Morice & Lakes IFPA

Morice & Lakes Innovative Forest Practices Agreement

Development and Calibration of a Multimetric Benthic Invertebrate Index of Biological Integrity

A Biomonitoring Study for Assessing Stream Condition in the Morice and Lakes TSAs

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EXECTUTIVE SUMMARY

The goal of this project was to develop and calibrate a biomonitoring system that characterizes benthic invertebrate communities on a human disturbance gradient from highly disturbed to undisturbed within the Morice and Lakes Timber Supply Areas (TSAs). The project is based on the work of Dr. James Karr from the University of Washington. Dr. Karr has established that an index of biological integrity (IBI), which is based on the sampling of benthic invertebrate communities, can be an effective tool for measuring the biological condition or integrity of streams.

This IBI was calibrated for the Morice and Lakes TSAs by sampling and scoring 26 streams across a gradient of human influence from low influence to high influence. Each sampled stream was assessed and scored on the basis of specific metrics which were found to indicate stream condition. The metrics used in the calibration of the Morice and Lakes IBI included: Total number of Ephemeroptera Taxa, Plecoptera Taxa, Trichoptera Taxa, Number of Intolerant Taxa, Number of Clinger Taxa, Relative Abundance of Predators, Relative Abundance of Shredders, Relative Abundance of Dipterans, Relative Total Taxa Richness, and Relative Abundance of Oligochaetes.

IBI scores for the streams sampled reasonably reflected the predicted level of human influence; however, there was a significant amount of overlap in terms of the definition of natural stream conditions in the area. This indicates that more data is needed to increase the effectiveness and reliability of this tool.

This report provides a preliminary look at the effectiveness of the IBI in the Morice and Lakes TSAs. Development and calibration of this B-IBI should be an iterative process, with continual re-evaluation of the index as a whole as well as the individual metrics chosen for inclusion as more data become available.

ACKNOWLEDGMENTS

The first stage of this multi-year project included the selection of potential sample sites and the development of a human influence gradient. The second stage consisted of field sampling twenty-six sites, taxonomically classifying the invertebrate samples and developing a preliminary index of biological integrity. The initiation, motivation and completion of these stages were greatly aided by several people. Many thanks to **Ian Sharpe**, Ministry of Water, Land and Air Protection for his enthusiasm, direction and provision of a portion of the funds for the taxonomic classification. Thank-you to **Shauna Bennett** for her expert advice and direction with regards to sampling protocols and index development. Thank-you to **Malcolm Grey**, Ministry of Sustainable Resource Management for providing the Geographic Information System (GIS) data utilized for the development and completion of a quantitative land use analysis.

Most of all thank-you to the members of the Morice and Lakes Innovative Forest Practices Agreement for their investment and the opportunity to be involved in a project such as this.

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INTRODUCTION

The Morice and Lakes Timber Supply Areas (TSAs) are rich in fresh water aquatic resources. The integrity of these natural resources is increasingly being influenced by human actions, such as those associated with forest management practices, recreation, agriculture and urbanization. As these activities encroach further on our rivers, streams and riparian habitats, the integrity of these resources may be affected through physical habitat alteration, modified hydrologic flows, increased sedimentation and temperatures and altered or disrupted energy and nutrient inputs.

To further our understanding of the overall health of aquatic ecosystems in the Morice and Lakes Timber Supply Areas and the impacts specific human disturbances have on these ecosystems, a biological monitoring study is being implemented. Historically, stream condition and aquatic health have been assessed primarily through chemical analysis of the water or assessments of the physical structure of aquatic habitats as they relate to salmonids. However, our reliance on these measurements alone as indicators of stream condition assumes we have a complete understanding of exactly what aquatic life needs to maintain a healthy state (Karr and Chu 1999). It is also assumed that we are able to effectively correlate the results of these physical and chemical assessments to give us an accurate picture of what is happening over time in terms of the cumulative effects associated with our actions. Since our collective knowledge with regards to these critical assumptions is limited, many of the management decisions regarding future development in and around a particular watershed or stream are made without a clear understanding of the true biological condition or integrity of the aquatic ecosystems present.

Biological integrity is defined as the ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition diversity and functional organization comparable to that of the natural habitat in the region (Karr et. al 1987). Since the stream biota is known to reflect the quality and state of the habitat present, a biological monitoring approach to stream assessment can incorporate and integrate ecology, life history, physiology, and taxonomy into a management and assessment tool (Thorp and Covich 2001). As such, biomonitoring studies have been used in other geographic regions to measure the response and recovery of aquatic communities to disturbances and to protect biodiversity, evaluate compliance, and improve our understanding of the relationship between the physical, chemical and biological components in these environments (Gurtz 1994).

A benthic index of biological integrity (B-IBI) is one such biomonitoring approach. A B-IBI is a multimetric assessment of stream condition based on biological data. A metric is described as a specific attribute of a community such as the number or diversity of benthic invertebrate taxa present. Benthic invertebrates were identified as effective organisms for biological monitoring because of their wide ecological amplitude, relatively sedentary behaviour and predictable responses of many taxa to different types human disturbance (Resh et. al 1996; Rysavy 2001).

