303	Latour Creek to Fourth of July Creek	1997RNIRO0Q006
Coeur d'Alene River (Medimont)	9-30-97	17010303	Robinson Creek to Cave Lake	1997RNIRO0Q007
Total=7				
Idaho Falls RO 10/07/97 -10/09/97				
Falls River	10-7-97	17040203	Conant Creek to Henry's Fork River	1997REIRO0Q001
Teton River (U)	10-8-97	17040204	Trail Creek to Hwy 33	1997REIRO0Q002
Henry's Fork (U)	10-8-97	17040202	Island Park Reservoir to Riverside	1997REIRO0Q003
Henry's Fork (L)	10-9-97	17040202	Riverside to Ashton Reservoir	1997REIRO0Q004
Total = 4				
Pocatello RO 10/14/97 -10/16/97				
Portneuf River (U)	10-14-97	17040208	Utah Bridge to Lava Hot Springs	1997RSEIROQ001
Portneuf River (UM)	10-14-97	17040208	Lava Hot Springs to MVC Diversion	1997RSEIROQ002
Portneuf River (M)	10-15-97	17040208	MVC Diversion to Marsh Creek	1997RSEIROQ003
Portneuf River (LM)	10-15-97	17040208	Marsh Creek to Johney Creek	1997RSEIROQ004
Blackfoot River (U)	10-16-97	17040207	Headwaters to Blackfoot Reservoir	1997RSEIROQ005
Blackfoot River (L)	10-16-97	17040207	Reservoir Dam to Wolverine Creek	1997RSEIROQ006
Total = 6				
Twin Falls RO 10/23/97 -10/29/97				
Snake River (Massacre)	10-23-97	17040206	Massacre Rocks to Lake Walcott	1997RSCIROQ001
Little Wood River (U)	10-24-97	17040221	Richfield (Town) to Big Wood River	1997RSCIROQ002
Snake River (Milner)	10-27-97	17040206	Lake Walcott Dam to Milner Dam	1997RSCIROQ003
Big Wood River (L)	10-28-97	17040219	Hwy 75 to Little Wood River	1997RSCIROQ004

Water Body	Date Sampled	HUC[1]	Boundaries	Site I.D.
Big Wood River (U)	10-29-97	17040219	Hwy 75 to Little Wood River	1997RSCIROQ005
Total = 5				
Total Sites Monitored = 31				

[1]HUC = Hydrologic Unit Catalog
[2]L = Lower
[3]M = Middle
[4]U = Upper

1998 RIVER BURP SITES

Water Body	Date Sampled	HUC	Boundaries	Site I.D.
Boise				
Weiser River	8-18-98	17050124	Galloway to Mouth	1998RBOIP001
Little Salmon River (U)[2]	8-19-98	17060210	Headwaters to Round Valley Creek	1998RBOIP002
South Fork Payette River	8-25-98	17050120	Headwaters to North Fork Payette River	1998RBOIP003
Snake River	8-26-98	17050115	Boise River to Weiser River	1998RBOIP004
South Fork Owyhee River	10-20-98	17050105	Nevada Line to Owyhee River	1998RBOIP005
Payette River	10-27-98	17050122	Black Canyon Dam to Mouth	1998RBOIP006
Total= 6				
Lewiston				
Little Salmon River	8-19-98	17060210	R1E T21N Sec 24 (Round Valley Creek) to Confluence with Salmon River	1998RLEWP001
Clearwater River	9-1-98	17060306	Hatwai Creek to Snake Confluence (area not on Nez Perce Reservation)	1998RLEWP002
Snake River (Asotin)	9-2-98	17060103	Lower Snake to Asotin	1998RLEWP003
Snake River (Grande Ronde)	9-3-98	17060103	Lower Snake to Asotin	1998RLEWP004
Total=4				
Coeur d’Alene				
Spokane River	9-16-98	17010305	Coeur d’Alene Lake to Heutter	1998RCDAP001
Spokane River	9-16-98	17010305	Heutter to Post Falls Bridge	1998RCDAP002
Spokane River	9-17-98	17010305	Washington State Line to Post Falls	1998RCDAP003
South Fork Coeur d’Alene River	9-17-98	17010302	Osborne to Coeur d’Alene River	1998RCDAP004
Moyie River	9-18-98	17010105	Moyie Falls Dam to Kootenai River	1998RCDAP005

Water Body	Date Sampled	HUC	Boundaries	Site I.D.
Clark Fork River	9-19-98	17010213	Clark Fork River (MT Border) to Lake Pend Oreille	1998RCDAP006
Priest River	9-20-98	17010215	Upper West Branch to Pend Oreille River	1998RCDAP007
Pend Oreille River	9-20-98	17010216	WA State Line to HUC Boundary- Albeni Falls Dam	1998RCDAP008
Coeur d'Alene River (I-90 Bridge)	9-21-98	17010303	Skeel Gulch to Latour Creek	1998RCDAP009
Coeur d'Alene River (Old Mission State Park)	9-21-98	17616303	French Gulch to Skeel Gulch	1998RCDAP0010
Coeur d'Alene River (Rose Bridge)	9-22-98	17010303	Fortier Creek to Fourth of July Creek	1998RCDAP0011
Coeur d'Alene River (Killarmey Lake)	9-22-98	17010303	Robinson Creek to Fortier Creek	1998RCDAP0012
Coeur d'Alene River (Cave Lake)	9-23-98	17010303	Cave Lake to Black Lake	1998RCDAP0013
Coeur d'Alene River (Black Lake)	9-23-98	17010303	Black Lake to Thompson Lake	1998RCDAP0014
Total = 14				
Idaho Falls				
Salmon River (U)	9-9-98	17060201	Hellroaring Creek to Redfish Lake Creek	1998RIDFP001
Salmon River (L)[3]	9-10-98	17060201	Redfish Lake Creek to East Fork Salmon River	1998RIDFP002
Teton River (U)	9-29-98	17040204	Headwaters to Trail Creek	1998RIDFP003
Teton River (Hwy 33)	9-29-98	17040204	Trail Creek to Hwy 33	1998RIDFP004
Salmon River (M)[4]	10-1-98	17060201	Redfish Lake Creek to East Fork Salmon River	1998RIDFP005
Total=5				
Pocatello				
Blackfoot River	10-5-98	17040207	Wolverine Creek to	1998RPOCP001

Water Body	Date Sampled	HUC	Boundaries	Site I.D.
			Snake River	
Bear River	10-6-98	16010102	Wyoming Line to Rocky Point	1998RPOCP002
Bear River	10-6-98	16010201	Rocky Point to Stewart Dam	1998RPOCP003
Bear River	10-7-98	16010202	Grace/Cove Dam to Oneida Reservoir	1998RPOCP004
Bear River	10-7-98	16010202	Riverdale to Utah Border	1998RPOCP005
Total=5				
Twin Falls				
Jarbidge River	10-13-98	17050102	Buck to East Fork Jarbidge River	1998RTWFP001
Bruneau River (Indian Hot Springs)	10-14-98	17050102	Nevada Line to Hot Creek	1998RTWFP002
Bruneau (@ Hwy 51)	10-15-98	17050102	Hot Creek to CJ Strike Reservoir	1998TWFP003
Bruneau River (U)	10-21-98	17050102	Nevada Border to Hot Creek	1998RTWFP004
Bruneau River (M)	10-22-98	17050102	Hot Creek to CJ Strike Reservoir	1998RTWFP005
Total=5				
TOTAL SITES=39				
TOTAL RIVERS=20				

[1]HUC = Hydrologic Unit Catalog
[2]L = Lower
[3]M = Middle
[4]U = Upper

Appendix B.
WATER BODY SIZE CRITERIA DATA WORKSHEETS

Key

(1) Drainage area above site
(2) Discharge from measurements (DEQ) or calculations using USGS data - see codes
Used calculated factor see (8)
(3) S = Calculation from flow on sampling date
L= Calculation from long term daily flow
M = No calculation-used measured flow
(4) Drainage area above gaging station
(5) Long-term daily flow for the month and day of the sampling date (data obtained from 1997 Earth Info CD: Extreme Value)
(6) Mean annual discharge for the period of record for the gage site
(7) Flow from gaging station
(8) Flow on sampling date or long-term daily flow (depending on data availability) divided by gaging station drainage area.

Discharge Worksheet

RIVER	SITE I.D.	(1) DRAINAGE AREA (mi2)	DATE SAMPLED	(2) DISCHG	CALC. DISCHG.	(3) CODE	DEQ = 1 USGS = 2 OTHER = 3
MF Boise R	1997RSWIROQ001	289	09/04/97	183	183	S	2
NF Boise R	1997RSWIROQ002	306	09/05/97	194	194	S	2
SF Boise R	1997RSWIROQ003	620	09/08/97	290	290	S	2
SF Salmon R	1997RSWIROQ004	366	09/10/97	194	194	S	2
EF SF Salmon R	1997RSWIROQ005	106	09/10/97	57	57	S	2
Portneuf R (U)	1997RSEIROQ001	330	10/14/97	77	77	L	2
Portneuf R (UM)	1997RSEIROQ002	588	10/14/97	138	138	L	2
Portneuf R (M)	1997RSEIROQ003	959	10/15/97	289	289	S	2
Portneuf R (LM)	1997RSEIROQ004	1120	10/15/97	338	338	S	2
Blackfoot R (U)	1997RSEIROQ005	186	10/16/97	47	47	L	2
Blackfoot R (L)	1997RSEIROQ006	650	10/16/97	174	174	L	2
Snake R (Massacre)	1997RSCIROQ001	15700	10/23/97	9,743	9,743	S	2
Little Wood R (U)	1997RSCIROQ002	769	10/24/97	210	210	L	2
Snake R (Milner)	1997RSCIROQ003	17180	10/27/97	10,002	10,002	S	2
Big Wood R (L)	1997RSCIROQ004	2755	10/28/97	492	492	S	2
Big Wood R (U)	1997RSCIROQ005	2755	10/29/97	492	492	S	2
SF Clearwater (L)	1997RNCIROQ001	1176	09/16/97	478	478	S	2
SF Clearwater (M)	1997RNCIROQ002	606	09/16/97	205	246	M	1
SF Clearwater (U)	1997RNCIROQ003	263	09/17/97	78	107	M	1
Lochsa R	1997RNCIROQ004	492	09/18/97	710	530	M	1
NF Coeur d'Alene R	1997RNIRO0Q001	306	09/24/97	119	119	S	2
Pend Oreille R	1997RNIRO0Q002	24200	09/25/97	12,700	12,700	S	2
Pack R	1997RNIRO0Q003	246	09/27/97	73	73	L	2
St. Marie's R	1997RNIRO0Q004	485	09/28/97	87	87	L	2
Coeur d'Alene R (Harrison)	1997RNIRO0Q005	1465	09/29/97	552	552	S	2
Coeur d'Alene R (Rose Lake)	1997RNIRO0Q006	1429	09/29/97	539	539	S	2
Coeur d'Alene R (Medimont)	1997RNIRO0Q007	1392	09/30/97	504	504	S	2
Falls R (L)	1997REIRO0Q001	370	10/07/97	260	260	S	2
Teton R (U)	1997REIRO0Q002	482	10/08/97	339	339	L	2
Henry's Fork (U)	1997REIRO0Q003	664	10/08/97	970	970	S	2
Henry's Fork (L)	1997REIRO0Q004	1388	10/09/97	2,029	2,029	S	2
Weiser R	1998RBOIP001	1777	08/18/98			S	2
Rapid River			08/19/98				
Little Salmon R (U)	1998RBOIP002	203	08/19/98				2
Little Salmon R (L)	1998RLEWP001	344	08/19/98				2
SF Payette R	1998RBOIP003	410	08/25/98				2
Snake R (Payette confluence	1998RBOIP004	58700	08/26/98				2
Clearwater R	1998RLEWP002	9346	09/01/98				2
Snake R (Asotin)	1998RLEWP003	92978	09/02/98				2
Grande Ronde			09/03/98				
Snake R (Grande Ronde)	1998RLEWP004	92960	09/03/98				2
Salmon R (U - Redfish Lk Cr)	1998RIDFP001	304	09/09/98				
Salmon R (L - Clayton)	1998RIDFP002	1149	09/10/98				
Spokane R (Blackwell Stn)	1998RCDAP001	646	09/16/98				2
Spokane R (Black Bay)	1998RCDAP002	826	09/16/98				2
Spokane R (Corbin Park)	1998RCDAP003	981	09/17/98				2
SF Coeur d'Alene R	1998RCDAP004	300	09/17/98		113	M	1
Moyie R	1998RCDAP005	755	09/18/98		94	M	1
Clark Fork R	1998RCDAP006	22132	09/19/98				2
Priest R	1998RCDAP007	782	09/20/98		327	M	1
Pend Oreille R	1998RCDAP008	2156	09/20/98				2
Coeur d'Alene R (I-90 Bridge)	1998RCDAP009	1214	09/21/98				2
Coeur d'Alene R (Cataldo)	1998RCDAP010	1218	09/21/98				2
Coeur d'Alene R (Rose Bridge	1998RCDAP011	1332	09/22/98				2
Coeur d'Alene R (Killarney Lk	1998RCDAP012	1362	09/22/98				2
Coeur d'Alene R (Cave Lake)	1998RCDAP013	1413	09/23/98				2
Coeur d'Alene R (Black Lake)	1998RCDAP014	1442	09/23/98				2
Teton R (Trail Creek)	1998RIDFP003	114	09/29/98		82	M	1

\ Page 1

Discharge Worksheet

RIVER	SITE I.D.	(1) DRAINAGE AREA (mi2)	DATE SAMPLED	(2) DISCHG	CALC. DISCHG.	(3) CODE	DEQ = 1 USGS = 2 OTHER = 3
Teton R (Hwy 33)	1998RIDFP004	431	09/29/98		334	M	1
Salmon R (M - O'Brien CG)	1998RIDFP005	818	10/01/98				
Blackfoot R	1998RPOCP001	948	10/05/98		269	M	1
Bear R (Thomas Fork Cr)	1998RPOCP002	2486	10/06/98				3
Bear R (Dingle Bridge)	1998RPOCP003	2810	10/06/98				3
Bear R (Cove Dam - Oneida)	1998RPOCP004	4241	10/07/98				3
Bear R (Hwy 36)	1998RPOCP005	4613	10/07/98				3
Jarbridge R	1998RTWFP001	180	10/13/98		49	M	1
Bruneau R (Indian Hot Spr)	1998RTWFP002	1039	10/14/98		77	M	1
Bruneau R (Hwy 51)	1998RTWFP003	3235	10/15/98		96	M	1
SF Owyhee R	1998RBOIP005	2777	10/20/98		63	M	1
Bruneau R (Homer Bedal)	1998RTWFP004	498	10/21/98		49	M	1
Bruneau R (Rec. Site)	1998RTWFP005	2605	10/22/98				2
Payette R	1998RBOIP006	3312	10/27/98				2

Discharge Worksheet

RIVER	SITE I.D.	GAGING STATION #	LOCATION	(4) DRAINAGE AREA (mi2)	PERIOD OF RECORD	(5) LT DAILY FLOW (cfs)	(6) MEAN ANNUAL DISCHARGE (cfs)	(7)FLOW ON SAMPLING DATE (cfs)	(8) USGS FACTOR (cfs/mi2)	COMMENTS: Station near site, use data	COMMENTS: Station near site, but requires extrapolation	COMMENTS: Station near site, but older data	Mean Annual Dischg Factor	Site Mean Annual Discharge
		USGS INFORMATION												
MF Boise R	1997RSWIROQ001	13185000	Boise R. nr Twin Springs	830	1911-1997	365	1,182	526	0.6337		X		1.4241	412
NF Boise R	1997RSWIROQ002	13185000	Boise R. nr Twin Springs	830	1911-1997	365	1,182	526	0.6337		X		1.4241	436
SF Boise R	1997RSWIROQ003	13186000	SF Boise R. nr Featherville	635	1945-1996	228	761	297	0.4677		X		1.1984	743
SF Salmon R	1997RSWIROQ004	13310700	SF Salmon R. nr Krassel R.S.	330	1966-1997	147	527	175	0.5303	X			1.5970	584
EF SF Salmon R	1997RSWIROQ005	13313000	Johnson Creek at Yellow Pine	213	1928-1997	87	340	115	0.5399		X		1.5962	169
Portneuf R (U)	1997RSEIROQ001	13072000	Portneuf R. nr Pebble	260	1912-1977	61	109		0.2346		X	X	0.4192	138
Portneuf R (UM)	1997RSEIROQ002	13072000	Portneuf R. nr Pebble	260	1912-1977	61	109		0.2346		X	X	0.4192	247
Portneuf R (M)	1997RSEIROQ003	13075500	Portneuf R. at Pocatello	1250	1897-1996	197	277	377	0.3016		X		0.2216	213
Portneuf R (LM)	1997RSEIROQ004	13075500	Portneuf R. at Pocatello	1250	1897-1996	197	277	377	0.3016	X			0.2216	248
Blackfoot R (U)	1997RSEIROQ005	13063000	Blackfoot R. ab Res. nr Henry	350	1914-1982	89	168		0.2543		X	X	0.4800	89
Blackfoot R (L)	1997RSEIROQ006	13065500	Blackfoot R. nr Henry	583	1908-1925	156	245		0.2676		X	X	0.4202	273
Snake R (Massacre)	1997RSCIROQ001	13077000	Snake at Neely	13600	1907-1997	3,872	7,574	8,440	0.6206		X		0.5569	8744
Little Wood R (U)	1997RSCIROQ002	13151000	Little Wood R. nr Richfield	570	1911-1972	156	162		0.2737		X	X	0.2842	219
Snake R (Milner)	1997RSCIROQ003	13081500	Snake R. nr Minidoka at Howells Ferry	15700	1910-1997	3,618	6,575	9,140	0.5822	X			0.4188	7195
Big Wood R (L)	1997RSCIROQ004	13152500	Malad R. nr Gooding	2990	1916-1997	103	288	534	0.1786		X		0.0963	265
Big Wood R (U)	1997RSCIROQ005	13152500	Malad R. nr Gooding	2990	1916-1997	103	288	534	0.1786		X		0.0963	265
SF Clearwater (L)	1997RNCIROQ001	13338500	SF Clearwater at Stites	1150	1911-1997	266	1,019	467	0.4061	X			0.8861	1042
SF Clearwater (M)	1997RNCIROQ002	13338500	SF Clearwater at Stites	1150	1911-1997	266	1,019	467	0.4061				0.8861	537
SF Clearwater (U)	1997RNCIROQ003	13338500	SF Clearwater at Stites	1150	1911-1997	266	1,019	467	0.4061				0.8861	233
Lochsa R	1997RNCIROQ004	13337000	Lochsa R. nr Lowell	1180	1910-1997	597	2,806	1,270	1.0763				2.3780	1170
NF Coeur d'Alene R	1997RNIRO0Q001	12411000	NF CDA ab Shoshone nr Prichard	335	1950-1997	107	694	130	0.3881		X		2.0716	634
Pend Oreille R	1997RNIRO0Q002	12395500	Pend Oreille at Newport, WA	24200	1903-1996	14,162	25,130	12,700	0.5248				1.0384	25130
Pack R	1997RNIRO0Q003	12392390	Pack R. ab Rapid Lightning Creek	218.7	1988-1993	65	440		0.2972		X	X	2.0119	495
St. Marie's R	1997RNIRO0Q004	12415000	St. Maries at Lotus	437	1912-1966	78	518		0.1785		X	X	1.1854	575
Coeur d'Alene R (Harrison)	1997RNIRO0Q005	12413500	CDA R. at Cataldo	1223	1911-1997	415	2,526	461	0.3769		X		2.0654	3026
Coeur d'Alene R (Rose Lake)	1997RNIRO0Q006	12413500	CDA R. at Cataldo	1223	1911-1997	415	2,526	461	0.3769		X		2.0654	2951
Coeur d'Alene R (Medimont)	1997RNIRO0Q007	12413500	CDA R. at Cataldo	1223	1911-1997	415	2,526	443	0.3622		X		2.0654	2875
Falls R (L)	1997REIRO0Q001	13047500	Falls R. nr Squirell	326	1904-1997	713	773	229	0.7025		X		2.3712	877
Teton R (U)	1997REIRO0Q002	13054000	Teton R. nr Tetonia	471	1929-1957	331	394		0.7028		X	X	0.8365	403
Henry's Fork (U)	1997REIRO0Q003	13046000	Henry's Fork nr Ashton	1040	1890-1997	1,193	1,474	1,520	1.4615		X		1.4173	941
Henry's Fork (L)	1997REIRO0Q004	13046000	Henry's Fork nr Ashton	1040	1890-1997	1,193	1,474	1,520	1.4615		X		1.4173	1967
Weiser R	1998RBOIP001	13266000	Weiser River nr Weiser, ID	1460	1952-1997	203	1,110	317		X			0.7603	1351
Rapid River								150						
Little Salmon R (U)	1998RBOIP002	13316500	Little Salmon R @ Riggins, ID (-Rapid)	576	1956-1997	243	792	265			X		1.3750	279
Little Salmon R (L)	1998RLEWP001	13316500	Little Salmon R @ Riggins, ID (-Rapid)	576	1956-1997	243	792	265			X		1.3750	47
SF Payette R	1998RBOIP003	13235000	SF Payette R @ Lowman, ID	456	1941-1997	454	870	481					1.9079	782
Snake R (Payette confluence	1998RBOIP004	13269000	Snake R @ Weiser, ID	69200	1910-1997	9,960	18,200	12,500					0.2630	942
Clearwater R	1998RLEWP002	13342500	Clearwater R @ Spalding, ID	9570	1925-1997	3,910	15,430	2,910					1.6123	29
Snake R (Asotin)	1998RLEWP003	13334300	Snake R nr Anatone, WA	92960	1958-1997	17,450	CALL WASH.	USGS R.O.					0.0000	0
Grande Ronde		13333000	Grande Ronde @ Troy, OR	3275	1944-1997	782	3,005	627						0
Snake R (Grande Ronde)	1998RLEWP004	13334300	Snake R nr Anatone, WA (-GrRonde)	92960	1958-1997	17,690	CALL WASH.	USGS R.O.					0.0000	0
Salmon R (U - Redfish Lk Cr)	1998RIDFP001	13295500	Salmon R bl Valley Cr @ Stanley, ID	501	1925-1960	336	664	*336*					1.3253	403
Salmon R (L - Clayton)	1998RIDFP002	13296500	Salmon R bl Yankee Fk nr Clayton, ID	802	1921-1991	494	990	*494*					1.2344	1418
Spokane R (Blackwell Stn)	1998RCDAP001	12419000	Spokane R nr Post Falls, ID	3840	1913-1997	1,180	6,237	SP					1.6242	1049
Spokane R (Black Bay)	1998RCDAP002	12419000	Spokane R nr Post Falls, ID	3840	1913-1997	1,180	6,237	SP					1.6242	1341
Spokane R (Corbin Park)	1998RCDAP003	12419000	Spokane R nr Post Falls, ID	3840	1913-1997	1,194	6,237	SP					1.6242	1594
SF Coeur d'Alene R	1998RCDAP004	12413470	SF CDA R nr Pinehurst, ID	299	1987-1997	105	542	SP					1.8127	545
Moyie R	1998RCDAP005	12307500	Moyie R @ Eileen, ID	755	1925-1978	171	885	*171*					1.1722	885
Clark Fork R	1998RCDAP006	12392000	Clark Fork @ Whitehorse Rapids nr Cab	22073	1928-1997	10,416	22,250	SP						0
Priest R	1998RCDAP007	12395000	Priest R nr Priest River, ID	902	1929-1997	425	1,503	SP					1.6663	1303
Pend Oreille R	1998RCDAP008	12395500	Pend Oreille at Newport, WA	1511	1952-1997	--	--	17,700						0
Coeur d'Alene R (I-90 Bridge)	1998RCDAP009	12413500	CDA R at Cataldo, ID	1220	1986-1997	424	2,545	310					2.0861	2533
Coeur d'Alene R (Cataldo)	1998RCDAP010	12413500	CDA R at Cataldo, ID	1220	1986-1997	424	2,545	310					2.0861	2541
Coeur d'Alene R (Rose Bridge	1998RCDAP011	12413500	CDA R at Cataldo, ID	1220	1986-1997	426	2,545	310					2.0861	2779
Coeur d'Alene R (Killarney Lk	1998RCDAP012	12413500	CDA R at Cataldo, ID	1220	1986-1997	426	2,545	310					2.0861	2840
Coeur d'Alene R (Cave Lake)	1998RCDAP013	12413500	CDA R at Cataldo, ID	1220	1986-1997	424	2,545	310					2.0861	2948
Coeur d'Alene R (Black Lake)	1998RCDAP014	12413500	CDA R at Cataldo, ID	1220	1986-1997	424	2,545	310					2.0861	3009
Teton R (Trail Creek)	1998RIDFP003	13052200	Teton R abv S Leigh Cr nr Driggs, ID	335	1961-1997	324	406	334					1.2119	138