A biomonitoring approach consists of five steps:

1) defining biological condition in a minimally disturbed area (i.e. what the natural, uninfluenced condition in the area is),

2) identifying and defining metrics that predictably change across a gradient of human influence,
3) associating those changes with specific human impacts,
4) identifying management practices for improving biological integrity, and
5) communicating the results to land managers and policy makers (Karr and Chu 1999).

The goal of this project is to develop and test a biomonitoring system that characterizes benthic invertebrate communities on a human disturbance gradient from highly disturbed to undisturbed aquatic ecosystems within the Morice and Lakes Timber Supply Areas. It is hoped that this B-IBI can then be used as a long term monitoring tool to evaluate the impacts of forest practices on aquatic ecosystems within the Morice and Lakes TSAs. Long term monitoring capabilities are essential to the success of adaptive management initiatives and will provide a greater ability to maintain and protect the integrity of aquatic ecosystems, and the quality and quantity of water within the natural range of variability.

METHODS

Site Selection

Within the Morice and Lakes TSAs , potential sample streams were selected based on their similar broad geographical, ecological and structural attributes including geographic location, stream order (3rd to 4th), elevation, biogeoclimatic classification (Sub-Boreal Spruce) and level of human influence. To clearly define the reference or control conditions for the Morice and Lakes TSAs, site selection focused on streams which were uninfluenced by human activities. To obtain adequate representation of the variability associated with the range of human influence within the Morice and Lakes TSAs, streams which were heavily influenced by forestry practices and non-forestry practices (eg: agriculture, range, urbanization etc) were also identified and selected for inclusion in the study (Figure 1).