Discharge Worksheet

RIVER	SITE I.D.	USGS INFORMATION: GAGING STATION #	LOCATION	(4) DRAINAGE AREA (mi2)	PERIOD OF RECORD	(5) LT DAILY FLOW (cfs)	(6) MEAN ANNUAL DISCHARGE (cfs)	(7)FLOW ON SAMPLING DATE (cfs)	(8) USGS FACTOR (cfs/mi2)	COMMENTS: Station near site, use data	Station near site, but requires extrapolation	Station near site, but older data	Mean Annual Dischg Factor	Site Mean Annual Discharge
Teton R (Hwy 33)	1998RIDFP004	13052200	Teton R abv S Leigh Cr nr Driggs, ID	335	1961-1997	324	406	334					1.2119	522
Salmon R (M - O'Brien CG)	1998RIDFP005	13296500	Salmon R bl Yankee Fk nr Clayton, ID	802	1921-1991	498	990	*498*					1.2344	1010
Blackfoot R	1998RPOCP001	13068500	Blackfoot R nr Blackfoot, ID	1295	1940-1997	148	158	216					0.1220	116
Bear R (Thomas Fork Cr)	1998RPOCP002		Pacific Corp. @			?	?	485						0
Bear R (Dingle Bridge)	1998RPOCP003		Pacific Corp. ab Stewart Dam			?	?	504						0
Bear R (Cove Dam - Oneida)	1998RPOCP004		Pacific Corp. @ Thatcher			?	?	1,899						0
Bear R (Hwy 36)	1998RPOCP005		Pacific Corp. @ Preston			?	?	1,232						0
Jarbridge R	1998RTWFP001	13162200	Jarbidge R @ Jarbidge, NV	22.6	1964-1978	CALL NEVADA USGS R.O.								0
Bruneau R (Indian Hot Spr)	1998RTWFP002	13168500	Bruneau R nr Hot Spring, ID	2631	1943-1996	100	388	*100*					0.1475	153
Bruneau R (Hwy 51)	1998RTWFP003	13168500	Bruneau R nr Hot Spring, ID	2631	1943-1996	99	388	*99*					0.1475	477
SF Owyhee R	1998RBOIP005	13177800	SF Owyhee R nr Whiterock, NV	1080	1955-1981	CALL NEVADA USGS R.O.							0.0000	0
Bruneau R (Homer Bedal)	1998RTWFP004	13168500	Bruneau R nr Hot Spring, ID	2631	1943-1996	105	388	*105*					0.1475	73
Bruneau R (Rec. Site)	1998RTWFP005	13168500	Bruneau R nr Hot Spring, ID	2631	1943-1996	107	388	*107*					0.1475	384
Payette R	1998RBOIP006	13251000	Payette R nr Payette, ID	3240	1935-1997	1,526	3,048	1,320					0.9407	3116

Key

	ISU Criteria:			DEQ Criteria:			
	Order	Baseflow Width (m)	Average Baseflow Depth (m)	**Ave. Greatest D (m)**	**(1) Site Dischg (cfs)**	**(2) Site Mean Annual Dischg (cfs)**	**Site Drainage Area (mi2)**
Large	>6	30 - 180	0.4 - 1.8	>0.91	>164	>744	>971
Medium	5 -6	15 - 40	0.2 -0.5	0.31 - 0.90	33 - 163	74 - 743	107 - 970
Stream	<5	<15	<0.4	<.30	<32	<73	<106

Water Body Criteria Analysis

RIVER	SITE I.D.	Site Ref	Stream Order	Ave. WW (m)	Ave. Depth (m)	Ave. Greatest D (m)	(1) Site Dischg (cfs)	(2) Site Mean Annual Dischg (cfs)	Site Drainage Area (mi2)
Falls R (L)	1997REIRO0Q001	17	4	54.50	0.52	0.65	260	877	370
Teton R (U)	1997REIRO0Q002	18	4	32.17	0.46	0.72	339	403	482
Henry's Fork (U)	1997REIRO0Q003	19	4	58.40	0.68	0.33	970	941	664
Henry's Fork (L)	1997REIRO0Q004	20	5	69.33	0.56	0.78	2,029	1,967	1388
SF Clearwater (L)	1997RNCIROQ001	6	5	40.22	0.34	0.67	478	1,042	1176
SF Clearwater (M)	1997RNCIROQ002	7	5	30.63	0.35	0.63	205	537	606
SF Clearwater (U)	1997RNCIROQ003	8	5	17.53	0.32	0.62	78	233	263
Lochsa R	1997RNCIROQ004	9	5	45.62	0.50	0.73	710	1,170	492
NF Coeur d'Alene R	1997RNIRO0Q001	10	5	33.70	0.24	0.38	119	634	306
Pend Oreille R	1997RNIRO0Q002	11	7	565.50	11.70	21.13	12,700	25,130	24200
Pack R	1997RNIRO0Q003	12	4	25.83	0.47	1.03	73	495	246
St. Marie's R	1997RNIRO0Q004	13	5	37.33	3.02	4.89	87	575	485
Coeur d'Alene R (Harrison)	1997RNIRO0Q005	14	6	89.58	7.13	11.89	552	3,026	1465
Coeur d'Alene R (Rose Lake)	1997RNIRO0Q006	15	6	94.67	12.40	17.67	539	2,951	1429
Coeur d'Alene R (Medimont)	1997RNIRO0Q007	16	6	83.00	5.74	8.53	504	2,875	1392
Snake R (Massacre)	1997RSCIROQ001	27	7	226.83	5.31	7.94	9,743	8,744	15700
Little Wood R (U)	1997RSCIROQ002	28	5	11.93	0.45	0.58	210	219	769
Snake R (Milner)	1997RSCIROQ003	29	7	316.83	1.27	2.33	10,002	7,195	17180
Big Wood R (L)	1997RSCIROQ004	30	6	13.70	0.51	0.83	492	265	2755
Big Wood R (U)	1997RSCIROQ005	31	6	12.02	0.50	0.77	492	265	2755
Portneuf R (U)	1997RSEIROQ001	21	4	18.00	0.57	0.90	77	138	330
Portneuf R (UM)	1997RSEIROQ002	22	4	17.18	1.31	1.85	138	247	588
Portneuf R (M)	1997RSEIROQ003	23	5	15.75	1.18	1.72	289	213	959
Portneuf R (LM)	1997RSEIROQ004	24	5	16.60	1.04	1.27	338	248	1120
Blackfoot R (U)	1997RSEIROQ005	25	4	16.45	0.41	0.58	47	89	186
Blackfoot R (L)	1997RSEIROQ006	26	5	30.50	0.39	0.60	174	273	650
MF Boise R	1997RSWIROQ001	1	4	31.50	0.45	0.78	183	412	289
NF Boise R	1997RSWIROQ002	2	5	33.08	0.37	0.60	194	436	306
SF Boise R	1997RSWIROQ003	3	5	33.90	0.35	0.50	290	743	620
SF Salmon R	1997RSWIROQ004	4	5	29.95	0.32	0.55	194	584	366
EF SF Salmon R	1997RSWIROQ005	5	4	17.62	0.30	0.52	57	169	106
Weiser River	1998RBOIP001	32	6	35.90	0.22	0.45		1351	1777
Little Salmon River (Upper)	1998RBOIP002	33	5	17.81	0.69	1.22		279	203
South Fork Payette River	1998RBOIP003	35	4	27.17	0.48	0.73		782	410
Snake River	1998RBOIP004	36	7	173.83	2.00	3.67		15438	58700
South Fork Owyhee River	1998RBOIP005	67		20.17	0.31	0.7	63		2777
Payette River	1998RBOIP006	70	6	86.67	1.03	1.63		3116	3312
Spokane River (Blackwell Station)	1998RCDAP001	42	6	206.33	1.10	2.00		1049	646
Spokane River (Black Bay)	1998RCDAP002	43	6	263.83	1.62	2.39		1341	826
Spokane River (Corbin Park)	1998RCDAP003	44	6	71.67	0.54	0.95		1594	981
South Fork Coeur d'Alene River	1998RCDAP004	45	5	18.17	0.26	0.48	113	545	300
Moyie River	1998RCDAP005	46		20.83	0.31	0.60	94	885	755
Clark Fork River	1998RCDAP006	47		182.50	1.71	3.07		22309	22132
Priest River	1998RCDAP007	48		39.50	0.54	1.02	327	1303	782
Pend Oreille River	1998RCDAP008	49	7	400.80	2.19	4.33			2156
Coeur d'Alene River (I-90 Bridge)	1998RCDAP009	50	6	42.17	0.44	0.73		2533	1214
Coeur d'Alene River (Cataldo)	1998RCDAP010	51	6	48.50	1.34	2.23		2541	1218
Coeur d'Alene River (Rose Bridge)	1998RCDAP011	52	6	90.83	1.16	1.85		2779	1332
Coeur d'Alene River (Killarney Lake)	1998RCDAP012	53	6	77.00	1.21	2.54		2840	1362
Coeur d'Alene River (Cave Lake)	1998RCDAP013	54	6	81.17	1.31	2.26		2948	1413
Coeur d'Alene River (Black Lake)	1998RCDAP014	55	6	82	1.27	2.05		3009	1442
Salmon River (Upper)	1998RIDFP001	40	5	26.00	0.32	0.63		403	304
Salmon River (Lower--Clayton)	1998RIDFP002	41	5	43.83	0.72	1.03		1418	1149
Teton River (Upper)	1998RIDFP003	56	3	11.06	0.4	0.62	82	138	114
Teton River (Highway 33)	1998RIDFP004	57	4	32	0.39	0.83	334	522	431
Salmon River (Middle)	1998RIDFP005	58	5	34	0.5	0.83		1010	818
Little Salmon River (Lower)	1998RLEWP001	34	5	18.45	0.46	0.78		473	344
Clearwater River	1998RLEWP002	37		201.67	1.07	1.73		15069	9346
Snake River (Asotin)	1998RLEWP003	38	7	179.67	1.13	2.71			92978

Water Body Criteria Analysis

RIVER	SITE I.D.	Site Ref	Stream Order	Ave. WW (m)	Ave. Depth (m)	Ave. Greatest D (m)	(1) Site Dischg (cfs)	(2) Site Mean Annual Dischg (cfs)	Site Drainage Area (mi2)
Snake River (Grande Ronde)	1998RLEWP004	39	7	174.17	5.26	9.75			92960
Blackfoot River	1998RPOCP001	59	5	21.17	0.45	0.67	269	116	948
Bear River	1998RPOCP002	60		40.5	0.82	1.28			2486
Bear River	1998RPOCP003	61		24.67	0.63	0.97			2810
Bear River	1998RPOCP004	62		52.83	1.5	2.11			4241
Bear River	1998RPOCP005	63		45.83	0.67	1.1			4613
Jarbidge River	1998RTWFP001	64	4	11.02	0.25	0.45	46		180
Bruneau River at Indian Hot Springs	1998RTWFP002	65	6	16.38	0.25	0.45	77	153	1039
Bruneau River at Highway 51	1998RTWFP003	66	6	17.67	0.25	0.45	96	477	3235
Bruneau River (Upper)	1998RTWFP004	68	5	10.79	0.3	0.47	49	73	498
Bruneau River (Middle)	1998RTWFP005	69	6	22	0.48	0.78		384	2605
Bear River near Pegram	beap		6	27.58	0.86				
Bear River near Riverdale	bear		6	36.50	0.63				
Big Creek near Taylor Ranch	bigc		5	43.00	0.56		618		
Bitch Creek near Felt	bitc		3	19.00	0.27		68		
Blackfoot River below Dam	blac		5						
Big Lost near Chilly	blos		4	17.24	0.42		133		
Boise River near Twin Springs	bois		6	36.83	0.68				
Bruneau River at Hot Springs	brun		6	24.66	0.25		69		
Big Wood above Ketchum	bwok		4	14.82	0.38		69		
Big Wood at Stanton Crossing	bwos		4	16.42	0.19		33		
Coeur d'Alene near Cataldo	cdac		6	63.33	1.19				
Coeur d'Alene near Shoshone	cdas		5	38.53	0.33				
Clearwater below Lowell	clea		6	88.33	1.59				
East Fork Salmon River near Boulder	efsa		4	15.50	0.30		85		
Falls River near Marysville	fall		5	46.00	0.55				
Henry's Fork near Ashton	hena		5	73.08	0.83				
Henry's Fork near Island Park	henc		5	67.00	0.52				
Henry's Fork near Pinehaven	henp		5	90.50	0.63				
Lower Blackfoot River near Firth	lbla		5	18.53	0.55				
Lower Boise near Middleton	lboi		7	26.60	0.58				
Lochsa above Lowell	loch		5	76.00	0.67				
Little Salmon near Riggins	lsal		5	22.34	0.34		260		
Middle Fork Salmon near Indian Cr.	mfsa		6	38.00	0.56		663		
Owyhee River near Battle Cr.	owyh		6	15.03	0.32				
Panther Creek near mouth	pant		5	10.50	0.40		118		
South Fork Payette R. near Garden V	paye		5	42.00	0.73				
Portneuf River above Lava	port		4						
Priest River below Lake	prie		5						
Running Creek near confluence	runn		4	7.60	0.27		32		
Rush Creek near Taylor Ranch	rush		4	9.00	0.27		69		
Salmon River near Challis	salc		6	48.40	0.45				
Salmon River near Deadwater	sald		7	75.00	0.78				
Salmon River near Yankee Fork	saly		6	25.70	0.57				
Selway above Lowell	selw		6	56.33	0.82				
South Fork Boise R. above Feathervi	sfbo		5	29.86	0.32		261		
South Fork Coeur d'Alene at confluen	sfcd		5	15.00	0.37		152		
South Fork Salmon River at Krassel	sfsa		5	28.50	0.44		122		
South Fork Snake near Heise	sfsn		7	126.67	0.87				
Snake at Buhl	snab		7	183.33	1.78				
Snake at King Hill	snak		7	114.17	1.78				
Snake near Blackfoot	snbl		7						
St. Joe at Avery	stja		5	37.83	0.35		241		
St. Joe at Calder	stjc		5	46.83	0.48				
Upper Coeur d'Alene	ucda		5	39.78	0.32		114		
Upper Lochsa near Powell	uloc		5	25.22	0.29		100		
Upper Salmon near Decker Flats	usal		5	24.10	0.48		108		
Upper Selway near Running Creek	usel		5	37.00	0.37		203		
Valley Creek above Stanley	vall		4	13.96	0.34		91		
Weiser below Cambridge	weis		5	33.08	0.35		102		

Water Body Criteria Analysis

RIVER	SITE I.D.	Site Ref	Stream Order	Ave. WW (m)	Ave. Depth (m)	Ave. Greatest D (m)	(1) Site Dischg (cfs)	(2) Site Mean Annual Dischg (cfs)	Site Drainage Area (mi2)
	MIN.		3.00	7.60	0.19	0.33	32.37	73.38	106.00
	MAX		7.00	565.50	12.40	21.13	12700.00	25130.00	92978.00
	AVG.		5.29	61.18	1.05	2.22	747.23	2458.60	5778.29
	MEDIAN		5.00	34.00	0.51	0.83	162.79	743.02	970.00
	STDS		0.96	80.19	1.82	3.69	2288.51	4936.98	17129.61

Water Body Criteria Analysis

RIVER	SITE I.D.	(3) ISU Criteria Analysis: Order	Baseflow Width	Average Baseflow Depth	DEQ Additional Criteria: Site Mean Annual Discharge		Site Drainage Area		Average Greatest Depth at Baseflow	DEQ Addl Criteria Ave.	DEQ Addl CriteriaRiver Size Class	ISU Criteria Ave.		ISU Criteria River Size Class	River Size Class (ISU designated)	All Criteria Ave.	All Criteria River Size Class	DEQ Addl CriteriaRiver Size Class	ISU Criteria River Size Class
Falls R (L)	1997REIRO0Q001	1	3	3	3	2	2			2.3	L	2.3	L	N	A	2.3	L	L	L
Teton R (U)	1997REIRO0Q002	1	2.5	2.5		2		2	2	2.0	L	2.0	L		NA	2.0	L	L	L
Henry's Fork (U)	1997REIRO0Q003	1	3	3	3	2	2			2.3	L	2.3	L	N	A	2.3	L	L	L
Henry's Fork (L)	1997REIRO0Q004	2	3	3	3	3	2			2.7	L	2.7	L	N	A	2.7	L	L	L
SF Clearwater (L)	1997RNCIROQ001	2	3	1.5		3		3	2	2.7	L	2.2	L		NA	2.4	L	L	L
SF Clearwater (M)	1997RNCIROQ002	2	2.5	1.5		2		2	2	2.0	L	2.0	L		NA	2.0	L	L	L
SF Clearwater (U)	1997RNCIROQ003	2	2	1.5		2		2	2	2.0	L	1.8	M		NA	1.9	M	L	M
Lochsa R	1997RNCIROQ004	2	3	3	3	2	2			2.3	L	2.7	L	N	A	2.5	L	L	L
NF Coeur d'Alene R	1997RNIRO0Q001	2	2.5	1.5		2		2	2	2.0	L	2.0	L		NA	2.0	L	L	L
Pend Oreille R	1997RNIRO0Q002	3	3	3	3	3	3			3.0	L	3.0	L	N	A	3.0	L	L	L
Pack R	1997RNIRO0Q003	1	2	2.5		2		2	3	2.3	L	1.8	M		NA	2.1	L	L	M
St. Marie's R	1997RNIRO0Q004	2	2.5	3	2	2	3			2.3	L	2.5	L	N	A	2.4	L	L	L
Coeur d'Alene R (Harrison)	1997RNIRO0Q005	2	3	3	3	3	3			3.0	L	2.7	L	N	A	2.8	L	L	L
Coeur d'Alene R (Rose Lake)	1997RNIRO0Q006	2	3	3	3	3	3			3.0	L	2.7	L	N	A	2.8	L	L	L
Coeur d'Alene R (Medimont)	1997RNIRO0Q007	2	3	3	3	3	3			3.0	L	2.7	L	N	A	2.8	L	L	L
Snake R (Massacre)	1997RSCIROQ001	3	3	3	3	3	3			3.0	L	3.0	L	N	A	3.0	L	L	L
Little Wood R (U)	1997RSCIROQ002	2	1	2.5		2		2	2	2.0	L	1.8	M		NA	1.9	M	L	M
Snake R (Milner)	1997RSCIROQ003	3	3	3	3	3	3			3.0	L	3.0	L	N	A	3.0	L	L	L
Big Wood R (L)	1997RSCIROQ004	2	1	3	2	3	2			2.3	L	2.0	L	N	A	2.2	L	L	L
Big Wood R (U)	1997RSCIROQ005	2	1	2.5		2		3	2	2.3	L	1.8	M		NA	2.1	L	L	M
Portneuf R (U)	1997RSEIROQ001	1	2	3	2	2	2			2.0	L	2.0	L	N	A	2.0	L	L	L
Portneuf R (UM)	1997RSEIROQ002	1	2	3	2	2	3			2.3	L	2.0	L	N	A	2.2	L	L	L
Portneuf R (M)	1997RSEIROQ003	2	2	3	2	2	3			2.3	L	2.3	L	N	A	2.3	L	L	L
Portneuf R (LM)	1997RSEIROQ004	2	2	3	2	3	3			2.7	L	2.3	L	N	A	2.5	L	L	L
Blackfoot R (U)	1997RSEIROQ005	1	2	2.5		2		2	2	2.0	L	1.8	M		NA	1.9	M	L	M
Blackfoot R (L)	1997RSEIROQ006	2	2.5	1.5		2		2	2	2.0	L	2.0	L		NA	2.0	L	L	L
MF Boise R	1997RSWIROQ001	1	2.5	2.5		2		2	2	2.0	L	2.0	L		NA	2.0	L	L	L
NF Boise R	1997RSWIROQ002	2	2.5	1.5		2		2	2	2.0	L	2.0	L		NA	2.0	L	L	L
SF Boise R	1997RSWIROQ003	2	2.5	1.5		3		2	2	2.3	L	2.0	L		NA	2.2	L	L	L
SF Salmon R	1997RSWIROQ004	2	2	1.5		2		2	2	2.0	L	1.8	M		NA	1.9	M	L	M
EF SF Salmon R	1997RSWIROQ005	1	2	1.5		2		2	2	2.0	L	1.5	M		NA	1.8	M	L	M
Weiser River	1998RBOIP001	2	2	1.5		3		3	2	2.7	L	1.8	M		NA	2.3	L	L	M
Little Salmon River (Upper)	1998RBOIP002	2	2	3	2	2	3			2.3	L	2.3	L	N	A	2.3	L	L	L
South Fork Payette River	1998RBOIP003	1	2	2.5		3		2	2	2.3	L	1.8	M		NA	2.1	L	L	M
Snake River	1998RBOIP004	3	3	3	3	3	3			3.0	L	3.0	L	N	A	3.0	L	L	L
South Fork Owyhee River	1998RBOIP005	1	2	1.5				3	2	2.5	L	1.5	M		NA	1.9	M	L	M
Payette River	1998RBOIP006	2	3	3	3	3	3			3.0	L	2.7	L	N	A	2.8	L	L	L
Spokane River (Blackwell Station)	1998RCDAP001	2	3	3	3	2	3			2.7	L	2.7	L	N	A	2.7	L	L	L
Spokane River (Black Bay)	1998RCDAP002	2	3	3	3	2	3			2.7	L	2.7	L	N	A	2.7	L	L	L
Spokane River (Corbin Park)	1998RCDAP003	2	3	3	3	3	3			3.0	L	2.7	L	N	A	2.8	L	L	L
South Fork Coeur d'Alene River	1998RCDAP004	2	2	1.5		2		2	2	2.0	L	1.8	M		NA	1.9	M	L	M
Moyie River	1998RCDAP005		2	1.5		3		2	2	2.3	L	1.8	x		NA	2.1	L	L	x
Clark Fork River	1998RCDAP006		3	3	3	3	3			3.0	L	3.0	x		NA	3.0	L	L	x
Priest River	1998RCDAP007		2.5	3	3	2	3			2.7	L	2.8	x		NA	2.7	L	L	x
Pend Oreille River	1998RCDAP008	3	3	3				3	3	3.0	L	3.0	L		NA	3.0	L	L	L
Coeur d'Alene River (I-90 Bridge)	1998RCDAP009	2	3	2.5		3		3	2	2.7	L	2.5	L		NA	2.6	L	L	L
Coeur d'Alene River (Cataldo)	1998RCDAP010	2	3	3	3	3	3			3.0	L	2.7	L	N	A	2.8	L	L	L
Coeur d'Alene River (Rose Bridge)	1998RCDAP011	2	3	3	3	3	3			3.0	L	2.7	L	N	A	2.8	L	L	L
Coeur d'Alene River (Killarney Lake)	1998RCDAP012	2	3	3	3	3	3			3.0	L	2.7	L	N	A	2.8	L	L	L
Coeur d'Alene River (Cave Lake)	1998RCDAP013	2	3	3	3	3	3			3.0	L	2.7	L	N	A	2.8	L	L	L
Coeur d'Alene River (Black Lake)	1998RCDAP014	2	3	3	3	3	3			3.0	L	2.7	L	N	A	2.8	L	L	L
Salmon River (Upper)	1998RIDFP001	2	2	1.5		2		2	2	2.0	L	1.8	M		NA	1.9	M	L	M
Salmon River (Lower--Clayton)	1998RIDFP002	2	3	3	3	3	3			3.0	L	2.7	L	N	A	2.8	L	L	L
Teton River (Upper)	1998RIDFP003	1	1	2.5		2		2	2	2.0	L	1.5	M		NA	1.8	M	L	M
Teton River (Highway 33)	1998RIDFP004	1	2.5	1.5		2		2	2	2.0	L	1.7	M		NA	1.8	M	L	M
Salmon River (Middle)	1998RIDFP005	2	2.5	2.5		3		2	2	2.3	L	2.3	L		NA	2.3	L	L	L
Little Salmon River (Lower)	1998RLEWP001	2	2	2.5		2		2	2	2.0	L	2.2	L		NA	2.1	L	L	L
Clearwater River	1998RLEWP002		3	3	3	3	3			3.0	L	3.0	x		NA	3.0	L	L	x
Snake River (Asotin)	1998RLEWP003	3	3	3				3	3	3.0	L	3.0	L		NA	3.0	L	L	L

Water Body Criteria Analysis		(3) ISU Criteria Analysis			DEQ Additional Criteria											
RIVER	SITE I.D.	Order	Baseflow Width	Average Baseflow Depth	Site Mean Annual Discharge	Site Drainage Area	Average Greatest Depth at Baseflow	DEQ Addl Criteria Ave.	DEQ Addl CriteriaRiver Size Class	ISU Criteria Ave.	ISU Criteria River Size Class	River Size Class (ISU designated)	All Criteria Ave.	All Criteria River Size Class	DEQ Addl CriteriaRiver Size Class	ISU Criteria River Size Class
Snake River (Grande Ronde)	1998RLEWP004	3	3	3		3	3	3.0	L	3.0	L	NA	3.0	L	L	L
Blackfoot River	1998RPOCP001	2	2	2.5	2	2	2	2.0	L	2.2	L	NA	2.1	L	L	L
Bear River	1998RPOCP002		3	3		3	3	3.0	L	3.0	x	NA	3.0	L	L	x
Bear River	1998RPOCP003		2	3		3	3	3.0	L	2.5	x	NA	2.8	L	L	x
Bear River	1998RPOCP004		3	3		3	3	3.0	L	3.0	x	NA	3.0	L	L	x
Bear River	1998RPOCP005		3	3		3	3	3.0	L	3.0	x	NA	3.0	L	L	x
Jarbidge River	1998RTWFP001	1	1	1.5		2	2	2.0	L	1.2	M	NA	1.5	M	L	M
Bruneau River at Indian Hot Springs	1998RTWFP002	2	2	1.5	2	3	2	2.3	L	1.8	M	NA	2.1	L	L	M
Bruneau River at Highway 51	1998RTWFP003	2	2	1.5	2	3	2	2.3	L	1.8	M	NA	2.1	L	L	M
Bruneau River (Upper)	1998RTWFP004	2	1	1	2 2	2		2.0	L	1.3	M	NA	1.7	M	L	M
Bruneau River (Middle)	1998RTWFP005	2	2	2.5	2	3	2	2.3	L	2.2	L	NA	2.3	L	L	L
Bear River near Pegram	beap	2	2	3						2.3	L	L	2.3	L		L
Bear River near Riverdale	bear	2	2.5	3						2.5	L	L	2.5	L		L
Big Creek near Taylor Ranch	bigc	2	3	3						2.7	L	L	2.7	L		L
Bitch Creek near Felt	bitc	1	2	1.5						1.5	M	M	1.5	M		M
Blackfoot River below Dam	blac	2								2.0	x M		2.0	L		x
Big Lost near Chilly	blos	1	2	2.5						1.8	M	M	1.8	M		L
Boise River near Twin Springs	bois	2	2.5	3						2.5	L	L	2.5	L		L
Bruneau River at Hot Springs	brun	2	2	1.5						1.8	M	M	1.8	M		M
Big Wood above Ketchum	bwok	1	1	1.5						1.2	M	M	1.2	M		M
Big Wood at Stanton Crossing	bwos	1	2	1						1.3	M	M	1.3	M		M
Coeur d'Alene near Cataldo	cdac	2	3	3						2.7	L	L	2.7	L		L
Coeur d'Alene near Shoshone	cdas	2	2.5	1.5						2.0	L	L	2.0	L		M
Clearwater below Lowell	clea	2	3	3						2.7	L	L	2.7	L		L
East Fork Salmon River near Boulder	efsa	1	2	1.5						1.5	M	M	1.5	M		M
Falls River near Marysville	fall	2	3	3						2.7	L	L	2.7	L		L
Henry's Fork near Ashton	hena	2	3	3						2.7	L	L	2.7	L		L
Henry's Fork near Island Park	henc	2	3	3						2.7	L	L	2.7	L		L
Henry's Fork near Pinehaven	henp	2	3	3						2.7	L	L	2.7	L		L
Lower Blackfoot River near Firth	lbla	2	2	3						2.3	L	M	2.3	L		L
Lower Boise near Middleton	lboi	3	2	3						2.7	L	L	2.7	L		L
Lochsa above Lowell	loch	2	3	3						2.7	L	L	2.7	L		L
Little Salmon near Riggins	lsal	2	2	1.5						1.8	M	M	1.8	M		M
Middle Fork Salmon near Indian Cr.	mfsa	2	2.5	3						2.5	L	L	2.5	L		L
Owyhee River near Battle Cr.	owyh	2	2	1.5						1.8	M	L	1.8	M		M
Panther Creek near mouth	pant	2	1	2.5						1.8	M	M	1.8	M		M
South Fork Payette R. near Garden V	paye	2	3	3						2.7	L	L	2.7	L		L
Portneuf River above Lava	port	1								1.0	x M		1.0	M		x
Priest River below Lake	prie	2								2.0	x M		2.0	L		x
Running Creek near confluence	runn	1	1	1.5						1.2	M	M	1.2	M		M
Rush Creek near Taylor Ranch	rush	1	1	1.5						1.2	M	M	1.2	M		M
Salmon River near Challis	salc	2	3	2.5						2.5	L	L	2.5	L		L
Salmon River near Deadwater	sald	3	3	3						3.0	L	L	3.0	L		L
Salmon River near Yankee Fork	saly	2	2	3						2.3	L	L	2.3	L		L
Selway above Lowell	selw	2	3	3						2.7	L	L	2.7	L		L
South Fork Boise R. above Feathervi	sfbo	2	2	1.5						1.8	M	M	1.8	M		M
South Fork Coeur d'Alene at confluen	sfcd	2	2	1.5						1.8	M	M	1.8	M		M
South Fork Salmon River at Krassel	sfsa	2	2	2.5						2.2	L	L	2.2	L		L
South Fork Snake near Heise	sfsn	3	3	3						3.0	L	L	3.0	L		L
Snake at Buhl	snab	3	3	3						3.0	L	L	3.0	L		L
Snake at King Hill	snak	3	3	3						3.0	L	L	3.0	L		L
Snake near Blackfoot	snbl	3								3.0	x L		3.0	L		x
St. Joe at Avery	stja	2	2.5	1.5						2.0	L	L	2.0	L		M
St. Joe at Calder	stjc	2	3	2.5						2.5	L	L	2.5	L		L
Upper Coeur d'Alene	ucda	2	2.5	1.5						2.0	L	M	2.0	L		M
Upper Lochsa near Powell	uloc	2	2	1.5						1.8	M	M	1.8	M		M
Upper Salmon near Decker Flats	usal	2	2	2.5						2.2	L	M	2.2	L		L
Upper Selway near Running Creek	usel	2	2.5	1.5						2.0	L	L	2.0	L		M
Valley Creek above Stanley	vall	1	1	1.5						1.2	M	M	1.2	M		M
Weiser below Cambridge	weis	2	2	1.5						1.8	M	M	1.8	M		M

Water Body Criteria Analysis		(3) ISU Criteria Analysis			DEQ Additional Criteria												
RIVER	SITE I.D.	Order	Baseflow Width	Average Baseflow Depth	Site Mean Annual Discharge	Site Drainage Area	Average Greatest Depth at Baseflow	DEQ Addl Criteria Ave.	DEQ Addl CriteriaRiver Size Class	ISU Criteria Ave.	ISU Criteria River Size Class	River Size Class (ISU designated)	All Criteria Ave.	All Criteria River Size Class	DEQ Addl CriteriaRiver Size Class	ISU Criteria River Size Class
	MIN.	1.00	1.00	1.00	0.00	0.00	0.00	2.00		1.00			1.00			0.00
	MAX	3.00	3.00	3.00	3.00	3.00	3.00	3.00		3.00			3.00			0.00
	AVG.	1.91	2.39	2.43	1.29	1.47	1.45	2.51		2.25			2.31			0.00
	MEDIAN	2.00	2.50	3.00	2.00	2.00	2.00	2.33		2.33			2.33			0.00
	STDS	0.56	0.63	0.69	1.31	1.29	1.28	0.41		0.52			0.50			0.00

Appendix C.
RMI DATA

Water Body	Site ID	Old Site ID	MBI	IMRI	IRI	Size	R,T,O
Snake R (Massacre)	1997RSCIROQ001		1.83	14	5	L	O
Snake R (Milner)	1997RSCIROQ003		3.77	18	9	L	O
Teton R (U)	1997REIRO0Q002		4.29	18	19	L	O
Big Wood R (L)	1997RSCIROQ004		3.47	10	19	L	R
Falls R (L)	1997REIRO0Q001		4.38	14	21	L	R
Henry's Fork (L)	1997REIRO0Q004		3.72	14	19	L	R
Henry's Fork (U)	1997REIRO0Q003		4.28	18	21	L	R
Lochsa R	1997RNCIROQ004		4.92	20	23	L	R
MF Boise R (T1)	1997RSWIROQ001A		4.95	24	23	L	R
MF Boise R (T4)	1997RSWIROQ001B		4.53	20	23	L	R
MF Boise R (T6)	1997RSWIROQ001C		4.88	20	23	L	R
NF Boise R	1997RSWIROQ002		4.83	18	21	L	R
Portneuf R (U)	1997RSEIROQ001		4.44	18	21	L	R
SF Boise R (T1)	1997RSWIROQ003A		4.51	16	21	L	R
SF Boise R (T4)	1997RSWIROQ003B		4.38	14	23	L	R
SF Boise R (T6)	1997RSWIROQ003C		4.67	14	21	L	R
SF Clearwater (L)	1997RNCIROQ001		4.01	20	17	L	R
SF Clearwater (M)	1997RNCIROQ002		4.80	18	21	L	R
Selway R	ISU1997VR1				23	L	R
Big Cr	ISU1997VR2				23	L	R
MF Salmon R	ISU1997VR3				23	L	R
Falls	1995ISU3				19	L	R
Henrys@Coffe	1995ISU4				21	L	R
Henrys@Pine	1995ISU5				21	L	R
Henrys@Ash	1995ISU6				13	L	R
Snake@Heise	1995ISU7				12	L	R
Owhyee	1995ISU10				21	L	R
Salmon@Y	1995ISU11				23	L	R
Salmon@Dead	1995ISU12				17	L	R
Salmon@Chall	1995ISU13				23	L	R
SF Payette	1995ISU14				21	L	R
MF Boise	1995ISU15				21	L	R
Selway	1995ISU16				21	L	R
Lochsa	1995ISU17				23	L	R
MF Clear	1995ISU18				21	L	R
CDA@Shosh	1995ISU19				21	L	R

Water Body	Site ID	Old Site ID	MBI	IMRI	IRI	Size	R,T,O
St Joe@Calder	1995ISU21				21	L	R
StJoe@Avery	1995ISU22				23	L	R
Blackfoot R (L)	1997RSEIROQ006		3.69	16	19	L	T
Coeur d'Alene R (Harrison)	1997RNIRO0Q005		1.93	10	13	L	T
Coeur d'Alene R (Medimont)	1997RNIRO0Q007		2.74	10	11	L	T
Coeur d'Alene R (Rose Lake)	1997RNIRO0Q006		2.27	14	7	L	T
NF Coeur d'Alene R	1997RNIRO0Q001		3.48	22	15	L	T
Pend Oreille R	1997RNIRO0Q002		2.27	10	11	L	T
Portneuf R (LM)	1997RSEIROQ004		3.64	16	17	L	T
Portneuf R (M)	1997RSEIROQ003		0.55	14	5	L	T
Portneuf R (UM)	1997RSEIROQ002		2.50	10	15	L	T
St. Marie's R	1997RNIRO0Q004		2.57	10	15	L	T
Snake R, Bingham Co	ISU1997VD1				15	L	T
SF Salmon R	ISU1997VD2				23	L	T
Boise R, Canyon Co	ISU1997VD3				15	L	T
Bear@Pea	1995ISU1				13	L	T
Bear@Riv	1995ISU2				11	L	T
Snake@Buhl	1995ISU8				7	L	T
Snake@King	1995ISU9				7	L	T
CDA@Cat	1995ISU20				7	L	T
BEAR CREEK	1996SIDFY031	96EIROY031	5.13	18	21	M	O
BIRCH CREEK (MIDDLE)	1995SIDF0B32	95EIRO0B32	4.06	10	15	M	O
BREAKFAST CREEK (LOWER)	1997SLEWB22	97NCIROB22	4.27	20	23	M	O
CLEAR CREEK (MIDDLE)	1996SLEWC17	96NCIROC17	5.06	26	23	M	O
DEEP CREEK (LOWER)	1996SBOIB018	96SWIROB18	3.50	8	21	M	O
DEEP CREEK (LOWER)	1997SBOIA031	97SWIROA31	3.03	8	17	M	O
EAST FORK WOOD RIVER	1996STWFA049	96SCIROA49	5.27	14	21	M	O
GOOSE CREEK (LOWER)	1997STWFA069	97SCIROA69	3.89	14	19	M	O
LIME CREEK (LOWER)	1996SBOIB038	96SWIROB38	3.21	14	13	M	O

Water Body	Site ID	Old Site ID	MBI	IMRI	IRI	Size	R,T,O
LITTLE WOOD RIVER	1996STWFB017	96SCIROB17	3.38	18	19	M	O
LITTLE WOOD RIVER (UPPER)	1996STWFA048	96SCIROA48	4.41	16	21	M	O
LONG MEADOW CREEK	1997SLEWB17	97NCIROB17	4.18	14	23	M	O
LOOP CREEK (UPPER)	1997SCDAA29	97NIRO0A29	4.82	24	21	M	O
MEDICINE LODGE (MIDDLE)	1994SIDF0067	94EIRO0067	3.36	10	19	M	O
MIDDLE FORK PAYETTE RIVER	1997SBOIB072	97SWIROB72	3.67	10	23	M	O
MORES CREEK (LOWER MID)	1996SBOIA054	96SWIROA54	2.85	12	15	M	O
MORES CREEK (LOWER)	1996SBOIA079	96SWIROA79	4.14	10	21	M	O
NF ST JOE RIVER	1997SCDAA36	97NIRO0A36	3.92	20	19	M	O
RAINEY CREEK	1996SIDFZ023	96EIROZ023	4.96	18	23	M	O
SAWMILL CREEK (LOWER)	1995SIDF0B38	95EIRO0B38	4.55	14	13	M	O
SQUAW CREEK	1994SIDF00042	94EIRO0042	4.55	18	23	M	O
SQUAW CREEK (UPPER)	1997SIDF00041	97EIRO0041	3.13	16	21	M	O
SQUAW CREEK (UPPER)	1995SIDF0A70	95EIRO0A70	4.07	16	23	M	O
WILLOW CREEK (LOWER)	1995SIDF0B70	95EIRO0B70	3.59	10	17	M	O
WILLOW CREEK (UPPER)	1995SIDFB072	95EIROB072	4.22	12	19	M	O
WILLOW CREEK (UPPER)	1995SIDFB068	95EIROB068	3.64	14	17	M	O
WOLF CREEK	1997SLEWB19	97NCIROB19	3.86	12	17	M	O
Blackfoot R (U)	1997RSEIROQ005		3.92	14	21	M	O
BEAR VALLEY CREEK	1997SIDFM085	97EIROM085	5.52	24	21	M	R
BEAR VALLEY CREEK (LOWER)	1997SBOIA063	97SWIROA63	3.47	14	17	M	R
BIG ELK CREKK	1996SIDFZ124	96EIROZ124	4.81	24	21	M	R