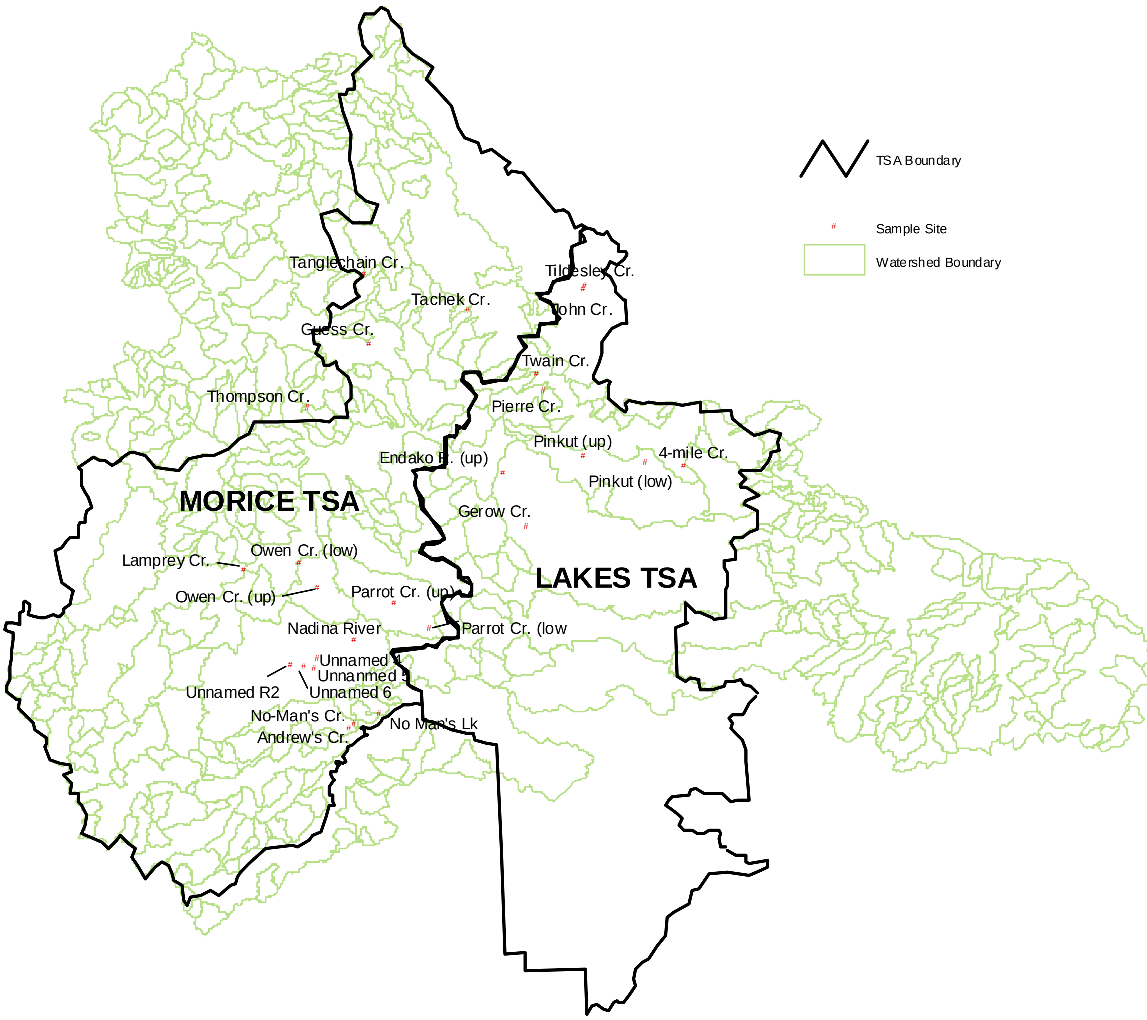


Figure 1: Sample Site Locations

Human Influence Gradient

In the past the classification of human influence into low, medium and high categories was performed utilizing a subjective approach (Fore et. al 1996; Rysavy 2000a, 2000b, 2001). In an attempt to improve on this subjective approach to developing a land use gradient, GIS data was utilized to develop an index for the classification of human influence across the Morice and Lakes TSAs.

With the use of a Geographic Data B.C. GIS database, entitled *Watersheds B.C.,* provided by the Ministry of Sustainable Resource Management, a quantitative index for the classification of human land use influence was developed. This province-wide database provides extensive summary information on many relevant land use indicators (e.g.: % forest land harvested) and is summarized on a watershed basis (3rd order or greater). All land use indicators or attributes are reported as a direct measurement of area, length, percentage or density which allow for a meaningful comparison between watersheds of different sizes.

To develop an accurate index for the classification of human influence in the Morice and Lakes TSAs, specific attributes were selected from the *Watersheds B.C.* database based on their ability to indicate a specific level of land use which would have the greatest impact on aquatic resources. These attributes included: % watershed area logged in the last twenty years, % total stream length logged to the bank, total stream crossing density (total # of stream crossings/total stream length), total road length density, total road length density within 100m of a stream, % watershed area utilized as urban, % watershed area utilized as agriculture, % watershed area utilized as range, % watershed area utilized by recreation and % watershed area utilized by mining.

The values for each of these human land use attributes were then summarized for every watershed in the Morice and Lakes TSAs. The highest and lowest values for each were then identified across both TSAs. With the upper and lower limits identified, the range of each attribute (except % watershed area logged and % stream length logged) was divided into eleven equal range categories. Each range category was then assigned an index value from 0-10 (0 = no influence, 10 = highest influence). The index value assigned to "percent watershed area logged" and "percent stream length logged" attributes was equivalent to the absolute percentage reported for each. This was done to preserve and accurately represent the level of influence associated with these two attributes.

With the establishment of index values for each attribute, a total index score was calculated by summing the values for every 3rd order or greater watershed in the Morice and Lakes TSAs. This calculated index score of human influence was then used to identify 37 potential sites with low, moderate and high influence in the two TSAs. This was done by dividing the range of index scores into equal thirds and assigning range values of <16.6 for low, 16.7 to 33.2 for moderate and >33.3 for high. This data was also used to classify the type of human influence as either forestry, non-forestry (agriculture, range, urbanization) and mining. Out of the 37 potential sites scored on the land use gradient 26 sites were chosen for sampling (Table 1).

Table 1: List of stream sites and level of human influence within the upstream catchment basin of the watershed.

	HUMAN LANDUSE INFLUENCE						
NAME	Site_ID#	Forestry	Non-Forestry	Minning	Total	TYPE	DEGREE
4 MILE CREEK	R32	0	0	0	0	Reference	Low
ALLIN CREEK	BU	9	0	0	9	Forestry	Low
ANDREWS CREEK	8	33	0	0	33	Forestry	Moderate
BEACH CREEK	BU	12	0	0	12	Forestry	Low
DECKER CREEK	14	28	20	0	48	Non Forestry/Forestry	High
DUNGATE CREEK	BU	30	0	0	30	Forestry	Moderate
ENDAKO RIVER (LOWER)	15	17	30	3	50	Non Forestry/Forestry	High
GEROW CREEK	R3	7	0	0	7	Reference	Low
GUESS CREEK	35	12	0	0	12	Forestry	Low
HILL-TOUT LAKE	6	26	0	0	26	Forestry	Moderate
JOHN CREEK	30	Unk	0	0	N/A	Forestry	Moderate
KEW CREEK	BU	7	0	0	7	Forestry	Low
LAMPREY REC SITE	28	18	0	0	18	Forestry	Moderate
MAXAN CREEK (upper)	R-BU	18	3	0	21	Reference	Low
MOXLEY CREEK	BU	17	9	0	26	Forestry	Moderate
NADINA RIVER	27	19	7	0	26	Non Forestry/Forestry	Moderate
NO MANS CREEK	9	23	0	0	23	Forestry	Moderate
OUTLET NO-MANS LAKE	10	25	0	0	25	Forestry	Moderate
OWEN CREEK LOWER	2	14	24	1	39	Non Forestry/Forestry	High
OWEN CREEK UPPER	33	14	24	1	39	Non Forestry/Forestry	High
PARROTT CREEK @ FORD	12	16	11	1	28	Non Forestry/Forestry	Moderate
PARROTT CREEK LOWER	11	16	11	1	28	Non Forestry/Forestry	Moderate
PIERRE CREEK	18	5	0	0	5	Reference	Low
PINKUT CREEK LOWER	16	17	0	0	17	Forestry	Moderate
PINKUT CREEK UPPER	31	17	0	0	17	Forestry	Moderate
RAMSAY CREEK	13	17	4	0	21	Non Forestry/Forestry	Moderate
TACHEK CREEK	34	12	5	1	18	Forestry	Moderate
TANGELCHAIN CREEK	36	26	0	0	26	Forestry	Moderate
TATALROSE	BU	16	29	0	45	Non Forestry/Forestry	High
THOMPSON CREEK	BU	20	27	0	47	Non Forestry/Forestry	High
TILDESLEY CREEK	29	2	0	0	2	Forestry	Moderate
TWAIN CREEK	17	6	0	0	6	Forestry	Low
UNNAMED CREEK	R2	0	0	0	0	Reference	Low
UNNAMED CREEK	4	32	0	0	32	Forestry	Moderate
UNNAMED CREEK	3	38	0	0	38	Forestry	High
UNNAMED CREEK	5	27	0	0	27	Forestry	Moderate
VALLEE CREEK	1	25	25	0	50	Non Forestry/Forestry	High