Water Body	Site ID	Old Site ID	MBI	IMRI	IRI	Size	R,T,O
BIG SMOKEY CREEK	1997STWFA056	97SCIROA56	5.33	16	23	M	R
BITCH CREEK	1996SIDFZ130	96EIROZ130	4.44	10	23	M	R
BITCH CREEK	1996SIDFZ131	96EIROZ131	4.19	18	21	M	R
EAST FORK WOOD RIVER (UPPER)	1996STWFA051	96SCURIA51	5.17	26	21	M	R
FEATHER RIVER (LOWER)	1996SBOIA064	96SWIROA64	4.91	20	23	M	R
FEATHER RIVER (UPPER)	1996SBOIA063	96SWIROA63	4.15	16	21	M	R
INDEPENDENCE CREEK (LOWER)	1997SCDAA18	97NIRO0A18	3.52	12	15	M	R
JARBIDGE RIVER	1997STWFA032	97SCIROA32	3.16	10	17	M	R
NORTH FORK BIG WOOD RIVER	1996STWFA043	96SCIROA43	4.49	14	23	M	R
NUGGET CREEK	1997SCDAA27	97NIRO0A27	3.82	16	15	M	R
OLSON CREEK	1997SCDAA40	97NIRO0A40	4.93	22	23	M	R
PALISADES CREEK	1996SIDF0Z125	96EIROZ125	4.95	26	23	M	R
PANTHER CREEK	1995SIDFB040	95EIROB040	5.09	22	23	M	R
SHAFER CREEK (LOWER)	1996SBOIA046	96SWIROA46	3.71	14	19	M	R
SQUAW CREEK (UPPER)	1995SIDF0A69	95EIRO0A69	4.69	16	23	M	R
TRINITY CREEK (LOWER)	1996SBOIA056	96SWIROA56	4.52	20	19	M	R
WILLOW CREEK	1997SIDFM03	97EIROM003	3.54	8	19	M	R
Bear R.		93SWIRO38	4.12	18	23	M	R
Big Wood River		95SCIROA66	4.11		21	M	R
Boise R., NF		94SWIROA26	4.34	16	21	M	R
Boise R., SF@Abbotts		95SWIROA56	4.6	16	23	M	R
Burneau R.		93SWIRO48	4.43	22	23	M	R
Camas Cr		EIROM090	5.27	22	23	M	R
Deadwood R.		93SWIRO24	3.89	20	23	M	R
EF Salmon		EIROl104	3.75	14	19	M	R
Gold Fork R.		94SWIROB04	4.80	20	23	M	R

Water Body	Site ID	Old Site ID	MBI	IMRI	IRI	Size	R,T,O
Hughes Cr		95niro050	4.1	14	23	M	R
Hughes Cr		95niro051	4.85	22	23	M	R
Hyndman Creek		96SCIROB28	3.57		13	M	R
Marsh Cr		EIROm147	4.34	14	23	M	R
MF East R		96niroa16	4.2	18	23	M	R
NF Salmon R		EIROm64	4.73	26	23	M	R
Owyhee R., NF		95SWIROB08	3.64	12	21	M	R
Roaring R.		96swiroa60	4.59	24	19	M	R
Ross Fork Creek		96SCIROA41	4.98		21	M	R
Ross Fork Creek		96SCIROA39	3.52		19	M	R
Salmon R@Hellroaring		EIROA75	3.08	14	21	M	R
Secesh R.		95swiroc12	4.41	18	23	M	R
Smith Cr		94niro036	4.02	16	19	M	R
South Fork Boise River		95SCIROA76	3.95		21	M	R
South Fork Boise River		95SCIROA67	4.17		21	M	R
South Fork Boise River		95SCIROA76	3.95		21	M	R
South Fork Boise River		95SCIROA67	4.17		21	M	R
Upper Priest		94niro21	4.77	24	23	M	R
Upper Priest		94niro22	4.59	22	23	M	R
Upper St Joe		94niro051	5	26	23	M	R
Upper St Joe		94niro050	4.28	14	23	M	R
Warm River		EIROM75	5.42	14	23	M	R
Wildhorse R.		94SWIROA33	5.46	24	23	M	R
Big Wood R (U)	1997RSCIROQ005		3.42	10	13	M	R
EF SF Salmon R (T1)	1997RSWIROQ005A		5.19	26	21	M	R
EF SF Salmon R (T3)	1997RSWIROQ005B		5.08	26	21	M	R
EF SF Salmon R (T6)	1997RSWIROQ005C		5.76	30	21	M	R
SF Clearwater (U)	1997RNCIROQ003		4.92	22	23	M	R
SF Salmon R	1997RSWIROQ004		4.86	22	23	M	R
Priest R	ISU1996R1			21	21	M	R
NF CD'A	ISU1996R2			25	23	M	R
Lochsa	ISU1996R3			29	23	M	R
Little Salmon	ISU1996R4			19	23	M	R
Salmon + Stanley	ISU1996R5			31	23	M	R
EF Salmon	ISU1996R6			29	21	M	R
Valley Cr	ISU1996R7			33	23	M	R

Water Body	Site ID	Old Site ID	MBI	IMRI	IRI	Size	R,T,O
SF Boise	ISU1996R8			31	23	M	R
Big Wood R+ Ketchum	ISU1996R9			33	21	M	R
Big Lost R + Chilly	ISU1996R10			33	21	M	R
Bitch	1997ISU			21		M	R
Running	1997ISU			19		M	R
Rush	1997ISU			17		M	R
Beaver Cr		EIROB63	1.13	18	5	M	T
Big Lost@Moore (L)		EIROa102	1.81	18	7	M	T
Big Lost@Moore (U)		EIROA103	2.29	18	7	M	T
Billingsley Creek		94SCIRO024	2.56		9	M	T
Boise@Caldwell		95SWIROC30	2.02	10	7	M	T
Boise@Notus		95SWIROC29	2.92	12	9	M	T
Boise@Star		95SWIROC31	3.13	16	9	M	T
Deep Creek		96SCIROB47	1.08		11	M	T
Lightning		94niro023	4.68	16	21	M	T
NF CD'A		96nirob03	4.74	24	21	M	T
Pack		94niro009	4.04	16	19	M	T
Payette R, below Payette WWTP		na	4.00	18	11	M	T
Payette R., MF@ Tie Cr camp		94SWIROA44	4.55	18	23	M	T
Payette R., MF@county line		95SWIROB09	2.62	10	19	M	T
Payette R@Black Canyon		na	3.14	12	11	M	T
Prichard		96nirob32	2.60	18	9	M	T
Rock Creek		95SCIROA59	2.88		7	M	T
Rock Creek		95SCIROA61	2.81		9	M	T
St Maries		96niroa40	4.83	24	23	M	T
St Maries, WF		96niroa46	3.91	22	21	M	T
ANTELOPE CREEK	1995SIDF0A57	95EIRO0A57	3.45	14	17	M	T
BEDROCK CREEK	1997SLEWZ03	97NCIROZ03	3.61	10	19	M	T
BIG CANYON CREEK	1997SLEWZ11	97NCIROZ11	3.31	10	17	M	T
BIG DEER CREEK (LOWER)	1995SIDF0B77	95EIRO0B77	2.68	18	13	M	T
CATHOLIC	1997SLEWZ01	97NCIROZ01	3.79	14	15	M	T

Water Body	Site ID	Old Site ID	MBI	IMRI	IRI	Size	R,T,O
CREEK							
CATHOLIC CREEK	1997SLEWZ02	97NCIROZ02	3.04	18	11	M	T
CATHOLIC CREEK	1997SLEWZ04	97NCIROZ04	4.14	20	15	M	T
CLEAR CREEK (LOWER)	1996SLEWA23	96NCIROA23	4.78	20	23	M	T
CLOVER CREEK	1997STWFA033	97SCIROA33	5.00	22	21	M	T
CLOVER CREEK	1997STWFA034	97SCIROA34	3.98	18	17	M	T
CLOVER CREEK	1997STWFA042	97SCIROA42	3.17	14	13	M	T
CLOVER CREEK (LOWER)	1997STWFB016	97SCIROB16	3.76	14	11	M	T
CLOVER CREEK (MIDDLE)	1997STWFA014	97SCIROA14	2.40	10	15	M	T
CLOVER CREEK (MIDDLE)	1997STWFB014	97SCIROB14	2.31	8	13	M	T
CRANE CREEK	1996SBOIB022	96SWIROB22	2.67	6	7	M	T
EF BIG LOST RIVER	1995SIDF0A36	95EIRO0A36	1.33	10	7	M	T
LAPWAI CREEK	1996SLEWZ01	96NCIROZ01	2.70	10	13	M	T
LAPWAI CREEK	1997SLEWZ16	97NCIROZ16	4.93	10	17	M	T
LAPWAI CREEK	1997SLEWZ17	97NCIROZ17	5.45	14	19	M	T
LAWYER CREEK	1997SLEWZ21	97NCIROZ21	5.25	12	21	M	T
LITTLE CANYON CREEK	1996SLEWZ10	96NCIROZ10	3.90	14	15	M	T
LITTLE SALMON RIVER (LOWER)	1997SBOIB027	97SWIROB27	2.68	10	17	M	T
LOOP CREEK (LOWER)	1997SCDAA28	97NIRO0A28	4.03	12	19	M	T
MEDICINE LODGE CREEK (UPPER)	1994SIDF00066	94EIRO0066	4.42	12	23	M	T
MISSION CREEK	1997SLEWZ08	97NCIROZ08	5.17	20	23	M	T
MISSION CREEK	1997SLEWZ19	97NCIROZ19	5.68	18	23	M	T
MISSION CREEK	1997SLEWZ20	97NCIROZ20	4.59	10	19	M	T
PALOUSE RIVER (LOWER)	1996SLEWB44	96NCIROB44	4.03	14	21	M	T
PANTHER	1995SIDF0B78	95EIRO0B78	1.29	10	11	M	T

Water Body	Site ID	Old Site ID	MBI	IMRI	IRI	Size	R,T,O
CREEK (LOWER)							
PANTHER CREEK (MIDDLE)	1995SIDFB079	95EIROB079	1.61	10	9	M	T
PRICHARD CREEK (LOWER)	1997SCDAB02	97NIRO0B02	4.48	18	15	M	T
PRICHARD CREEK (UPPER)	1997SCDAB01	97NIRO0B01	4.65	22	15	M	T
RAPID LIGHTNING CREEK	1997SCDAA13	97NIRO0A13	4.61	16	19	M	T
RED ROCK CREEK	1997SLEWZ12	97NCIROZ12	1.97	10	9	M	T
SALMON FALLS CREEK (MID)	1996STWFA040	96SCIROA40	4.09	16	17	M	T
SAND CREEK (LOWER)	1997SCDAA16	97NIRO0A16	3.81	16	15	M	T
SAND CREEK (UPPER)	1997SCDAA17	97NIRO0A17	3.21	10	17	M	T
SHERIDAN CREEK (LOWER)	1995SIDF0A64	95EIRO0A64	2.80	12	11	M	T
SHERIDAN CREEK (LOWER)	1995SIDF0A65	95EIRO0A65	3.40	12	13	M	T
SHOSHONE CREEK	1996STWFA007	96SCIROA07	4.49	12	21	M	T
SHOSHONE CREEK	1996STWFA008	96SCIROA08	3.33	18	13	M	T
ST MARIES RIVER	1997SCDAA33	97NIRO0A33	4.53	24	21	M	T
SUCCOR CREEK (LOWER)	1997SBOIA008	97SWIROA08	3.71	18	19	M	T
SUCCOR CREEK (MIDDLE)	1997SBOIA009	97SWIROA09	3.17	8	9	M	T
SWEETWATER CREEK	1997SLEWZ14	97NCIROZ14	4.77	12	23	M	T
YANKEE FORK (LOWER)	1995SIDF0A92	95EIRO0A92	5.17	18	23	M	T
Little Wood R (U)	1997RSCIROQ002		4.38	14	21	M	T
Pack R	1997RNIRO0Q003		2.30	10	15	M	T
Weiser R	ISU1996D1			13	23	M	T
Bruneau R	ISU1996D2			21	23	M	T

Water Body	Site ID	Old Site ID	MBI	IMRI	IRI	Size	R,T,O
Big Wood R - Bellvue	ISU1996D3			13	21	M	T
Blackfoot R	ISU1996D4			9	23	M	T
Portneuf R	ISU1996D5			13	23	M	T
SF CDA	1997ISU			15		M	T
Panther	1997ISU			15		M	T
Blackfoot	1997ISU			9		M	T

Appendix D.
RFI DATA

Water Body	Site ID	River Basin	R,T,O	RFI
Bear Cr	96SIDFY31	USNK	R	81
Big Lost R@Chilly93	USNK-24	USNK	R	71
Big Lost R@Chilly94	USNK-24	USNK	R	74
Big Lost R@Chilly95	USNK-24	USNK	R	71
Big Lost R+Chilly94	USNK-24-94a	USNK	R	75
Big Lost R-Chilly94	USNK-24-94c	USNK	R	76
Big Wood R nr Baker Cr (9/93)	1995STWFB049	USNK	R	79
Big Wood R nr Boulder Cr	USNK-26	USNK	R	84
Bitch Cr + Swanner Cr	1996SIDFY131	USNK	R	91
Bitch Cr near Lamont, ID	USNK-8-93	USNK	R	87
Falls River nr Squirrel	USNK-7	USNK	R	77
Grays Lake Outlet	95SIDFB69	USNK	O	56
Greys@Palisades	USNK-3	USNK	R	79
Henrys@Ashton, ID	USGS-13046000-99	USNK	R	80
Henry's@Rexburg, ID	USGS-13056500-99	USNK	T	62
Henrys@Rexburg93	USNK-10-93	USNK	T	39
Henrys@Rexburg96	USNK-10-96	USNK	T	45
Henrys@St Anthony, ID	USGS-13050500-99	USNK	R	78
Little Granite@Hoback	USNK-2-93	USNK	R	84
Little Wood@Carey	USNK-27	USNK	R	82
Malad River	USNK-28	USNK	T	18
Marsh@McCammon, ID	USGS-130075000-97	USNK	T	46
Medicine@Small93	USNK-23	USNK	R	84
Medicine@Small97	94SIDF67	USNK	R	77
Portneuf@Pocatello96a	USNK- ?-96	USNK	T	TFF
Portneuf@Pocatello96b	USNK- ?-96	USNK	T	60
Portneuf@Topaz93	USNK-12	USNK	T	19
Portneuf@Topaz94	USNK-12	USNK	T	36
Portneuf@Topaz95	USNK-12	USNK	T	36
Robinson Cr + Rock Cr	1996SIDFY055	USNK	R	75
Robinson@Warm	USNK-6	USNK	R	74
Rock@Rock93	USNK-17	USNK	T	36
Rock@US30 93	USNK-18-93	USNK	T	61
Rock@US30 94	USNK-18-94b	USNK	T	75
Rock@US30 95	USNK-18-95	USNK	T	73
Rock@US30 96	USNK-18-96	USNK	T	62
Rock@US30 97a	USNK-18-97a	USNK	T	64
Rock@US30 97b	USNK-18-97b	USNK	T	53
Rock+US30 94	USNK-18-94a	USNK	T	53
Rock-US30 94	USNK-18-94c	USNK	T	63
Salt@Etna93	USNK-5	USNK	T	77

Water Body	**Site ID**	**River Basin**	**R,T,O**	**RFI**
Salt@Etna94	USNK-5	USNK	T	76
Salt@Etna95	USNK-5	USNK	T	73
Salt@Smoot	USNK-4	USNK	R	96
Sheridan@IPR	95SIDFA64	USNK	T	40
Snake@Blackfoot93	USNK-11-93	USNK	T	46
Snake@Blackfoot96	USNK-11-96	USNK	T	60
Snake@Buhl93	USNK-19-93	USNK	T	10
Snake@Buhl96	USNK-19-96	USNK	T	9
Snake@Buhl97	USNK-19-97	USNK	T	20
Snake@Buhl99	USNK-19-99	USNK	T	29
Snake@Flagg93	USNK-1	USNK	R	73
Snake@Flagg94	USNK-1	USNK	R	82
Snake@Flagg95	USNK-1	USNK	R	81
Snake@Glenns Ferry	? Data provided by IDEQ-TWF	USNK	T	17
Snake@Heise, ID	USGS-13037500-99	USNK	R	83
Snake@Kings93	USNK-30	USNK	T	9
Snake@Kings94	USNK-30	USNK	T	32
Snake@Kings95	USNK-30	USNK	T	20
Snake@Kings96	USNK-30-96	USNK	T	27
Snake@Kings97	USNK-30-97	USNK	T	15
Snake@Kings98	USNK-30-98	USNK	T	25
Snake@Kings99	USNK-30-99	USNK	T	19
Snake@Massacre Rocks, ID	IPC1995AFB	USNK	T	58
Snake@Minidoka93	USNK-14-93	USNK	T	3
Snake@Moose	USNK-	USNK	R	84
Spring Cr@Ft Hall	USNK-13	USNK	R	74
Teton@Driggs	95SIDFA112	USNK	R	86
Teton@St Anthony	USNK-9	USNK	T	81
Warm+Robinson	97SIDFM75	USNK	R	71
Willow-GLO	94SIDF79	USNK	O	48
Bitterroot@Missoula, MT	NROK-5	PAN	R	54
Blackfoot@Helmville, MT	NROK-4	PAN	R	70
Clark Fk@Bonner, MT	NROK-3	PAN	T	35
Clark Fk@Galen, MT	NROK-1	PAN	T	79
Clark Fk@St Regis, MT	NROK-6	PAN	T	71
Clark Fork@Cabinet	WWP-94	PAN	T	44
Flathead@Perma, MT	NROK-9	PAN	T	23
Hangman Ck@ Spokane, WA	NROK-22	PAN	T	30
Lightning Ck@Clark Fk, ID	NROK-11	PAN	T	49
Mid Fk Flathead@Glacier, MT	NROK-8	PAN	R	75
N Fk Coeur d'Alene + Enaville, 6/88	NF1-Dames&Moore 89	PAN	R	90
N Fk Coeur d'Alene R + Enaville, 9/87	NF1-Dames&Moore 89	PAN	R	89
N Fk Coeur d'Alene@Enaville, ID	NROK-14	PAN	R	51
Priest@Priest R, ID	NROK-12	PAN	T	21
Rock Ck@Clinton, MT	NROK-2	PAN	R	69

Water Body	Site ID	River Basin	R,T,O	RFI
0	0	Name?	0	Basin?
S Fk Coeur d' Alene nr Mullan	NROK98	PAN	R	81
S Fk Coeur d'Alene - Big Cr 6/88	SF2-Dames&Moore 89	PAN	T	64
S Fk Coeur d'Alene - Big Cr 9/87	SF2-Dames&Moore 89	PAN	T	20
S Fk Coeur d'Alene@Kellogg 6/88	SF4-Dames&Moore 89	PAN	T	TFF
S Fk Coeur d'Alene@Kellogg 9/87	SF4-Dames&Moore 89	PAN	T	29
S Fk Coeur d'Alene@Pinehurst, ID	NROK16	PAN	T	39
S Fk Coeur d'Alene@Pinehurst, ID	NROK-16-1999A	PAN	T	65
S Fk Coeur d'Alene@Pinehurst, ID	NROK-16-1999B	PAN	T	58
S Fk Coeur d'Alene@Pinehurst, ID	NROK-16-1999C	PAN	T	50
S Fk Coeur d'Alene@Pinehurst, ID 6/88	SF8-Dames&Moore 89	PAN	T	41
S Fk Coeur d'Alene@Pinehurst, ID 9/87	SF8-Dames&Moore 89	PAN	T	TFF
S Fk Coeur d'Alene@Smelterville 6/88	SF5-Dames&Moore 89	PAN	T	TFF
S Fk Coeur d'Alene@Smelterville 9/87	SF5-Dames&Moore 89	PAN	T	26
Spokane R. @ Green St, WA	USGS 12420800	PAN	T	25
Spokane R. @ Sullivan Bridge,WA	USGS 12420800	PAN	T	45
Spokane R. + Liberty Bridge,WA	USGS 12420800	PAN	T	28
Spokane R.@ Post Falls, ID	NROK-20-1999	PAN	T	1
Spokane R.+ 7-mile bridge, WA	USGS 12424500	PAN	T	54
Spokane R@ Spokane, WA	NROK-21	PAN	T	16
Spokane R@Post Falls, ID	NROK-20	PAN	T	25
St Joe@ Calder, ID	NROK-19	PAN	R	51
St Joe@ Red Ives Ranger Station	NROK-18-1999A	PAN	R	96
St Joe@ Red Ives Ranger Station	NROK-18-1999B	PAN	R	100
St Joe@ Red Ives Ranger Station	NROK-18-1999C	PAN	R	100
St Joe@ Red Ives, ID	NROK-18	PAN	R	99
Big Smokey Cr	95SCIROA75	LSNK	R	TFF
Boise (Caldwell)	WRIR99-4178-5-AUG97	LSNK	T	23
Boise (Glenwood Br)	WRIR99-4178-3-DEC96	LSNK	T	52
Boise (Glenwood Br)	WRIR99-4178-3-FEB95	LSNK	T	46
Boise (Loggers Cr Div)	WRIR99-4178-2-DEC96	LSNK	T	90
Boise (Middleton)	WRIR99-4178-4-AUG97	LSNK	T	27
Boise (Middleton)	WRIR99-4178-4-DEC96	LSNK	T	39
Boise (Parma 96)	WRIR99-4178-6-DEC96	LSNK	T	11
Boise (Parma 97)	WRIR99-4178-6-AUG97	LSNK	T	7

Water Body	Site ID	River Basin	R,T,O	RFI
Boise R - Lander St WWTF	WRIR98-4123-2-DEC96	LSNK	T	57
Boise R - Lander St WWTF	WRIR98-4123-2-MAR95	LSNK	T	48
Boise R - W Boise WWTF	WRIR98-4123-4-DEC96	LSNK	T	60
Boise R - W Boise WWTF	WRIR98-4123-4-MAR95	LSNK	T	66
Boise R + Lander St WWTF	WRIR98-4123-1-DEC96	LSNK	T	78
Boise R + Lander St WWTF	WRIR98-4123-1-MAR95	LSNK	T	92
Boise R + W Boise WWTF	WRIR98-4123-3-DEC96	LSNK	T	65
Boise R + W Boise WWTF	WRIR98-4123-3-MAR95	LSNK	T	62
Bruneau R. - Hot Creek, ID	1997STWFA035	LSNK	R	TFF
Jarbidge River - EF Jarbidge	1997SCIROA032	LSNK	R	92
Malheur R, OR	EMAP ORST97-073	LSNK	T	31
Malheur R, OR	EMAP ORST97-070	LSNK	T	36
Marsh Cr + MF Salmon R conf.	1997SIDFM147	LSNK	R	TFF
McCoy Cr, OR	EMAP ORST97-153	LSNK	T	85
NF Burnt R, OR	EMAP ORST97-135	LSNK	T	73
North Powder River, OR	EMAP ORST97-113	LSNK	T	54
Payette (Black Canyon)	RM36-97 (IDFG)	LSNK	T	60
Payette (Blacks Br)	RM15-97 (IDFG)	LSNK	T	43
Payette (County line)	RM18-97 (IDFG)	LSNK	T	23
Payette (Fruitland)	RM4-97 (IDFG)	LSNK	T	24
Payette (Hwy 52 Br)	RM33-97 (IDFG)	LSNK	T	52
Payette (Letha Br)	RM25-97 (IDFG)	LSNK	T	32
Payette (mouth)	RM1-97 (IDFG)	LSNK	T	14
Payette (Smiths)	RM30-97 (IDFG)	LSNK	T	40
Salmon Falls Cr(8/96)	96SCIROA40	LSNK	R	25
Salmon Falls Cr(TF1)	? Data provided by IDEQ-TWF	LSNK	O	59
Salmon Falls Cr(TF2)	? Data provided by IDEQ-TWF	LSNK	O	56
Salmon Falls Cr@Bal.Rock	96SCIROA06	LSNK	R	TFF
Salmon R @ Whitebird	USGS 13317000	LSNK	R	51
Salmon R - Partridge Cr, nr Riggins, ID	1999RLEW001 (USGS 13315000)	LSNK	R	82
Salmon R - Yankee Fork nr Clayton, ID	1999RIDF001 (USGS 13296500)	LSNK	R	95
Salmon R + NF Salmon nr N Fork, ID	1999RIDF003 (USGS 13298500)	LSNK	R	84
Salmon R + Pahsimeroi R nr Challis, ID	1999RIDF002 (USGS 13298500)	LSNK	R	93

Water Body	Site ID	River Basin	R,T,O	RFI
Salmon R nr Obsidian (1)	1998SIDFC057	LSNK	R	TFF
Salmon R nr Obsidian (2)	19995SIDFA76	LSNK	R	87
SalmonFalls Cr@Lily	USNK-22	LSNK	R	83
SF Boise	IDFG 8/94	LSNK	R	98
Snake - Lower Salmon Falls dam	IPC1995AJW	LSNK	T	31
Snake - Swan Falls dam	IPC1995SFB	LSNK	T	20
Snake@Nyssa, OR	USGS 97-13213100	LSNK	T	8
Squaw Cr nr Clayton, ID	Chadwick80-SQ2	LSNK	R	100
Squaw Cr nr Clayton, ID	Chadwick81-SQ2	LSNK	R	100
Squaw Cr nr Clayton, ID	Chadwick82-SQ2	LSNK	R	100
Squaw Cr nr Clayton, ID	Chadwick86-SQ2	LSNK	R	89
Squaw Cr nr Clayton, ID	Chadwick89-SQ2	LSNK	R	98
Squaw Cr nr Clayton, ID	Chadwick90-SQ2	LSNK	R	98
Squaw Cr nr Clayton, ID	Chadwick91-SQ2	LSNK	R	94
Squaw Cr nr Clayton, ID	Chadwick96-SQ2	LSNK	R	100
Squaw Cr nr Clayton, ID	Chadwick97-SQ3	LSNK	R	98
Squaw Cr nr Clayton, ID	Chadwick98-SQ2	LSNK	R	94
Squaw Cr nr Clayton, ID	Chadwick99-SQ2	LSNK	R	99
Valley Cr nr Stanley, ID	1995SIDFA073	LSNK	R	92
Wallowa R, OR	EMAP ORST97-179	LSNK	R	85
Wenaha R, OR	EMAP ORST97-194	LSNK	R	91
Yankee Fork Salmon(L)	95SIDFA93	LSNK	T	TFF
Yankee Fork Salmon(U)	95SIDFA92	LSNK	R	91
Sprague R. OR	EMAP ORST97-215	KLAM	O	25
Sprague R. OR	EMAP ORST97-216	KLAM	O	38
Bear R. - Smiths Fork, WY	USGS 10038000	GBAS	O	40
Bear R. nr Corrine, UT	USGS 1012600	GBAS	O	6
Bear R. nr Montpelier, ID	USGS 10068500	GBAS	O	22
Donner and Blitzen R, OR	EMAP ORST97-333	KLAM	O	93
American River nr Nile, WA	USGS YAKI-5	COL	R	86
Big Marsh,OR	EMAP ORST97-311	COL	T	62
Clatskanie R,OR	EMAP ORST97-004	COL	O	62
Deschutes R, OR	EMAP ORRV98-027	COL	R	80
Deschutes R, OR	EMAP ORRV98-029A	COL	R	86
Deschutes R, OR	EMAP ORRV98-029B	COL	R	75
Hood R, OR	EMAP ORST97-020	COL	R	98
John Day R,OR	EMAP ORRV98-067	COL	R	13
John Day R,OR	EMAP ORST97-028	COL	R	19
MF Willamette R, OR	EMAP ORRV98-133A	COL	O	77
MF Willamette R, OR	EMAP ORRV98-133B	COL	O	85
MF Willamette R, OR	EMAP ORRV98-135	COL	O	89
MF Willamette R, OR	EMAP ORST97-313	COL	O	80
Mill Cr, OR	EMAP ORST97-046	COL	R	78
NF John Day R, OR	EMAP ORRV98-073	COL	R	33
NF John Day R, OR	EMAP ORST97-176	COL	R	55
NF MF Willamettee	EMAP ORST97-308	COL	O	81
South Santiam R, OR	EMAP ORRV98-179A	COL	O	83

Water Body	**Site ID**	**River Basin**	**R,T,O**	**RFI**
Willamette R, OR	EMAP ORRV98-181	COL	O	32
Willow Cr,OR	EMAP ORST97-058	COL	T	45
Yakima R - Toppenish Cr, WA	USGS YAKI-26	COL	T	31
Yakima R + Umtanum Cr, WA	USGS YAKI-22	COL	R	54
Yakima R at Cle Elum, WA	USGS YAKI-21	COL	R	87
Yakima R at Kiona, WA	USGS YAKI-28	COL	T	19
Yakima R at Parker, WA	USGS YAKI-25	COL	T	21
Nehahem R, OR	EMAP ORRV98-003	COAST	O	83
Rogue R, OR	EMAP ORRV98-091A	COAST	O	81
Rogue R, OR	EMAP ORRV98-091B	COAST	O	86
Umpqua R, OR	EMAP ORRV98-161	COAST	O	20
Alsea R	EMAP ORRV98-191-10	COL	O	74
Alsea R	EMAP ORRV98-191-9	COL	O	59
Siletz R.	EMAP ORST97-429	COL	O	61
Palouse R., at Hooper, WA	USGS PAL018	COL	T	22
SF Palouse R. at Colfax, WA	USGS SFP002 9/27/93	COL	T	33
SF Palouse R. at Colfax, WA	USGS SFP002 8/31/94	COL	T	29
SF Palouse R. at Colfax, WA	USGS SFP002 9/01/94	COL	T	34

Appendix E.
RDI DATA

Site Name	Site ID	Date	RDI
bgwdl	97RSCIROQ004	10/28/1997	18
bgwdu	97RSCIROQ005	10/29/1997	16
blkft	1998RPOCP001	10/5/1998	16
br1	1998RPOCP002	10/6/1998	14
br2	1998RPOCP003	10/6/1998	22
br4	1998RPOCP005	10/7/1998	10
brn51	1998RTWFP003	10/15/1998	26
brnhs	1998RTWFP002	10/14/1998	30
brnm	1998RTWFP005	10/21/1998	36
brnu	1998RTWFP004	10/21/1998	36
jrb	1998RTWFP001	10/13/1998	36
lwdu	97RSCIROQ002	10/24/1997	38
pyt	1998RBOIP006	10/27/1998	8
sfowy	1998RBOIP005	10/20/1998	28
snk	1998RBOIP004	8/27/1998	10
snkmlnr	97RSCIROQ003	10/27/1997	16
snkmsscr	97RSCIROQ001	10/23/1997	20
wsr	1998RBOIP001	8/18/1998	12
blkftl	97RSEIROQ006	10/16/1997	20
blkftu	97RSEIROQ005	10/15/1997	26
flls	97REIRO0Q001	10/7/1997	38
hnrfkl	97REIRO0Q004	10/9/1997	28
hnrfku	97REIRO0Q003	10/8/1997	30
pnflm	97RSEIROQ004	10/15/1997	16
pnfu	97RSEIROQ001	10/14/1997	30
tetnu97	97REIRO0Q002	10/8/1997	40
cdacat	1998RCDAP010	9/21/1998	32
cdahr	97RNIRO0Q005	9/29/1997	26
cdai90	1998RCDAP009	9/21/1998	28
cdarsbr	1998RCDAP011	9/22/1998	28
cdarslk	97RNIRO0Q006	9/29/1997	34
clkfk	1998RCDAP006	9/19/1998	18
efsfslm	97RSWIROQ005	9/10/1997	34
lchs	97RNCIROQ004	9/18/1997	36
lslml	1998RLEWP001	8/19/1998	16
mfbs	97RSWIROQ001	9/4/1997	38
myi	1998RCDAP005	9/18/1998	34

Site Name	**Site ID**	**Date**	**RDI**
nfbs	97RSWIROQ002	9/5/1997	38
nfcda	97RNIRO0Q001	9/24/1997	38
prst	1998RCDAP007	9/20/1998	24
sfbs	97RSWIROQ003	9/8/1997	32
sfcda	1998RCDAP004	9/17/1998	22
sfclwtrl	97RNCIROQ001	9/16/1997	32
sfclwtrm	97RNCIROQ002	9/16/1997	30
sfclwtru	97RNCIROQ003	9/17/1997	24
sfpyt	1998RBOIP003	8/25/1998	40
sfslm	97RSWIROQ004	9/10/1997	24
slmlcly	1998RIDFP002	9/10/1998	22
slmm	1998RIDFP005	10/1/1998	30
tetn33	1998RIDFP004	9/29/1998	34
tetu98	1998RIDFP003	9/29/1998	30
clwtr			
snkastn			
snkgrnd			
spkblby			
spkblst			
spkcp			

Appendix F.
OREGON WATER QUALITY INDEX: REVISION AND APPLICATION (Draft 1998)

Curtis. G. Cude[17]

For more information on current document, see: Cude C.G. in press. Oregon Water Quality Index: A tool for evaluating water quality management effectiveness. Journal of American Water Resource Association. Paper # 99051

ABSTRACT

The Oregon Water Quality Index (OWQI) is a single number that expresses water quality by integrating measurements of eight water quality variables (temperature, dissolved oxygen, biochemical oxygen demand, pH, ammonia+nitrate nitrogen, total phosphorus, total solids, and fecal coliform). Its purpose is to provide a simple and concise method for expressing ambient water quality. The index relies on data generated from routine ambient monitoring and can be used to analyze trends in water quality over long time periods. Oregon's ambient water quality monitoring network, maintained by the Oregon Department of Environmental Quality (DEQ) Laboratory, is designed to measure cumulative impacts from point and non-point sources of pollution in a variety of conditions. In order to maintain a manageable, yet representative, index, the OWQI has certain limitations. The OWQI is designed to aid in the assessment of general water quality and cannot determine the quality of water for specific uses. The index provides a summary of water quality data and cannot be used to provide definitive information about water quality without considering all appropriate chemical, biological, and physical data. Also, the OWQI cannot evaluate all health hazards. However, the OWQI can be used to show water quality variation both spatially and temporally. The index allows users to easily interpret data and relate overall water quality variation to variations in specific categories of impairment. The OWQI can also identify problem areas and trends in general water quality. These can be screened out and evaluated in greater detail by direct observation of pertinent data. Used in this manner, the OWQI provides a basis to evaluate effectiveness of water quality management programs and assist in establishing priorities for management purposes.

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INTRODUCTION

Raw water quality data can be misleading and confusing for the general public. It may be difficult for a person interested in water quality to interpret multiple sources of data and draw valid conclusions on overall water quality conditions and trends. This may lead to faulty assessments of water quality status and management practices. It can also be difficult to effectively communicate the results from water quality management programs. As a solution, a water quality index integrates complex data and generates a single number reflecting the overall status of general water quality in a given water body. This can ultimately increase awareness of water quality conditions and improve communication of water quality issues.

Water quality indices were first seriously proposed and demonstrated beginning in the 1970s, but were not widely utilized or accepted by agencies that monitor water quality. Oregon DEQ developed the original Oregon Water Quality Index (OWQI) in 1979 (Dunnette, 1979; Dunnette, 1980). Use of the index by Oregon DEQ was discontinued because calculations in the pre-personal computer era were too labor intensive. In 1980, the US Environmental Protection Agency (EPA) Region 10 developed complex water quality indices for each state in its region (Peterson, 1980). Oregon's EPA index contained over ninety variables, which were used in various combinations depending on hydrology and beneficial use protection. These indices were used in EPA's Environmental Management Reports until 1990, when the reports were phased out.

INDEX DEVELOPMENT

While water quality indices appear in the literature as early as 1965 (Horton, 1965), the science of water quality index development did not mature until the 1970's. Detailed discussion of environmental index theory and development is available (Ott, 1978b), as is a review of water quality indices contemporary to the original OWQI (Ott, 1978a). More recent water quality indices, including the present OWQI, are based on these earlier works.

Most water quality indices are calculated in two steps. The raw analytical results for each water quality variable, having different units of measurement, are first transformed into unitless subindex values. These subindices are then combined, or aggregated, to give a single, unitless water quality index value. Typically, aggregation is accomplished using a type of averaging function. The original OWQI was modeled after the National Sanitation Foundation's (NSF) Water Quality Index (WQI); (McClelland, 1974). In both indices, variables were chosen using the Delphi method (Dalkey, 1968), which generates results from the convergence of experts' opinions. Both indices used logarithmic transforms to convert variable results into subindex values. Logarithmic transforms take advantage of the fact that a change in magnitude at lower levels of impairment has a greater impact than an equal change in magnitude at higher levels of impairment. For aggregation, the original OWQI used a weighted arithmetic mean function (Eqn. 1) while the NSF WQI used a weighted geometric mean function (Eqn. 2). The NSF found the geometric mean function to be more sensitive to changes in individual variables.

(Eqn. 1) $WQI = \sum_{i=1}^{n} SI_i W_i$ Weighted Arithmetic Mean Function

and

(Eqn. 2) $WQI = \prod_{i=1}^{n} SI_i^{W_i}$ Weighted Geometric Mean Function

Where:
WQI is Water Quality Index result
SI_i is Subindex i
W_i is Weight given to Subindex i.

The original OWQI was discontinued in 1983 due to the excessive resources required to manually calculate index results. Improvements in computer hardware/software availability and sophistication, coupled with a desire for accessible, easily understood water quality information, renewed interest in the re-examination of the index. Gains in the understanding of the physical, chemical, and biological aspects of water quality had been made since 1979. A literature review of water quality indices developed since the introduction of the original OWQI revealed fresh approaches and new tools for index development (Dinius, 1978; Stoner, 1978; Yu and Fogel, 1978; Joung et al., 1979; Bhargava, 1983; Smith, 1987; Kung et al., 1992; Dojlido et al., 1994). Information from those sources was used to revise the OWQI.

Variable Selection and Transformation

The original OWQI included six variables: dissolved oxygen saturation, biochemical oxygen demand, pH, total solids, ammonia+nitrate nitrogen, and fecal coliform. These variables were chosen from a larger set of water quality variables compiled from water quality indices in contemporary literature. A panel of water quality experts was surveyed to determine statistical importance ratings (weighting factors) for each variable. The final six variables and their weighting factors were chosen based upon their significance to Oregon's streams (Dunnette, 1980).

In the original OWQI, subindex values were obtained from transform tables. These original subindices served as the framework for the development of the present index. Subindex transformation formulae for the present OWQI were derived from these tables. In addition, two variables, temperature and total phosphorus, were added to the present OWQI based on increased significance of those variables to water quality in Oregon. The subsaturation portion of the dissolved oxygen (saturation) subindex was replaced with a dissolved oxygen concentration transformation, while the supersaturation portion was modified to include higher levels of supersaturated oxygen found in Oregon's streams. Other subindices were slightly modified to provide consistency throughout the index. Lists of subindex transformation formulae are provided in Addendums 1 and 2.

The temperature subindex (Figure F-1) was specifically designed to be protective of cold water fisheries. The equation used to derive the subindex is a modified version of the EPA Region X temperature subindex (Peterson, 1980) for Oregon's cold water fisheries. The subindex reflects temperature effects on various life stages of chinook salmon, bull trout, and tailed frog (Oregon DEQ, 1994a).

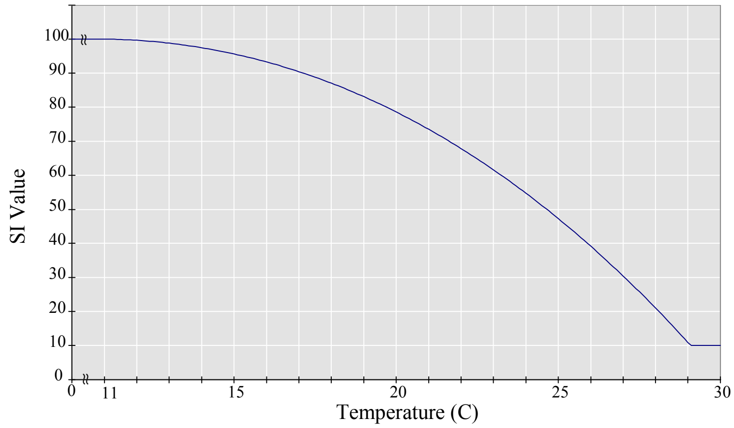

Figure F-1. Temperature Subindex (SI_T)

The original OWQI calculated dissolved oxygen (DO) subindex values based only on saturation. Evaluation of DO only in terms of saturation may result in inadequate protection at high temperatures and greater than necessary protection at low temperatures. The present OWQI uses both dissolved oxygen concentration (mg/L) and supersaturation. It is designed to meet specific DO concentration requirements for spawning, rearing, and passage, mainly of salmonids. It also addresses the concerns of gas bubble trauma, swim bladder overinflation, and respiratory distress caused by high total dissolved gas concentration. DEQ Laboratory measures DO supersaturation, a component of total dissolved gas. The DO subindices were developed as qualitative damage functions derived from impacts noted in literature (Oregon DEQ, 1994b and Baumgartner, personal communication). If DO saturation is less than 100%, subindex calculation is based on concentration (Figure F-2). If DO saturation is greater than 100%, the DO subindex calculation is based on supersaturation (Figure F-3).

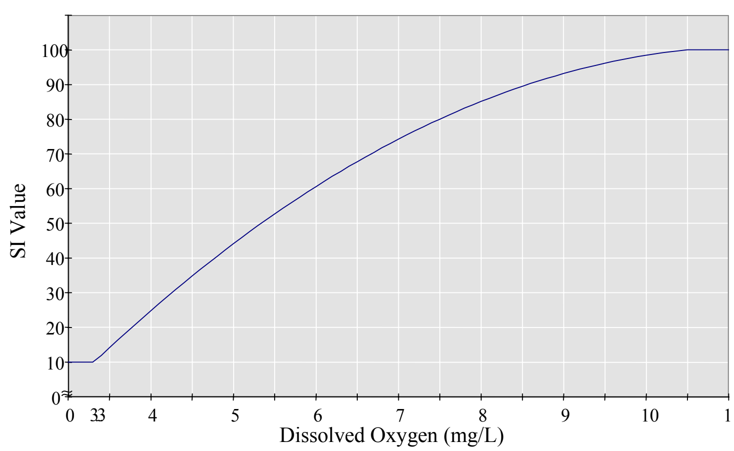

Figure F-2. Dissolved Oxygen Concentration Subindex (SI_{DOc})

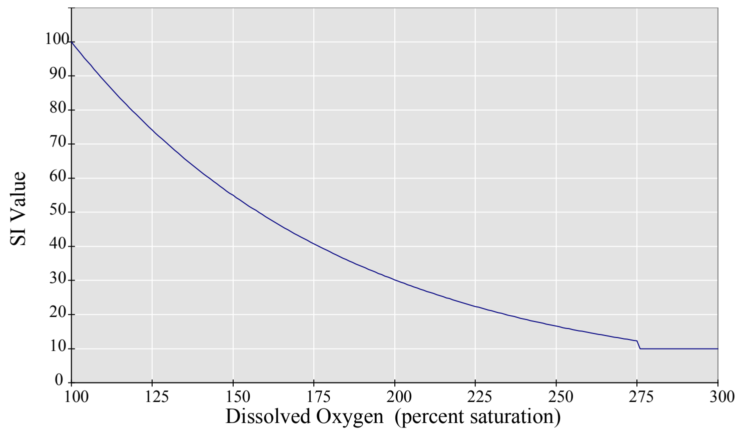

Figure F-3. Dissolved Oxygen Supersaturation Subindex (SI_{DOs})

Biochemical oxygen demand (BOD) represents the oxygen demanding capacity of organic material in a water body. BOD is widely measured by the Oregon DEQ Laboratory and is not as dependent on site-specific conditions as other measures of oxygen demand. The BOD subindex (Figure F-4) was developed for the original OWQI from expert opinions on acceptable waste loads. The present BOD subindex transforms higher BOD concentrations than did the original BOD subindex in order to characterize higher levels of BOD found in Oregon's streams.