Field Sampling

Just as most vertebrate communities vary in structure from season to season, so do benthic invertebrate communities. Therefore, to ensure accurate, defendable and comparable sampling it was recommended that the calibration and use of an IBI be linked to one particular period in the year (Karr and Chu, 1999). Late summer to early fall was previously chosen as the sampling period for the Kispiox, Upper Bulkley and Bulkley TSA IBI's (Rysavy 2000a and 2000b; Rysavy 2001). Therefore, to ensure compatibility with these ongoing projects, this sampling period was also chosen for the Morice and Lakes TSA project. This period was chosen because stream flows and turbidity are usually lower at the end of the summer and stream temperatures are high, ensuring that sampling occurs during safe and effective conditions immediately after peak biomass production (Rysavy 2000a). Twenty-six sites, representing a range of human influence, were sampled within a two-week period beginning August 15th, 2002.

Although there are no British Columbia provincial sampling standards for the sampling of benthic invertebrates, sampling at each site followed the protocols used by Karr and Chu

(1999) and Rysavy (2000a, 2000b, 2001) in order to ensure continuity between projects. At each site, the best and most accessible natural riffle within the thalweg was selected for sampling. Three replicates of three sub-samples were collected at each site starting at the downstream end of the riffle. All sampling was performed with a 250 micron Surber sampler with a Dolphin Adaptor cod end at water depths between 10 and 40 cm. All large cobble within the Surber sampling area was carefully lifted and all crawling or loosely attached organisms were brushed off so that they drifted into the Surber net. Once brushing was complete the large cobble was placed in a wash basin. With the large cobble removed the small substrate within the Surber sample area was vigorously disturbed to a 10 cm depth with a screwdriver for a period of one minute. The sample was then carefully transferred from the cod end to a labelled sample jar. Upon completion of the disturbance sampling, each piece of large cobble placed in the wash basin was carefully examined and all remaining invertebrates were washed or picked off and placed in the appropriate jars. Each set of three sub-samples was then combined into one sample in order to ensure an adequate sample size for each replicate (Figure 2). Samples containing less than 300 individuals have been correlated with increased sampling error for some metrics (Fore et. al 2000; Bennett 2001). To preserve the samples, 10% buffered Formalin solution was added to each sample jar.