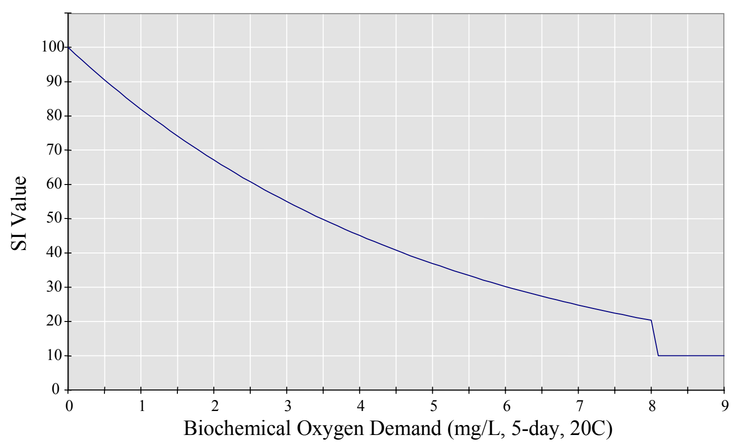

Figure F-4. Biochemical Oxygen Demand Subindex (SI_{BOD})

The pH subindex included in the original OWQI was based on the mean pH value in the Willamette River (Dunnette, 1980). While that subindex adequately characterized variation in pH in the Willamette and Coastal basins, it was not necessarily representative of other basins. Geological formations in the southern and eastern basins of Oregon tend to be more alkaline. As a result, pH of surface waters tends to be naturally higher. The pH subindex for the present OWQI (Figure F-5) is designed to protect aquatic life (Oregon DEQ, 1994c), while recognizing natural geological differences between basins. To account for geological variability, a pH subindex value of 100 was assigned to all waters having pH between and including 7.0 and 8.0 Standard Units.

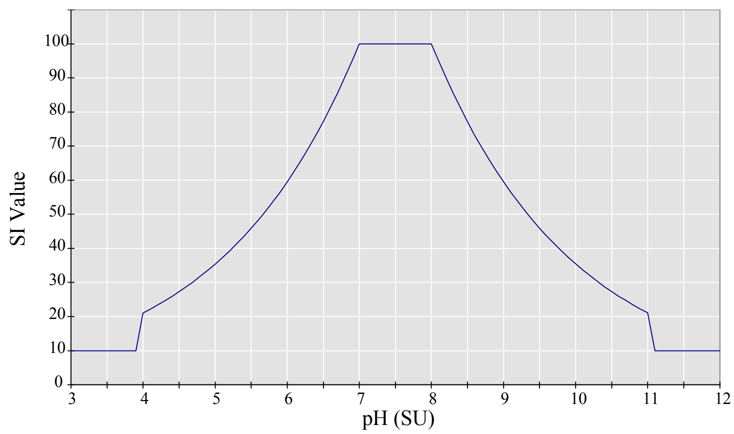

Figure F-5. pH Subindex (SI_{pH})

The nutrients subindices (ammonia+nitrate nitrogen and total phosphorus) were designed to address the potential for eutrophication. An increase in the availability of nitrogen and phosphorus increases the potential for algal growth. Excessive algal growth and the subsequent large diurnal variations in pH and DO, corresponding to the algal respiration cycle, can severely impact fish and other aquatic life. For the nitrogen subindex (Figure F-6), ammonia and nitrate concentrations are summed prior to calculating the subindex value. Ammonia nitrogen was included in the subindex because ammonia is highly toxic to aquatic fauna and nitrogenous oxygen demand is a significant impact to some of Oregon's waterbodies (Dunnette, 1980).

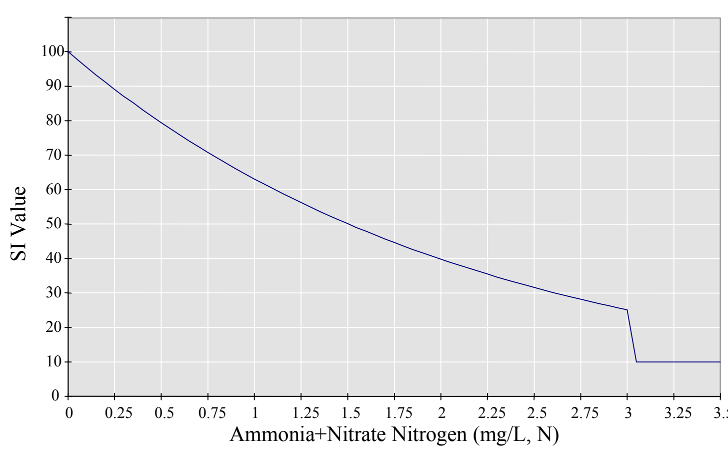

Figure F-6. Ammonia+Nitrate Nitrogen Subindex (SI_N)

Phosphorus was not included in the original OWQI, as insufficient information was available on the significance of phosphorus in Oregon waters at that time (Dunnette, 1980). Phosphorus is now recognized as a limiting nutrient for most nuisance algal growth. Dissolved orthophosphate (PO_4^{-3}) provides an indication of readily available phosphorus. However, considerable quantities of phosphorus can be bound to fine and coarse particulate material traveling in the water column. Thus, total phosphorus provides a measure of the potential pool of this nutrient. The total phosphorus subindex (Figure F-7) is based upon field experience of risk of eutrophication in Oregon's waters (Baumgartner, personal communication).

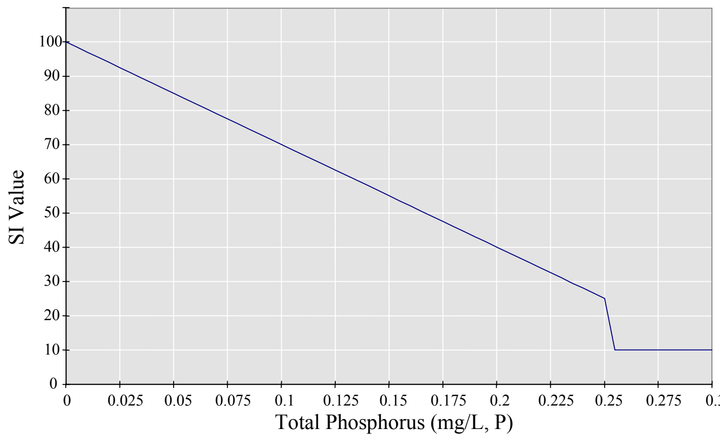

Figure F-7. Total Phosphorus Subindex (SI_P)

The total solids subindices were designed to account for geological variability of Oregon's basins. Geologically similar basins were grouped together and transformation equations were developed to distinguish background conditions (mainly dissolved solids) from erosional processes (mainly suspended solids). Eight separate total solids subindices were developed for the original OWQI. Modifications were made to some of these subindices to better reflect available geological information. Figure F-8 presents one of the total solids subindices. Most of the water quality data from ambient monitoring sites in the Powder, Malheur, and Owyhee Basins between 1986 and 1996 were collected by the US Bureau of Reclamation (USBR). As the USBR did not analyze for total solids, it was necessary to derive total solids concentrations using the following relationship:

(Eqn. 3) Total solids (mg/L) = $f * \chi$ (Dojlido and Best, 1993),
where f = 0.55-0.9, determined experimentally on the particular water,
and χ = specific conductivity in µS/cm.

Using all historic DEQ data (including total solids and specific conductivity analyses) for the Powder, Malheur, and Owyhee Basins, f was empirically determined to be 0.78.

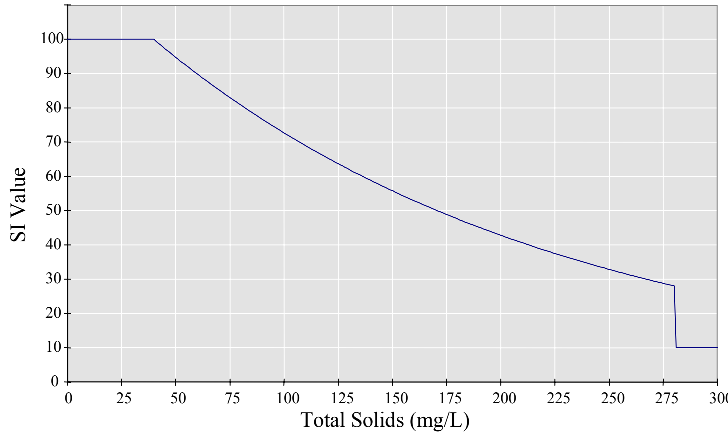

Figure F-8. Total Solids Subindex (SI_{TS}). Willamette, Sandy, and Hood Basins

Fecal coliform serves as an indication of possible microbial contamination of water because direct search for a specific pathogen is too costly and impractical for routine monitoring purposes. The fecal coliform subindex (Figure F-9) was designed to indicate potentially dangerous microbial contamination. Fecal coliform counts of less than 50 per 100 mL are assigned a subindex value of 98. This is due to the uncertainty of analytical procedures for counting bacteria.

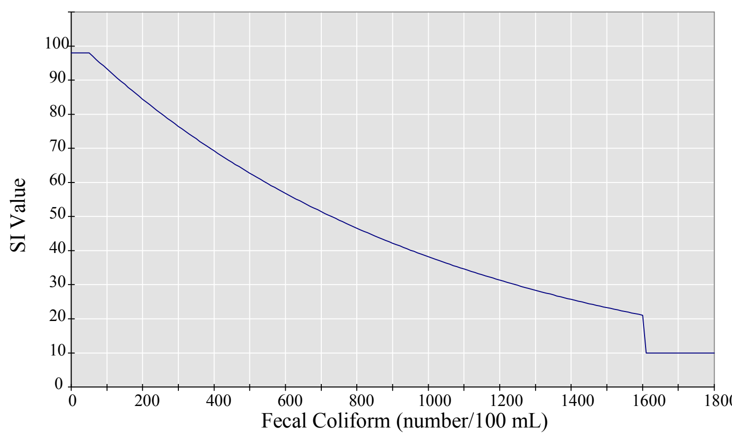

Figure F-9. Fecal Coliform Subindex (SI_{FC})

Aggregation and Calculation of OWQI

To determine the sensitivity of various aggregation methods to changes in various water quality variables, the unweighted harmonic square mean formula (Eqn. 4 and Addendum 3), the weighted arithmetic mean formula from the original OWQI (Eqn. 1), and the weighted geometric mean formula of the NSF WQI (Eqn. 2) were compared using real and idealized sets of water quality data. For the idealized data sets, each subindex value was varied from 100 (ideal) to 10 (worst case) while the other subindex values were set at a value of 100. In all trials, the unweighted harmonic square mean formula was most sensitive to changes in single variables. This formula (Dojlido et al., 1994) allows the most impacted variable to impart the greatest influence on the water quality index. This method acknowledges that different water quality variables will pose differing significance to overall water quality at different times and locations. In methods that assign fixed weights to variables, the variable given the greatest statistical weight has the greatest influence on water quality index scores. For instance, in an index heavily weighted towards DO, high concentrations of fecal coliform may not be reflected in index results if DO concentration is near ideal. This characteristic may be desirable in water quality indices specific to the protection of aquatic life. However, the OWQI is designed to communicate general water quality rather than the quality of water for any specific use. For this general type of water quality index, sensitivity to changes in each variable is more desirable than sensitivity to the most heavily weighted variable.

(Eqn. 4) $$WQI = \sqrt{\frac{n}{\sum_{i=1}^{n} \frac{1}{SI_i^2}}}$$ Unweighted Harmonic Square Mean Function

Where:
WQI is Water Quality Index result
n is the number of subindices
SI_i is Subindex i.

Classification of OWQI Scores

To develop a classification scheme and descriptive labels for the OWQI, a distribution curve was generated from OWQI scores calculated from data collected at 136 monitoring sites located throughout Oregon from water years 1986 through 1995. Streams with severe water quality impacts often receive more attention with respect to increased ambient monitoring and intensive surveys. To normalize the data from each monitoring site for variability in sampling frequency, water quality data for each site was thinned to a maximum of one sample per quarter. Mean values from the normalized data set were calculated for each monitoring site. The OWQI classification scheme was derived from the distribution of the normalized mean OWQI scores for each monitoring site. OWQI scores that are less than 60 are considered very poor; 60-79 poor; 80-84 fair; 85-89 good; and 90-100 excellent.

APPLICATIONS

Spatial Comparison

The OWQI is designed to permit spatial comparison of water quality among different reaches of a river or between different watersheds. This is accomplished, in part, because the pH and total solids functions within the index account for geological variability. Also, the OWQI aggregation formula accounts for the variability of factors limiting water quality in different watersheds. In order to account for differences in water quality between low flow summer months (June - September) and higher flow fall, winter, and spring (October - May), seasonal average values are calculated and compared. Mean is used as the measure of central tendency, because the distribution of means for all monitoring sites more closely resembles a normal distribution than does the distribution of medians. The distribution of medians is bimodal and more left-skewed than the distribution of means. Ambient water quality monitoring sites are ranked based on the minimum of the seasonal averages (Cude, 1997). For each site, the data are analyzed to determine which variables influence general water quality during various seasons.

Figure F-10 presents the spatial distribution of minimum seasonal average OWQI scores for ambient water quality monitoring sites on the Tualatin River. Water quality in the Tualatin Subbasin is influenced by logging operations, intensive agricultural and container nursery operations, confined animal feeding operations (CAFOs), industrial operations, municipal sewage treatment plants, urban nonpoint source pollution, and natural hydrological conditions. Because of the low gradient of the primary streams in the subbasin, water flows slowly. Point and nonpoint source pollution is slowly moved downstream and is not readily assimilated. Two advanced tertiary wastewater treatment plants (AWWTP) are located on the Tualatin River: Rock Creek AWWTP at river mile 38.0 and Durham AWWTP at river mile 9.6. Two smaller municipal point sources are located on the Tualatin River above Rood Bridge. Loading from the major point sources is reflected in the OWQI scores of the two downstream sites (HWY 210 and Boones Ferry Road). Inspection of the individual subindices for the monitoring stations reveals very high concentrations of ammonia and nitrate nitrogen and total phosphorus. High concentrations of fecal coliform, total solids, and biochemical oxygen demand also impact water quality. This indicates the presence of organic matter and sediments in the water. Low dissolved oxygen concentrations were seen in conjunction with high concentrations of ammonia nitrogen at all sites except the most upstream site, indicating that ammonia was scavenging oxygen for conversion to nitrate nitrogen. These individual impacts were greater at the monitoring sites downstream of the AWWTPs. Average OWQI scores range from poor to very poor, generally decreasing from upstream to downstream. The poor average OWQI score at the most upstream site indicates that non-point source pollution, with some contribution from point sources, limits water quality in the Tualatin Subbasin. Specific information pertaining to individual monitoring sites in the Tualatin Subbasin is available (Cude, 1996).

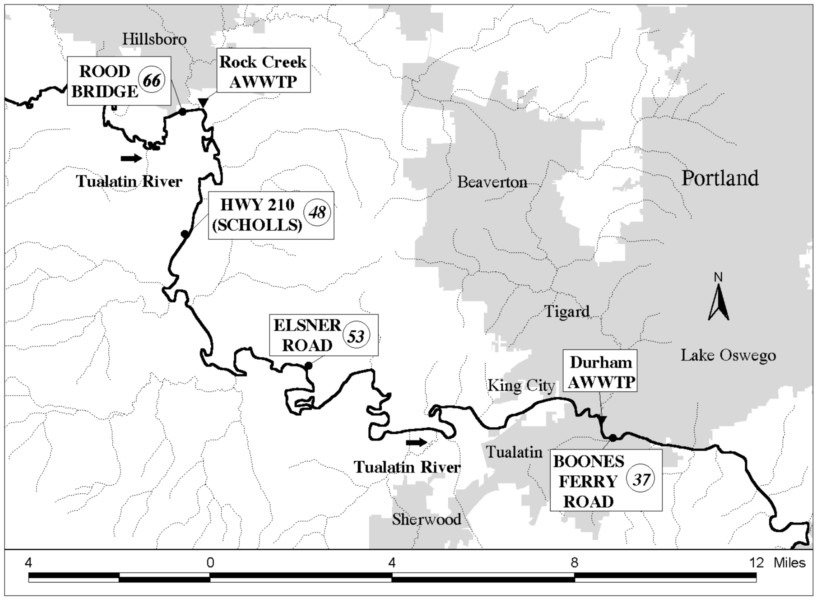

Figure F-10. Minimum Seasonal Average OWQI Results for the Tualatin River (WY 1986-1995)

Trend Analysis

For long-term trend analysis, ten water years of ambient water quality monitoring data were analyzed for each monitoring site. This time period attenuates the effects of drought cycles and ensures that sufficient data are available to analyze for trends. The nonparametric Seasonal-Kendall trend analysis (Hirsch et al., 1982) is appropriate for trending OWQI scores since the test assumes neither normal distribution nor independence (OWQI scores derived from ambient water quality data are serially correlated). This test can also analyze for trends in data sets with missing values. For each site with sufficient data, the Seasonal-Kendall test divides the data set into twelve subsets, one for each month. Each of these subsets is analyzed for the direction, magnitude, and significance of trends. These subsets are compared and an annualized result is generated, indicating whether or not a significant trend exists. This procedure ensures that increasing or decreasing trends are consistent through most of the year and that the trends are not due to normal seasonal variation.

Figure F-11 displays application of the Seasonal-Kendall trend analysis to OWQI scores for the Tualatin River at Oregon Highway 210 in Scholls, Oregon. Starting in mid-1989, the Unified Sewerage Agency (Washington County, Oregon) began to take steps to improve treatment of wastewater treatment plant effluents, per the Total Maximum Daily Load allocations established by the Oregon Department of Environmental Quality (State of Oregon, 1988; Oregon DEQ, 1988a; Oregon DEQ, 1988b). The Rock Creek AWWTP began conversion of effluent ammonia nitrogen to nitrate nitrogen in August 1989. The new process should have no net effect on ammonia and nitrate nitrogen subindex scores because nitrate nitrogen concentration increased as ammonia nitrogen concentration decreased.

However, the new process did reduce nitrogen-related biochemical oxygen demand, so BOD and DO subindex scores should improve over time. The Rock Creek AWWTP began removal of phosphorous in August 1990. Due to the advanced treatment of nutrients in effluent, total solids concentrations increased. A basin-wide phosphate detergent ban was instituted in February 1991. This ban had no direct impact on WWTP effluent as phosphates were already eliminated from the effluent, but it did decrease the cost of treatment of influent. However, the ban helped to decrease non-point source pollution from phosphate-based detergents entering streams via storm drains and faulty septic systems. A Seasonal-Kendall trend analysis show that OWQI values increased 34 points over ten years. The improvement seen at this site was the greatest improvement seen of all DEQ Laboratory-monitored sites in the state.

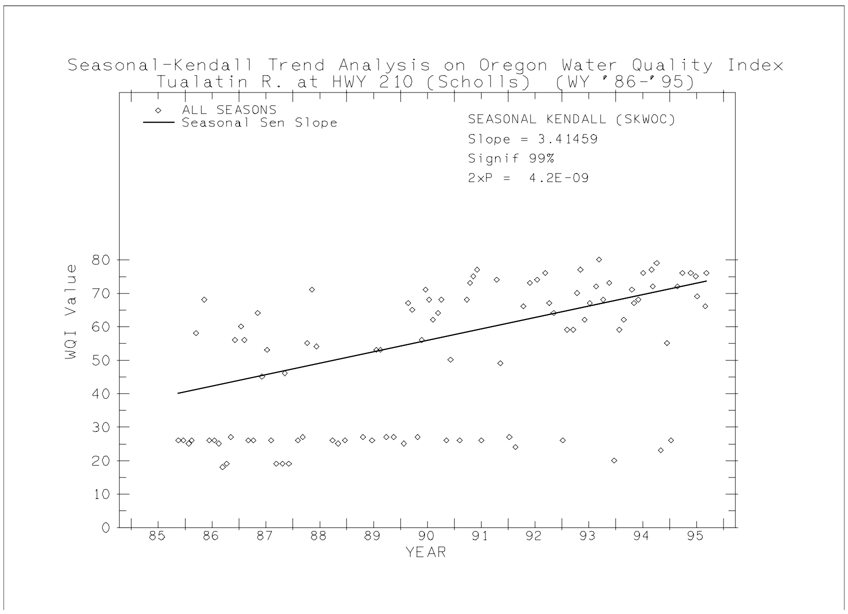

Figure F-11. Trend Analysis Results for Tualatin River at HWY 210 (Scholls)

Seasonal Wilcoxon-Mann-Whitney step trend analyses (Crawford, et al., 1983) were performed on raw data, subindex values, and OWQI results to determine whether these management changes had a statistically significant effect on water quality. Seasonal Hodges-Lehman Estimators (Crawford, et al., 1983) were calculated to measure the magnitude of the effects (Table F-1). Data collected prior to August 1989 were compared to data collected after February to determine whether there was a significant difference between these two datasets. There were insufficient data collected during the intervening period, so step trend results reflect the combined effects of the three management changes. Results show that while ammonia nitrogen concentration decreased, nitrate nitrogen concentrations increased, resulting in no difference in nitrogen subindex scores. As predicted, the BOD and DO subindices improved, likely due to a reduction in reduce nitrogen-related biochemical oxygen demand. Reductions of total phosphorus concentrations led to an improvement in total phosphorus subindex scores of 35 points. Total solids concentrations increased, but the resultant reduction of total subindex scores was small in magnitude, compared to the improvement in the total phosphorus subindex. pH significantly increased, probably because of the increased oxygenation of the water. This change in pH values did not significantly change pH subindex values. Neither temperature nor fecal coliform counts significantly changed. The difference in OWQI values represents an improvement of 33 WQI points, comparable to the 34 point improvement measured over time by the Seasonal-Kendall trend analysis (Figure F-11).