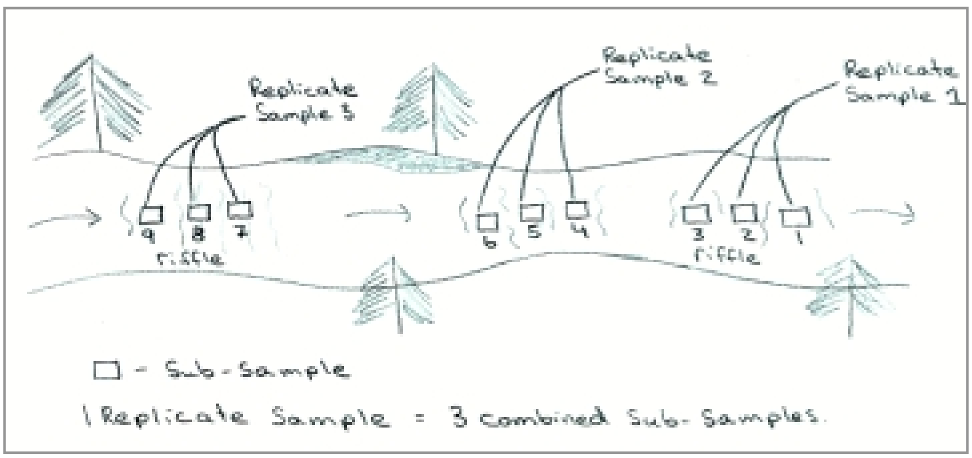


Figure 2: Field Sampling Methods

Once the benthic invertebrate sampling was complete, each site was assessed for in-stream and riparian habitat conditions utilizing modified Fish Habitat Assessment Procedure parameters (Johnston and Slaney 1996) and the Standard Operating Procedures for the Alaska Stream Condition Index (ASCI) (Major and Barbour 1997). Examples of field forms that were used for assessing the habitat are included in Appendix 2. Stream condition, structure, substrate, riparian habitat and obvious land use influences were documented and photographed at each site.

Taxonomic Classification

Upon completion of the field sampling, each benthic invertebrate sample was shipped to Fraser Environmental Services in Surrey, B.C. for taxonomic classification. Whole samples were then sorted, analyzed, and identified to the lowest practical level (usually genus with the exception of chironomids which were sorted to family) by taxonomists.

Due to the composite nature of the samples, streams with abundant invertebrates resulted in samples with greater than 1,000 individuals. In order to maintain cost effectiveness and efficient laboratory practices, taxonomists used a subsampling protocol for the larger samples which were estimated to be greater than 1,000 individuals. Samples with less than 1,000 individuals were sorted and classified as a whole. Samples with greater than 1,000 individuals were screened using a one millimeter and 212 micron nested sieve system. The entire contents of the one millimeter seive were then sorted and counted while the contents of the 212 micron sieve were subsampled using a Caton Tray. A minimum of 600 individuals were sorted and counted in split samples.

Metric Calculation

Benthic invertebrate taxonomic data received from Fraser Environmental Services was summarized and sorted by taxonomic classification. Due to the ability of adults to leave aquatic habitats when conditions become less favourable and the effective isolation of pupae from the external environment, all adults and pupae were eliminated from the data. Taxa that were highlighted as being "very large", but without an identified life stage were assumed to be adults and were also eliminated. As well all individuals not classified to the family level were ignored during metric calculations due to the diversity within invertebrate classes and orders.

Replicate samples that did not have at least 300 individuals were not used in the metric calculations. Taxa richness and relative abundance measurements are known to be affected by sample size (Karr et al 1987), with larger samples producing more vigorous results. Only two of the sites sampled (Owen Creek Lower and Lamprey Creek Rec Site) had replicates of less than 300 individuals. As a result, one replicate from each site was eliminated during metric calculations.

All metrics were calculated at the genus level as described on the Salmonweb internet site (www.salmonweb.org), except % oligochaetes and % non-insects which were only classified to family. The genus level 10 Metric B-IBI method was chosen due to the increased level of precision that is expected to be achieved in portraying stream condition. This is because index development at the genus level allows for a greater number of metrics to be used with increased data per metric associated with lower levels of taxonomic classification (Salmonweb 2001).

Functional group measures rely on functional rather than taxonomic information, and in this sense they bridge community and ecosystem level approaches to biomonitoring (Thorp and Covich 2001). Therefore, utilizing the Northwest Taxa Database from the Salmonweb, as well as Bennett (2001) and Merritt and Cummins (1996), behavioral, feeding and habitat characteristics of invertebrate taxa were identified and correlated with individual genera and families. Where discrepancy was encountered between the three references, the information presented on the Northwest Taxa Database was utilized.

Eighteen different invertebrate community attributes, or metrics, were calculated for each site. Metrics calculated for this study were chosen from four broad categories of metrics; community richness and composition, tolerance and intolerance, feeding and habit and population attributes that have been identified as key components in a balanced multimetric index (Karr and Chu 1999; Barbour et. al 1999). The metrics calculated for the Morice and Lakes B-IBI were shown to vary predictably across a gradient of human influence in previous studies (Barbour et. al 1996a; Kerans & Karr 1994; Karr & Chu 1999; Major et. al 2001) as well. The metrics calculated include:

Taxa Richness and Composition

Total Number of Taxa The total number of unique taxa is identified in each replicate. The numbers from the three replicates were then averaged for this metric.

Ephemeroptera Taxa The total number of unique mayfly (Ephemeroptera) taxa was identified in each replicate. The numbers from the three replicates were then averaged for this metric.

Plecoptera Taxa The total number of unique stonefly (Plecoptera) taxa was identified in each replicate. The numbers from the three replicates were then averaged for this metric.

Trichoptera Taxa The total number of unique caddisfly (Tricoptera) taxa was identified in each replicate. The numbers from the three replicates were then averaged for this metric.

Number of Long-Lived Taxa The cumulative number of unique long-lived taxa identified across all three replicates.