Table F-1. Seasonal Hodges-Lehmann Estimator (Δ_{HL}), Magnitude of Step Trend. Before Period: 10/85-7/89; After Period: 3/91-9/95

Variable	Δ_{HL}	*Variable*	Δ_{HL}
Ammonia, mg/L N	-0.43	Nitrogen Subindex	No Change
Nitrate, mg/L N	+0.30		
BOD, mg/L	-1.0	BOD Subindex	+13
Dissolved Oxygen, % sat.	+8.0	DO Subindex	+5.3
Dissolved Oxygen, mg/L	+1.1		
Total Phosphorus, mg/L P	-0.11	Phosphorus Subindex	+35
Total Solids, mg/L	+10	Total Solids Subindex	-3.6
pH, SU	+0.2	pH Subindex	No Change
Temperature, C	No Change	Temperature Subindex	No Change
Fecal Coliform, #/100 mL	No Change	Fecal Coliform Subindex	No Change
		OWQI	**+33**

Since 1988, general water quality conditions have significantly improved at all of the Tualatin Subbasin sites monitored by DEQ Laboratory. It is important to note that water quality has improved while population has significantly grown at the same time. Water quality trends show that changes in water quality management in the Tualatin basin have proven to be beneficial.

USE AS AN ENVIRONMENTAL INDICATOR

Environmental indicators analyze, describe, and present scientifically-based information on the significance of environmental conditions and trends. They can assist in communicating, consensus building, priority setting, and budgeting in natural resource areas. The OWQI is used as an environmental indicator in the Oregon Benchmarks, published in “Oregon Shines II” (Oregon Progress Board, 1997). Oregon Benchmarks reports statewide trends in areas ranging from the arts to public safety to the economy. In the Benchmark report, “Percentage of stream monitoring sites with improving water quality” is contrasted with “Percentage of stream monitoring sites with decreasing water quality” to measure the relative success of the combined efforts to manage general water quality throughout the state. The OWQI is used as an environmental indicator in the Environmental Partnership Agreement between Oregon DEQ and the US EPA Region 10 (US EPA, 1996; US EPA, 1997). In the agreement, the OWQI is used to monitor the progress of various individual water quality management projects. Portland State University publishes “Portland Today” (PSU Center for Science

Education, 1996), an annual journal promoting awareness of the urban environment in the Portland metropolitan area. "Portland Today" uses the OWQI to indicate conditions and trends in the Willamette River as it flows through Portland.

CONCLUSION

The original OWQI was designed to be a simple and concise method for expressing ambient water quality information. Its use was discontinued due to insufficient resources available for the maintenance of the index and its database. Modern computer technology, better understanding of water quality, and enhanced tools for displaying data now make an improved OWQI feasible. By combining multiple variables into a single score, the present OWQI allows the analyst to study the influences of these variables on general water quality. It is easier to determine, for a given location, which water quality variables are most impacted during various seasons. The OWQI can be used to detect trends over time and compare conditions across river basins. The OWQI indicates impairment of water quality and progress of water quality management practices. Most importantly, the Oregon Water Quality Index improves comprehension of general water quality issues, communicates water quality status, and illustrates the need for and effectiveness of protective practices.

ADDENDUM 1. SUBINDEX (SI) CALCULATION

Temperature (T)

$T \leq 11C$:	$SI_T = 100$
$11C < T \leq 29C$:	$SI_T = 76.54407 + 4.172431*T - 0.1623171*T^2 - 2.055666E-3*T^3$
$29C < T$:	$SI_T = 10$

Dissolved Oxygen (DO)

DO saturation (DOs) ≤ 100%:

- DO concentration (DOc) ≤ 3.3 mg l^{-1}: $SI_{DO} = 10$
- 3.3 mg/L < DO_C < 10.5 mg/L: $SI_{DO} = -80.28954 + 31.88249*DO_C - 1.400999*DO_C^2$
- 10.5 mg/L ≤ DO_C: $SI_{DO} = 100$

100% < DOs ≤ 275%:	$SI_{DO} = 100 * \exp((DO_S - 100) * -1.197429E-2)$
275% < DOs:	$SI_{DO} = 10$

Biochemical Oxygen Demand, 5-day (BOD)

BOD ≤ 8 mg/L:	$SI_{BOD} = 100 * \exp(BOD * -0.199314)$
8 mg/L < BOD:	$SI_{BOD} = 10$

pH

pH < 4 :	$SI_{pH} = 10$
4 ≤ pH < 7:	$SI_{pH} = 2.628419 * \exp(pH * 0.520025)$
7 ≤ pH ≤ 8:	$SI_{pH} = 100$
8 < pH ≤ 11:	$SI_{pH} = 100 * \exp((pH-8) * -0.5187742)$
11 < pH:	$SI_{pH} = 10$

Total Solids (TS)

Geologically variable - basin specific. See Addendum 2.

Ammonia + Nitrate Nitrogen (N)

N ≤ 3 mg/L:	$SI_N = 100 * \exp(N * -0.460512)$
3 mg/L < N:	$SI_N = 10$

Total Phosphorus (P)

P ≤ 0.25 mg/L:	$SI_P = 100 - 299.5406*P - 0.1384108*P^2$
0.25 mg/L < P:	$SI_P = 10$

Fecal Coliform (FC)

FC ≤ 50 #/100 mL:	$SI_{FC} = 98$
50 #/100 mL < FC ≤ 1600 #/100 mL:	$SI_{FC} = 98 * \exp((FC-50) * -9.917754E-4)$
1600 #/100 mL < FC:	$SI_{FC} = 10$

ADDENDUM 2. BASIN-SPECIFIC TOTAL SOLIDS (TS) SUBINDEX CALCULATION

Coastal Basins

$TS \leq 40$ mg/L:	$SI_{TS} = 100$
40 mg/L $< TS \leq$ 220 mg/L:	$SI_{TS} = 142.62116 * \exp(TS * -8.86166E-3)$
220 mg/L $< TS$:	$SI_{TS} = 10$

Willamette, Sandy, and Hood Basins

$TS \leq 40$ mg/L:	$SI_{TS} = 100$
40 mg/L $< TS \leq$ 280 mg/L:	$SI_{TS} = 123.43562 * \exp(TS * -5.29647E-3)$
280 mg/L $< TS$:	$SI_{TS} = 10$

Umpqua Basin

$TS \leq 40$ mg/L:	$SI_{TS} = 100$
40 mg/L $< TS \leq$ 300 mg/L:	$SI_{TS} = 124.69467 * \exp(TS * -5.55213E-3)$
300 mg/L $< TS$:	$SI_{TS} = 10$

Rogue Basin

$TS \leq 50$ mg/L:	$SI_{TS} = 100$
50 mg/L $< TS \leq$ 350 mg/L:	$SI_{TS} = 127.13859 * \exp(TS * -4.81795E-3)$
350 mg/L $< TS$:	$SI_{TS} = 10$

Deschutes Basin, excluding Crooked Subbasins

$TS \leq 80$ mg/L:	$SI_{TS} = 100$
80 mg/L $< TS \leq$ 300 mg/L:	$SI_{TS} = 179.48950 * \exp(TS * -7.32601E-3)$
300 mg/L $< TS$:	$SI_{TS} = 10$

Klamath Basin

$TS \leq 100$ mg/L:	$SI_{TS} = 100$
100 mg/L $< TS \leq$ 450 mg/L:	$SI_{TS} = 144.90986 * \exp(TS * -3.58002E-3)$
450 mg/L $< TS$:	$SI_{TS} = 10$

John Day, Umatilla, and Grande Ronde Basins, Crooked Subbasins

$TS \leq 100$ mg/L:	$SI_{TS} = 100$
100 mg/L $< TS \leq$ 800 mg/L:	$SI_{TS} = 116.27594 * \exp(TS * -1.49786E-3)$
800 mg/L $< TS$:	$SI_{TS} = 10$

Powder, Burnt, Malheur, and Owyhee Basins

$TS \leq 200$ mg/L:	$SI_{TS} = 100$
200 mg/L $< TS \leq$ 1600 mg/L:	$SI_{TS} = 116.26522 * \exp(TS * -7.48861E-4)$
1600 mg/L $< TS$:	$SI_{TS} = 10$

ADDENDUM 3. OREGON WATER QUALITY INDEX (OWQI) CALCULATION

Unweighted Harmonic Square Mean

$$OWQI = \sqrt{\frac{n}{\sum_{i=1}^{n} \frac{1}{SI_i^2}}}$$

=SQRT(8/(1/ SI_T^2+1/ SI_{DO}^2+1/ SI_{BOD}^2+1/ SI_{pH}^2+1/ SI_{TS}^2+1/ SI_N^2+1/ SI_P^2+1/ SI_{FC}^2))

Where: *n* is number of subindices;
SI_i is subindex *i*;
SI_T is temperature subindex;
SI_{DO} is dissolved oxygen subindex;
SI_{BOD} is biochemical oxygen demand subindex;
SI_{pH} is pH subindex;
SI_{TS} is total solids subindex;
SI_N is ammonia+nitrate nitrogen subindex;
SI_P is total phosphorus subindex;
and SI_{FC} is fecal coliform subindex.

Classifications

0-59	Very Poor
60-79	Poor
80-84	Fair
85-89	Good
90-100	Excellent

ACKNOWLEDGMENT

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Appendix G.
RPI DATA

STAID	Site Name	Dates	00010 Water Temperature (degrees)	00400 pH (standard units)	00300 Oxygen Dissolved (MG/L)	Total Solids (MG/L)
10092700	Bear River at Idaho-Utah State Line	19940516	15.2	8.2	7.8	551
10092700	Bear River at Idaho-Utah State Line	19960917	12.4	8.3	8.3	574
12413470	South Fork Coeur d'Alene River nr. Pinehurst	19960906	10.5	6.9	9.3	225
12413470	South Fork Coeur d'Alene River nr. Pinehurst	19970917	11.5	7.1	9.5	190
12419000	Spokane River nr. Post Falls	19940907	20.2	7.6	8.3	42
13056500	Henrys Fork nr. Rexburg	19940913	15.6	7.9	7.6	134
13068500	Blackfoot River nr. Blackfoot	19930521	15	8.4	8.2	591
13068500	Blackfoot River nr. Blackfoot	19960919	11.4	8.4	10.3	221
13069500	Snake River nr. Blackfoot	19940718	20.5	8.5	10.1	212
13073000	Portneuf River near Blackfoot	19960918	11.3	8.1	8	519
13075000	Marsh Creek nr. McCammon	19930524	17	8.2	8.4	470
13075000	Marsh Creek nr. McCammon	19950517	12.4	8.1	7.4	541
13075000	Marsh Creek nr. McCammon	19960918	10.3	7.8	8.5	562
13081500	Snake River nr. Minidoka	19940916	16	8.3	7.6	275
13090000	Snake River nr. Kimberly	19930520	17.5	8.5	9.3	315
13090000	Snake River nr. Kimberly	19950914	18.4	8.3	8.4	285
13092747	Rock Creek above Hwy.30/93 Twin Falls	19960906	14.5	8.4	9.4	480
13094000	Snake River Nr. Buhl	19930514	16.6	8.3	6.8	387
13094000	Snake River Nr. Buhl	19930723	17.8	8.4	9.2	392
13094000	Snake River Nr. Buhl	19950524	14.4	8.5	9.3	438
13094000	Snake River Nr. Buhl	19950718	18.6	8.4	8	344
13094000	Snake River Nr. Buhl	19950906	17.2	8.3	8.3	340
13108150	Salmon Falls Creek nr. Hagerman	19940517	13.6	8.6	11.6	477
13108150	Salmon Falls Creek	19940922	14.7	8.6	12	516

STAID	Site Name	Dates	00010 Water Temperature (degrees)	00400 pH (standard units)	00300 Oxygen Dissolved (MG/L)	Total Solids (MG/L)
	nr. Hagerman					
13108900	Camas Creek at Red Road nr. Kilgore	19970923	10.4	8.1	9	147
13113000	Beaver Creek at Spencer	19970922	10.6	8.6	9.5	260
13152500	Malad River nr. Gooding	19930722	19	8.7	9.1	260
13168500	Bruneau River nr. Hot Springs	19940517	12.4	7.8	11.9	100
13172500	Snake River nr. Murphy	19940520	17.1	8.8	9.9	305
13172500	Snake River nr. Murphy	19940914	18.1	8.6	10.1	318
13206000	Boise River at Glenwood Bridge	19960924	16	8.1	10.7	63
13213000	Boise River nr. Parma	19930513	15.6	8	9.8	188
13213000	Boise River nr. Parma	19930908	18.7	8.5	11.8	321
13213000	Boise River nr. Parma	19940510	18.4	8	8.7	345
13213000	Boise River nr. Parma	19940907	17.2	8.3	12	353
13213000	Boise River nr. Parma	19950719	21	8	8.3	437
13213100	Snake River at Nyssa	19930917	17.9	8.6	11.5	362
13251000	Payette River nr. Payette	19930629	16.3	8	9.4	81
13251000	Payette River nr. Payette	19930825	17.9	8.3	10.9	143
13266000	Weiser River nr. Weiser	19930323	4.9	7.4	11.6	375
13266000	Weiser River nr. Weiser	19930517	12.4	7.8	10.5	131
13266000	Weiser River nr. Weiser	19930915	18	8.7	11.4	110
13269000	Snake River at Weiser	19930916	18.1	8.7	10.3	336
13302005	Pahsimeroi River at Ellis	19950608	8.7	8.1	9.7	233
13302500	Salmon River at Salmon	19950607	6.3	7.4	10.1	215
13338500	South Fork Clearwater River at Stites	19930512	10.5	7.5	11	98
13342450	Lapwai Creek nr. Lapwai	19930317	5	7.8	11.7	152
13342450	Lapwai Creek nr. Lapwai	19930512	18.8	8	8.6	152
13342450	Lapwai Creek nr. Lapwai	19930910	15	8.3	13.4	194
13342450	Lapwai Creek nr.	19950315	8.3	7.8	11.6	396

STAID	Site Name	Dates	00010 Water Temperature (degrees)	00400 pH (standard units)	00300 Oxygen Dissolved (MG/L)	Total Solids (MG/L)
	Lapwai					
13342450	Lapwai Creek nr. Lapwai	19970910	15	7.8	9.6	248
13345000	Palouse River nr. Potlatch	19930525	16.9	7.4	9.9	68

STAID	Site Name	Dates	31625 Coliform Fecal 0 cols./100 ML	Total Nitrogen (MG/L as N)	00665 Phosphorus Total (MG/L as P)	Temperature Sub-index score
10092700	Bear River at Idaho-Utah State Line	19940516	210	0.109	0.04	93.48476417
10092700	Bear River at Idaho-Utah State Line	19960917	140	0.22	0.02	98.44973539
12413470	South Fork Coeur d'Alene River nr. Pinehurst	19960906	220	0.44	0.04	100
12413470	South Fork Coeur d'Alene River nr. Pinehurst	19970917	26	0.276	0.035	99.17221825
12419000	Spokane River nr. Post Falls	19940907	54	0.25	0.02	73.52225168
13056500	Henrys Fork nr. Rexburg	19940913	61	0.15	0.02	92.42634361
13068500	Blackfoot River nr. Blackfoot	19930521	300	0.25	0.07	93.980445
13068500	Blackfoot River nr. Blackfoot	19960919	150	0.16	0.03	99.2272374
13069500	Snake River nr. Blackfoot	19940718	180	0.061	0.04	71.83917824
13073000	Portneuf River near Blackfoot	19960918	110	0.9	0.02	99.27726146
13075000	Marsh Creek nr. McCammon	19930524	150	0.4	0.06	88.00486752
13075000	Marsh Creek nr. McCammon	19950517	720	0.37	0.13	98.44973539
13075000	Marsh Creek nr. McCammon	19960918	620	0.74	0.06	100
13081500	Snake River nr. Minidoka	19940916	66	0.13	0.06	91.27769304
13090000	Snake River nr. Kimberly	19930520	38	0.42	0.04	86.14988344
13090000	Snake River nr. Kimberly	19950914	22	0.61	0.08	82.43598093
13092747	Rock Creek above Hwy.30/93 Twin Falls	19960906	350	2.03	0.08	95.12283713
13094000	Snake River Nr. Buhl	19930514	230	1.53	0.16	89.38338831
13094000	Snake River Nr. Buhl	19930723	220	1.36	0.11	84.96584569
13094000	Snake River Nr. Buhl	19950524	88	0.31	0.17	95.33484229
13094000	Snake River Nr. Buhl	19950718	44	1.24	0.07	81.54430514
13094000	Snake River Nr. Buhl	19950906	140	1.32	0.09	87.28054367
13108150	Salmon Falls Creek nr. Hagerman	19940517	56	2.11	0.04	96.83578145

STAID	Site Name	Dates	31625 Coliform Fecal 0 cols./100 ML	Total Nitrogen (MG/L as N)	00665 Phosphorus Total (MG/L as P)	Temperature Sub-index score
13108150	Salmon Falls Creek nr. Hagerman	19940922	50	2.31	0.04	94.68239957
13108900	Camas Creek at Red Road nr. Kilgore	19970923	88	0.091	0.066	100
13113000	Beaver Creek at Spencer	19970922	54	0.09	0.017	100
13152500	Malad River nr. Gooding	19930722	200	0.08	0.07	79.68763596
13168500	Bruneau River nr. Hot Springs	19940517	37	0.098	0.03	98.44973539
13172500	Snake River nr. Murphy	19940520	27	0.69	0.11	87.64564033
13172500	Snake River nr. Murphy	19940914	54	0.94	0.04	83.72801624
13206000	Boise River at Glenwood Bridge	19960924	45	0.3	0.1	91.27769304
13213000	Boise River nr. Parma	19930513	590	0.96	0.2	92.42634361
13213000	Boise River nr. Parma	19930908	260	1.92	0.28	81.08932556
13213000	Boise River nr. Parma	19940510	1000	1.75	0.46	82.43598093
13213000	Boise River nr. Parma	19940907	330	1.82	0.3	87.28054367
13213000	Boise River nr. Parma	19950719	270	1.68	0.21	68.90603064
13213100	Snake River at Nyssa	19930917	240	1.23	0.07	84.55923318
13251000	Payette River nr. Payette	19930629	380	0.18	0.02	90.35640108
13251000	Payette River nr. Payette	19930825	180	0.38	0.05	84.55923318
13266000	Weiser River nr. Weiser	19930323	120	1.45	0.15	100
13266000	Weiser River nr. Weiser	19930517	200	0.17	0.12	98.44973539
13266000	Weiser River nr. Weiser	19930915	100	0.26	0.13	84.14662848
13269000	Snake River at Weiser	19930916	220	1.13	0.06	83.72801624
13302005	Pahsimeroi River at Ellis	19950608	1100	0.27	0.07	100
13302500	Salmon River at Salmon	19950607	130	0.09	0.11	100
13338500	South Fork Clearwater River at Stites	19930512	100	0.102	0.07	100
13342450	Lapwai Creek nr. Lapwai	19930317	110	5.83	0.18	100
13342450	Lapwai Creek nr. Lapwai	19930512	520	0.89	0.14	80.62823106

STAID	Site Name	Dates	31625 Coliform Fecal 0 cols./100 ML	Total Nitrogen (MG/L as N)	00665 Phosphorus Total (MG/L as P)	Temperature Sub-index score
13342450	Lapwai Creek nr. Lapwai	19930910	39	0.45	0.09	93.980445
13342450	Lapwai Creek nr. Lapwai	19950315	89	3.12	0.38	100
13342450	Lapwai Creek nr. Lapwai	19970910	89	2.446	0.091	93.980445
13345000	Palouse River nr. Potlatch	19930525	200	0.11	0.07	88.3582405 7