Number of Diptera Taxa The total number of unique Diptera taxa identified in each replicate. The numbers from the three replicates were then averaged for this metric.

Percent Non Insects The total number of non-insect individuals counted in each replicate, divided by the total number of individuals in that replicate, multiplied by 100. The percentages from the three replicates were then averaged for this metric.

Percent Non-Insects and Diptera The total number of non-insect and Dipteran individuals counted in each replicate divided by the total number of individuals in that replicate, multiplied by 100. The percentages from the three replicates were then averaged for this metric.

Percent Dipterans The total number of Dipteran individuals counted in each replicate divided by the total number of individuals in that replicate, multiplied by 100. The percentages from the three replicates were then averaged for this metric.

Percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) The total number of Ephemeroptera, Plecoptera, and Trichoptera individuals counted in each replicate divided by the total number of individuals in that replicate, multiplied by 100. The percentages from the three replicates are then averaged for this metric.

Tolerance and Intolerance

Number of Intolerant Taxa The cumulative number of unique intolerant taxa identified across all three replicates.

Percent Tolerant Individuals The total number of tolerant individuals counted in each replicate, divided by the total number of individuals in that replicate, multiplied by 100. The percentages from the three replicates were then averaged for this metric.

Percent Oligochaetes The total number of individuals in the class Oligochaetes counted in each replicate, divided by the total number of individuals in that replicate, multiplied by 100. The percentages from the three replicates were then averaged for this metric.

Functional Feeding and Habits

Number of Clinger Taxa The total number of unique clinger taxa was identified in each replicate. The numbers from the three replicates were then averaged for this metric.

Percent Predator Individuals The total number of predator individuals counted in each replicate, divided by the total number of individuals in that replicate, multiplied by 100. The percentages from the three replicates were then averaged for this metric.

Percent Clingers The total number of clinger individuals counted in each replicate, divided by the total number of individuals in that replicate, multiplied by 100. The percentages from the three replicates were then averaged for this metric.

Percent Shredders The total number of shredder individuals counted in each replicate, divided by the total number of individuals in that replicate, multiplied by 100. The percentages from the three replicates were then averaged for this metric.

Population Attributes

Percent Dominance The sum of individuals in the three most abundant taxa in each replicate, divided by the total number of individuals in that replicate, multiplied by 100. The percentages from the three replicates were then averaged for this metric.

Metric Testing

The development and calibration of a benthic invertebrate multimetric index of biological integrity for the Morice and Lakes TSAs requires the identification of a core group of metrics that will reliably reflect changes in the aquatic biota resulting from varying degrees of human influence. A multimetric index combines a number of individual metrics into one score or value to allow effective comparison of multiple sites. An overall index is then the sum of the scores for the group of identified core metrics (Karr and Chu 1999).

Each calculated metric was tested for its response to increasing human influence by plotting metric values against human influence scores (Figure 3.) In order to simplify the graphical representation of the metric test human influence scores associated with each site were given a number value from 1 to 3 where 1 = low influence, 2=moderate influence and 3=high influence. The expected response of each metric to increasing human influence is outlined in table 2.

Each correctly responding metric was then analysed by testing the significance of the regression with an analysis of the variance (ANOVA) at a 95% confidence level.

Metrics chosen for inclusion in the index were then ranked utilizing Microsoft Excels rank function and plotted to allow for the identification of cut-off points between high, moderate and low human influence. The rank function returns the rank of a number in a list of numbers. The rank of a number is its size relative to other values in a list. (If you were to sort the list, the rank of the number would be its position.) Ranked graphs are presented in Figure 4, with the three sections, 1= low influence, 3=moderate influence and 5=heavy influence, identified after a careful subjective examination of the graphs for distinct trends and natural breaks.

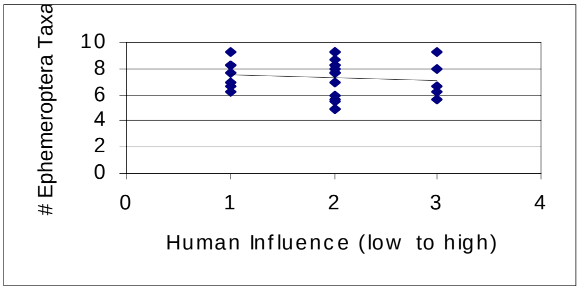
Table 2 Definitions of best candidate benthic metrics and predicted metric response to increasing human influence (modified from Karr and Chu 1999; Barbour et. al 1999;).