STAID	Site Name	Dates	D.O. Sub-index Score	pH Sub-index Score	Total Solids Sub-index Score	Total Nitrogen Sub-index Score
10092700	Bear River at Idaho-Utah State Line	19940516	83.21180408	90.14462689	50.93983851	95.10431844
10092700	Bear River at Idaho-Utah State Line	19960917	87.88224489	85.58738716	49.2148063	90.36504714
12413470	South Fork Coeur d'Alene River nr. Pinehurst	19960906	95.12297665	101.855488	83.00888576	81.65841745
12413470	South Fork Coeur d'Alene River nr. Pinehurst	19970917	96.23509903	100	87.47672512	88.06444482
12419000	Spokane River nr. Post Falls	19940907	87.88224489	100	100	89.12520563
13056500	Henrys Fork nr. Rexburg	19940913	81.14761378	100	95.13081262	93.32550033
13068500	Blackfoot River nr. Blackfoot	19930521	87.00416072	81.26053757	47.97743995	89.12520563
13068500	Blackfoot River nr. Blackfoot	19960919	99.56350861	81.26053757	83.50772139	92.89671327
13069500	Snake River nr. Blackfoot	19940718	98.8994182	77.15243082	84.64108943	97.22996579
13073000	Portneuf River near Blackfoot	19960918	85.1639864	94.94452427	53.44092399	66.06964322
13075000	Marsh Creek nr. McCammon	19930524	88.73232706	90.14462689	57.51075417	83.17654408
13075000	Marsh Creek nr. McCammon	19950517	78.97141548	94.94452427	51.70858901	84.33363237
13075000	Marsh Creek nr. McCammon	19960918	89.55440723	100	50.10740689	71.12161549
13081500	Snake River nr. Minidoka	19940916	81.14761378	85.58738716	77.01919368	94.1890211
13090000	Snake River nr. Kimberly	19930520	95.12297665	77.15243082	72.54015418	82.41398521
13090000	Snake River nr. Kimberly	19950914	88.73232706	85.58738716	75.87415096	75.50945393
13092747	Rock Creek above Hwy.30/93 Twin Falls	19960906	95.69303884	81.26053757	56.65574301	39.26489356
13094000	Snake River Nr. Buhl	19930514	71.77077262	85.58738716	65.12407779	49.43144825
13094000	Snake River Nr. Buhl	19930723	94.52491246	81.26053757	64.63816588	53.4568008
13094000	Snake River Nr. Buhl	19950524	95.12297665	77.15243082	60.3344638	86.69632245
13094000	Snake River Nr. Buhl	19950718	85.1639864	81.26053757	69.45661544	56.49404905
13094000	Snake River Nr. Buhl	19950906	87.88224489	85.58738716	69.87400973	54.45062599
13108150	Salmon Falls Creek nr. Hagerman	19940517	100	73.2520084	56.91090298	37.84465922

STAID	Site Name	Dates	D.O. Sub-index Score	pH Sub-index Score	Total Solids Sub-index Score	Total Nitrogen Sub-index Score
13108150	Salmon Falls Creek nr. Hagerman	19940922	100	73.2520084	53.68160542	34.51477406
13108900	Camas Creek at Red Road nr. Kilgore	19970923	93.2447781	94.94452427	93.29632699	95.89593509
13113000	Beaver Creek at Spencer	19970922	96.23509903	73.2520084	78.76923953	95.94010649
13152500	Malad River nr. Gooding	19930722	93.89884628	69.5487709	78.76923953	96.38294106
13168500	Bruneau River nr. Hot Springs	19940517	100	100	100	95.5873042
13172500	Snake River nr. Murphy	19940520	98.1233198	66.03274966	73.63488242	72.77823247
13172500	Snake River nr. Murphy	19940914	98.8994182	73.2520084	72.21492048	64.86374935
13206000	Boise River at Glenwood Bridge	19960924	100	94.94452427	100	87.09649013
13213000	Boise River nr. Parma	19930513	97.6932676	100	87.73917381	64.26908137
13213000	Boise River nr. Parma	19930908	100	77.15243082	71.89114496	41.3051482
13213000	Boise River nr. Parma	19940510	91.11456157	100	69.35265703	44.66875152
13213000	Boise River nr. Parma	19940907	100	85.58738716	68.52657179	43.25177816
13213000	Boise River nr. Parma	19950719	87.88224489	100	60.42490409	46.13214641
13213100	Snake River at Nyssa	19930917	100	73.2520084	67.60898168	56.75481088
13251000	Payette River nr. Payette	19930629	95.69303884	100	100	92.04504032
13251000	Payette River nr. Payette	19930825	100	85.58738716	93.85698423	83.94615874
13266000	Weiser River nr. Weiser	19930323	100	100	66.30522214	51.28651161
13266000	Weiser River nr. Weiser	19930517	100.115591	100	95.55925243	92.46989629
13266000	Weiser River nr. Weiser	19930915	100	69.5487709	98.6128482	88.71571696
13269000	Snake River at Weiser	19930916	99.56350861	69.5487709	70.29391232	59.42955289
13302005	Pahsimeroi River at Ellis	19950608	97.23521341	94.94452427	82.0201361	88.3081097
13302500	Salmon River at Salmon	19950607	98.8994182	100	84.26160119	95.94010649
13338500	South Fork Clearwater River at Stites	19930512	100	100	100	95.41138987
13342450	Lapwai Creek nr. Lapwai	19930317	100	100	92.60021277	10
13342450	Lapwai Creek nr. Lapwai	19930512	90.3484854	100	92.60021277	66.37460351

STAID	Site Name	Dates	D.O. Sub-index Score	pH Sub-index Score	Total Solids Sub-index Score	Total Nitrogen Sub-index Score
13342450	Lapwai Creek nr. Lapwai	19930910	100	85.58738716	86.95418053	81.28323518
13342450	Lapwai Creek nr. Lapwai	19950315	100	100	64.25204804	10
13342450	Lapwai Creek nr. Lapwai	19970910	96.74915722	100	80.19786386	32.41942674
13345000	Palouse River nr. Potlatch	19930525	98.1233198	100	100	95.06053184

STAID	Site Name	Dates	Total Phosphorus Sub-index Score	Fecal Coliform Sub-Index Score	RPI Score	Total Phosphorus Sub-index Score
10092700	Bear River at Idaho-Utah State Line	19940516	88.01815454	83.62005759	78.0211239	88.01815454
10092700	Bear River at Idaho-Utah State Line	19960917	94.00913264	89.63157816	78.28764542	94.00913264
12413470	South Fork Coeur d'Alene River nr. Pinehurst	19960906	88.01815454	82.79483338	89.34267365	88.01815454
12413470	South Fork Coeur d'Alene River nr. Pinehurst	19970917	89.51590945	98	93.64697538	89.51590945
12419000	Spokane River nr. Post Falls	19940907	94.00913264	97.61199418	90.29968585	94.00913264
13056500	Henrys Fork nr. Rexburg	19940913	94.00913264	96.93667684	92.74451535	94.00913264
13068500	Blackfoot River nr. Blackfoot	19930521	79.03147979	76.47956865	73.71631796	79.03147979
13068500	Blackfoot River nr. Blackfoot	19960919	91.01365743	88.74702784	90.17488793	91.01365743
13069500	Snake River nr. Blackfoot	19940718	88.01815454	86.14540951	84.81037683	88.01815454
13073000	Portneuf River near Blackfoot	19960918	94.00913264	92.33847987	77.68403464	94.00913264
13075000	Marsh Creek nr. McCammon	19930524	82.02706572	88.74702784	79.71204465	82.02706572
13075000	Marsh Creek nr. McCammon	19950517	61.05738286	50.42453997	67.18928747	61.05738286
13075000	Marsh Creek nr. McCammon	19960918	82.02706572	55.68192014	70.91803963	82.02706572
13081500	Snake River nr. Minidoka	19940916	82.02706572	96.45716968	86.02974077	82.02706572
13090000	Snake River nr. Kimberly	19930520	88.01815454	98	84.35530677	88.01815454
13090000	Snake River nr. Kimberly	19950914	76.03586617	98	82.16544603	76.03586617
13092747	Rock Creek above Hwy.30/93 Twin Falls	19960906	76.03586617	72.77953905	64.29990721	76.03586617
13094000	Snake River Nr. Buhl	19930514	52.06996068	81.97775309	65.76493209	52.06996068
13094000	Snake River Nr. Buhl	19930723	67.04885923	82.79483338	71.75659116	67.04885923
13094000	Snake River Nr. Buhl	19950524	49.07409793	94.37535918	72.71723351	49.07409793
13094000	Snake River Nr. Buhl	19950718	79.03147979	98	75.6070284	79.03147979
13094000	Snake River Nr. Buhl	19950906	73.04022487	89.63157816	74.79473833	73.04022487
13108150	Salmon Falls Creek nr. Hagerman	19940517	88.01815454	97.41856773	65.443531	88.01815454

STAID	Site Name	Dates	Total Phosphorus Sub-index Score	Fecal Coliform Sub-Index Score	RPI Score	Total Phosphorus Sub-index Score
13108150	Salmon Falls Creek nr. Hagerman	19940922	88.01815454	98	62.05881335	88.0181545 4
13108900	Camas Creek at Red Road nr. Kilgore	19970923	80.22971748	94.375359 18	92.5513449	80.2297174 8
13113000	Beaver Creek at Spencer	19970922	94.9077698	97.611994 18	89.1818823	94.9077698
13152500	Malad River nr. Gooding	19930722	79.03147979	84.453506 89	81.775967	79.0314797 9
13168500	Bruneau River nr. Hot Springs	19940517	91.01365743	98	97.42674069	91.0136574 3
13172500	Snake River nr. Murphy	19940520	67.04885923	98	77.57584525	67.0488592 3
13172500	Snake River nr. Murphy	19940914	88.01815454	97.611994 18	79.96471795	88.0181545 4
13206000	Boise River at Glenwood Bridge	19960924	70.04455589	98	89.66185399	70.0445558 9
13213000	Boise River nr. Parma	19930513	40.08634357	57.363531 56	65.73323414	40.0863435 7
13213000	Boise River nr. Parma	19930908	10	79.574575 99	24.8259258	10
13213000	Boise River nr. Parma	19940510	10	38.197911 78	24.39536754	10
13213000	Boise River nr. Parma	19940907	10	74.237570 77	24.89272594	10
13213000	Boise River nr. Parma	19950719	37.09037008	78.789275 56	58.12582886	37.0903700 8
13213100	Snake River at Nyssa	19930917	79.03147979	81.168736 35	74.31978846	79.0314797 9
13251000	Payette River nr. Payette	19930629	94.00913264	70.646007 51	90.04997672	94.0091326 4
13251000	Payette River nr. Payette	19930825	85.02262397	86.145409 51	87.95355307	85.0226239 7
13266000	Weiser River nr. Weiser	19930323	55.06579576	91.427215 86	71.82054349	55.0657957 6
13266000	Weiser River nr. Weiser	19930517	64.05313488	84.453506 89	87.54507837	64.0531348 8
13266000	Weiser River nr. Weiser	19930915	61.05738286	93.258826 54	81.22231886	61.0573828 6
13269000	Snake River at Weiser	19930916	82.02706572	82.794833 38	75.43052712	82.0270657 2
13302005	Pahsimeroi River at Ellis	19950608	79.03147979	34.591338 16	66.36370899	79.0314797 9
13302500	Salmon River at Salmon	19950607	67.04885923	90.524944 87	88.378654	67.0488592 3
13338500	South Fork Clearwater River at Stites	19930512	79.03147979	93.258826 54	94.43497974	79.0314797 9
13342450	Lapwai Creek nr. Lapwai	19930317	46.07820749	92.338479 87	25.22064304	46.0782074 9
13342450	Lapwai Creek nr. Lapwai	19930512	58.06160315	61.487447 03	73.92005999	58.0616031 5

STAID	Site Name	Dates	Total Phosphorus Sub-index Score	Fecal Coliform Sub-Index Score	RPI Score	Total Phosphorus Sub-index Score
13342450	Lapwai Creek nr. Lapwai	19930910	73.04022487	98	86.99566132	73.04022487
13342450	Lapwai Creek nr. Lapwai	19950315	10	94.28180642	18.40938552	10
13342450	Lapwai Creek nr. Lapwai	19970910	72.74065922	94.28180642	63.63801669	72.74065922
13345000	Palouse River nr. Potlatch	19930525	79.03147979	84.45350689	91.12885597	79.03147979

Glossary

Note:
This glossary is intended to define terms in the context used in the Idaho Rivers 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	Plant 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 (see also community) (EPA 1996).
Attribute	A biological characteristic or feature of an assemblage; for example, motile diatoms or piscivorous fish or invertebrates that cling.
Autecological guild	A group of species (usually algae) that share an ecological feature, such as tolerance of high nutrients.
Average depth at baseflow	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.
Average greatest depth	This is an average of the three greatest depths in the reach.
Average width at baseflow	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 difference in water body size due to diversions or other water flow regulations.

Term	Definition
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, and lakes and reservoirs.
Beneficial use	Any of the various uses that may be made of water, including, but not limited to, aquatic biota, recreation in or on the water, water supply, wildlife habitat, and aesthetics.
Benthic	Located on or near the bottom of the stream bed.
Best professional judgment	An option arrived at by a trained and/or technically competent individual when he/she applies interpretation and synthesizes information to derive a conclusion and/or interpretation.
Bias	The error caused by systematic deviation of an estimate from the true value (Suter 1993).
Biochemical oxygen demand (BOD)	(1) The dissolved oxygen required to oxidize inorganic chemicals in water. (2) A measure of oxygen consumption during a fixed period of time. (3) the amount (milligram per liter) of molecular oxygen required to stabilize decomposable organic matter by aerobic biochemical action.
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).
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.
Candidate metric	An attribute of the biological assemblage that has been proposed, but not tested for its association with human disturbance.
Catchment area	The area draining into a river, stream, lake or other water body.
Cold water fishes	A broad term applied to fish species that inhabit waters with relatively cold temperatures (optimum temperatures generally between 4-15EC [40-60EF]). Examples are salmon, trout, chars, and whitefish (Armantrout 1998).

Term	Definition
Coliform	A group of bacteria found in the intestines of warm-blooded animals (including humans) and in plants, soil, air, and water. Fecal coliform are a specific class of bacteria which only inhibit the intestines of warm-blooded animals. The presence of coliform is an indication that the water is polluted and may contain pathogenic organisms.
Community (aquatic)	An association of interacting assemblages in a given water body, the biotic component of an ecosystem (see also assemblage) (EPA 1996).
Cool water fishes	A broad term applied to fish species that inhabit waters with relatively cool temperatures (optimum temperatures generally between 10-21EC [50-70EF]) (Armantrout 1998).
Cottid	
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.
Cyanobacteria	Blue green algae.
Designated uses	Those water uses identified in state water quality standards that must be achieved and maintained as required under the Clean Water Act.
Diatom	Single-celled algae with a silica
Discharge	The amount of water flowing in the stream channel at the time of measurement. Usually expressed as cubic feet per second (cfs).
Dissolved oxygen (DO)	The oxygen freely available in water, vital to fish and other aquatic life and for the prevention of odors. DO levels are considered an important indicator of a water body's ability to support desirable aquatic life.
Disturbance	Any event or series of events that disrupt ecosystem, community, or population structure and alters the physical environment.
Diversity	Variation that occurs in plant and animal taxa (i.e., species composition), habitats, or ecosystems within a geographic location.

Term	Definition
Ecological indicator	A characteristic of an ecosystem that is related to, or derived from, a measure of 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 integrity	(1) A living system exhibits integrity if, when subjected to disturbance, it sustains and organizes a self-correcting ability to recover toward a biomass end-state that is normal for that system. End-states other than the pristine or naturally whole may be accepted as abnormal but good. (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 (man□caused) or other natural changes in their environment. Requirements for declaring a species endangered are contained in the Endangered Species Act.
Euhalobus	Prefers or tolerates high concentrations of chloride.
Euthermal	Prefers or tolerates high temperatures.
Eutrophic	High nutrients, typically derived from nonorganic sources.
Exceedance	Violation of the pollutant levels permitted by environmental protection standards.
Exotic species	A species that is not indigenous to a region.
Extrapolation	Estimation of unknown values by extending or projecting from known values.
Fecal coliform bacteria	Bacteria found in the intestinal tracts of mammals. Their presence in water is an indicator of pollution and possible contamination by pathogens.
Fully supporting of cold water biota	Reliable data indicate functioning, sustainable biological assemblages (e.g., fish, macroinvertebrates, or algae) none of which have been modified significantly beyond the natural range of reference conditions (EPA 1995).
Grab sample	A single sample collected at a particular time and place which represents the composition of the water only at that time and place.
Guild	Group of species that share some ecological feature.

Term	Definition
Habitat	The place where a population (e.g., human, animal, plant, microorganism) lives and its surroundings, both living and non-living.
Human made	Relating to or resulting from the influence of human beings on nature; anthropogenic.
Indicator	(1) In biology, any biological entity, process, or community whose characteristics show the presence of specific environmental conditions. (2) In chemistry, a substance that shows a visible change, usually of color, at a desired point in a chemical reaction. (3) A device that indicates the result of a measurement; e.g., a pressure gage or a moveable scale.
Lotic	Fast moving waters, e.g., rivers or streams. Contrast with *lentic* which means still or slow and refers to lakes.
Macroinvertebrate	An invertebrate animal (without backbone) large enough to be seen without magnification and retained by a 0.595 mm (US #30) screen.
Major criteria exceedance	A violation of water quality standards or criteria sufficient in magnitude, frequency, or duration to adversely affect a beneficial use.
Metric	One discrete measure of an ecological indicator (e.g., number of distinct taxon).
Mean annual site discharge	Similar to the site discharge, the mean annual site discharge is determined using data from nearby USGS gaging stations and a similar extrapolation technique.
Metric	A biological attribute or characteristic that is reliably (in terms of statistics) and meaningfully (in terms of underlying biological processes) associated with human degradation.
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.
Morphological guild	Group of diatoms that have similar growth forms.
Non-point sources	Diffuse pollution sources (i.e., without a single point of origin or not introduced into a receiving stream from a specific outlet). The pollutants are generally carried off the land by storm water. Common non-point sources are agriculture, forestry, cities, mining, construction, dams, channels, land disposal, saltwater intrusion, and city streets.

Term	Definition
Not fully supporting of cold water biota	At least one biological assemblage has been significantly modified beyond the natural range of its reference condition (EPA 1995).
Nutrient	Any substance assimilated by living things that promotes growth. In water, the term is generally applied to nitrogen and phosphorus, but is also applied to other essential and trace elements and organic carbon.
Oligosaprobic	Low nutrients and high oxygen.
Oligotrophic	A body of water with low levels of nutrients.
Organic matter	(1) In the ecology of running waters, organic matter, either as a mass or elemental carbon, relates to potential sources and fates of energy in an ecosystem. Organic matter may be classified as being dissolved organic matter, different size classifications of particulate organic carbon, or larger organic debris (Minshall 1996). (2) Carbonaceous waste contained in plant or animal matter and originating from domestic or industrial sources.
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).
Pathogens	Microorganisms (e.g., bacteria, viruses, or parasites) that can cause disease in humans, animals, and plants.
Periphyton	Attached microflora growing on the bottom of a water body, or on other submerged substrates, including higher plants. Epilithic periphyton is flora growing on the surface of rock or stones.
pH (pronounce as separate letters)	pH is an expression of the intensity of the basic or acid condition of a liquid. Mathematically, pH is the logarithm (base 10) of the reciprocal of the hydrogen ion concentration, [H+]. pH= Log (I/[H+]). The pH may range from 0 to 14, where 0 is most acidic, 14 most basic, and 7 neutral.
Phosphorus	An essential chemical food element that can contribute to the eutrophication of lakes and other water bodies. Increased phosphorus levels result from discharge of phosphorus-containing materials into surface waters.

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.
Polysaprobic	High nutrients and low oxygen associated with organic waste.
Population at risk	A population subgroup that is more likely to be exposed to a chemical, or is more sensitive to the chemical, than is the general population.
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.

Term	Definition
Reference condition	(1) A condition that fully supports applicable beneficial uses, with little effect from human activity and representing the highest level of support attainable. (2) The benchmarks for populations of aquatic ecosystems used to describe desired conditions in a biological assessment and acceptable or unacceptable departures from them. Reference conditions can be determined through examining regional reference sites, historical conditions, quantitative models, and expert judgment (Hughes 1995).
Reference site	A specific locality on a water body which 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	A 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.
Secondary drinking water standards	Non-enforceable federal guidelines regarding cosmetic effects (i.e., tooth or skin discoloration) or aesthetic effects (i.e., taste, odor, or color) of drinking water.
Sediments	Fragmented material from weathered rocks and organic material that is suspended in, transported by, and eventually deposited by water or air.
Signal to noise ratio (S/N)	A comparison of the variance among streams ("signal") with the variance between repeat stream visits (measurement "noise"). Higher S/N indicates better precision. Higher precision means that measures at different stream sites are more different repeat measures at the same sites.
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) (4^{th} and 5^{th} 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.

Term	Definition
Spring	Ground water seeping out of the earth where the water table intersects the ground surface.
Stratification	Separating into layers.
Stream	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 1^{st}-order stream is an unforked or unbranched stream. Two 1^{st} -order streams flow together to form a 2^{nd}-order stream, two 2^{nd} orders combine to make a 3^{rd}-order stream, etc. (Strahler 1957).
Stressors	Physical, chemical, or biological entities that can induce adverse effects on ecosystems or human health.
Taxon	Any formal taxonomic unit or category of organisms (e.g., species, genus, family, order). The plural of taxon is taxa (Armantrout 1998).
Trophic state	Refers to the concentrations of inorganic nutrients, particularly nitrogen and phosphorus, in a water body.
Turbidity	A measurement used to indicate the clarity of water. Technically, turbidity is an optical property of the water based on the amount of light reflected by suspended particles. Turbidity cannot be directly equated to suspended solids because white particles reflect more light than dark-colored particles and many small particles will reflect more light than an equivalent large particle.
Valve	Diatoms are shaped like small boxes, they have a hard top and a bottom made of silica. Each part is called a valve. The two parts together make up the frustule.
Warm water fishes	A broad term applied to fish species that inhabit waters with relatively cool temperatures (optimum temperatures generally between 15-27EC [60-80EF]) (Armantrout 1998).
Water body	A homogeneous classification that can be assigned to rivers, lakes, estuaries, coastlines, or other water features.
Water quality	A term used to describe the biological, chemical, and physical characteristics of water with respect to its suitability for a beneficial use.

Term	Definition
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 "subwatersheds" each of which contributes runoff to different locations that ultimately combine at a common delivery point.

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