CATEGORY	METRIC	DEFINITION	EXPECTED RESPONSE	REFERENCE
Taxa richness & composition	No. of Taxa	Total number of taxa	Decrease	Karr and Chu 1999
	No. of Ephemeroptera Taxa	Total # of Ephemeroptera taxa	Decrease	Karr and Chu 1999
	No. of Plecoptera Taxa	Total # of Plecoptera taxa	Decrease	Karr and Chu 1999
	No. of Trichoptera Taxa	Total # of Trichoptera taxa	Decrease	Karr and Chu 1999
	% EPT individuals	Relative abundance of Ephemeroptera, Plecoptera, and Trichoptera individuals	Decrease	Barbour et. al 1999
	No. of Diptera Taxa	Total # of Diptera taxa	Decrease	Karr and Chu 1999
	% Dipterans	Relative abundance of Diptera individuals	Increase	Barbour et. al 1999
	% Non Insect Individuals	Relative abundance of non-insect individuals	Increase	Karr and Chu 1999
	% Diptera and Non-Insect Individuals	Relative abundance of non-insect individuals	Increase	Karr and Chu 1999
	No. of Long-Lived Taxa	Cumulative number of unique long-lived taxa	Decrease	Karr and Chu 1999
Tolerance / Intolerance	No. of Intolerant Taxa	Cumulative number of unique intolerant taxa	Decrease	Karr and Chu 1999
	% Tolerant Individuals	Relative abundance of tolerant individuals	Increase	Karr and Chu 1999
	% Oligochaetes	Relative abundance of Oligochaete individuals	Increase	Karr and Chu 1999
Feeding / Habit Metrics	% Predators	Relative abundance of predator individuals	Decrease	Karr and Chu 1999
	% Shredders	Relative abundance of shredder individuals	Decrease	Barbour et. al 1999
	No. of Clinger Taxa	Total number of clinger taxa	Decrease	Karr and Chu 1999
	% Clingers	Relative abundance of clinger individuals	Decrease	Karr and Chu 1999
Population Attributes	% Dominance (3 taxa)	The proportion of the three most abundant taxa relative to the sample size	Increase	Karr and Chu 1999

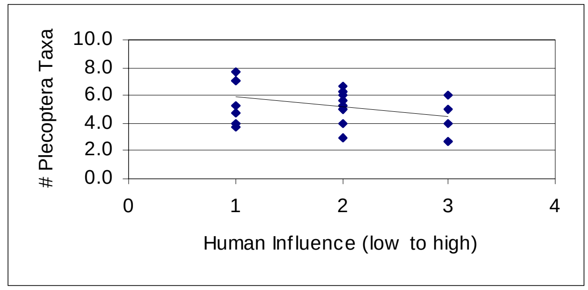
RESULTS

The graphical results associated with each of the metric tests are presented in Figure 3. Regression lines indicate the general trend of the metric response to increasing human influence.

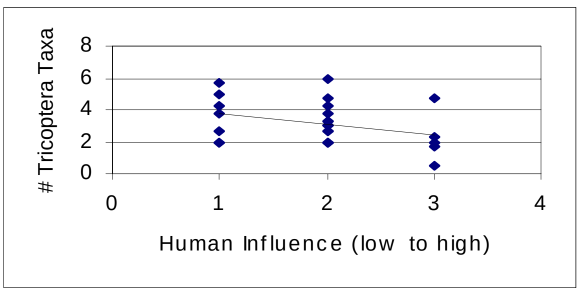
1) Ephemeroptera Taxa Richness



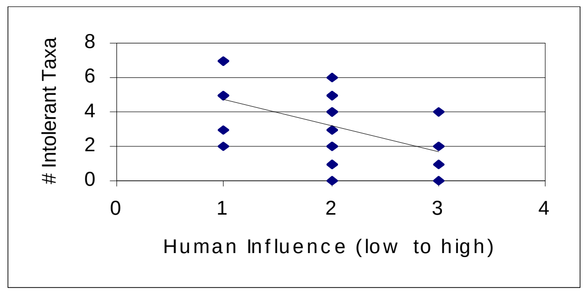
2) Plecoptera Taxa Richness



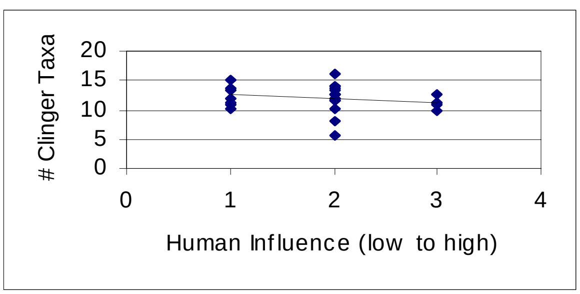
3) Trichoptera Taxa Richness



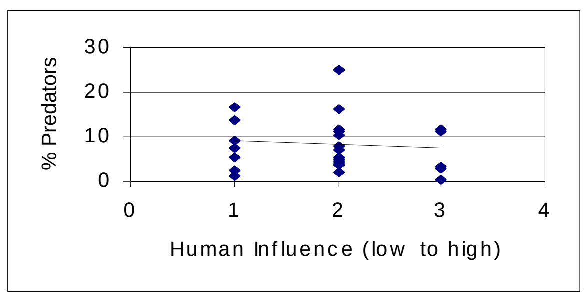
4) Number of Intolerant Taxa



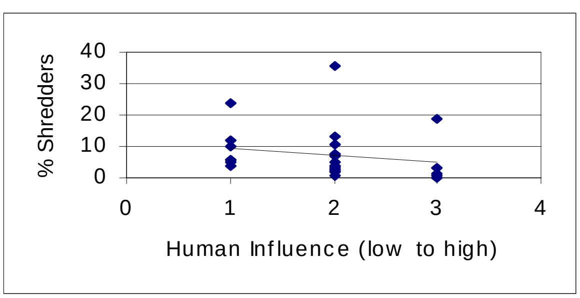
5) Number of Clinger Taxa



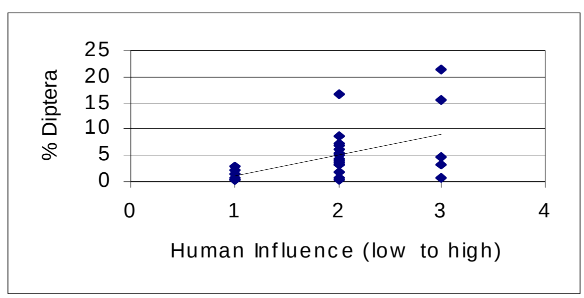
6) Relative Abundance of Predators



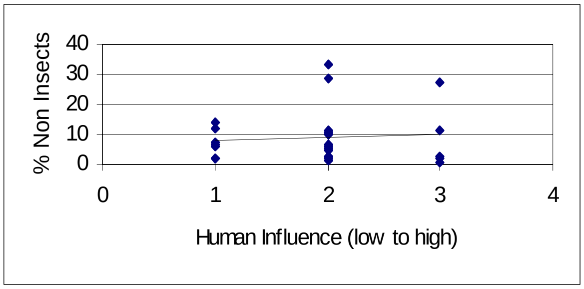
7) Relative Abundance of Shredders



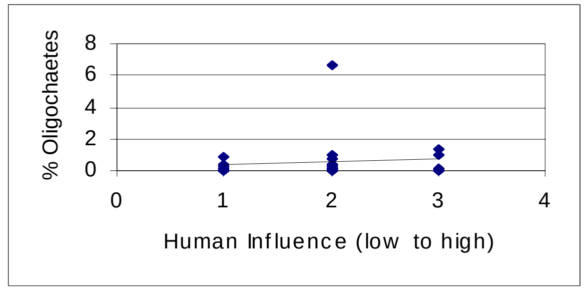
8) Relative Abundance of Dipterans



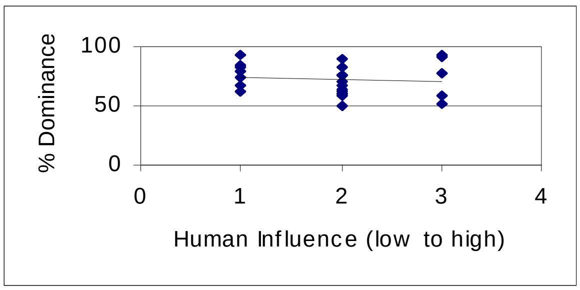
9) Relative Abundance of Non-Insects



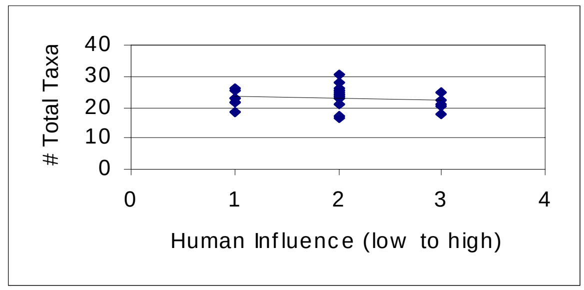
10) Relative Abundance of Oligochaetes



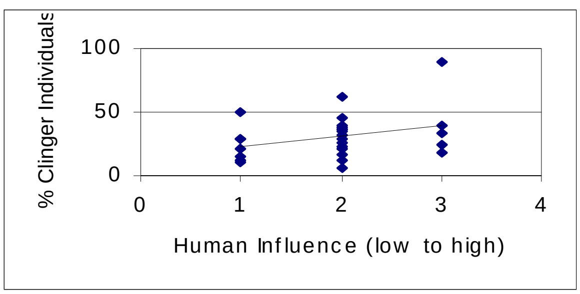
11) Relative Dominance (3 taxa)



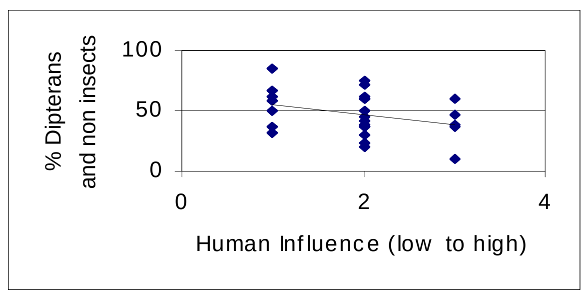
12) Taxa Richness



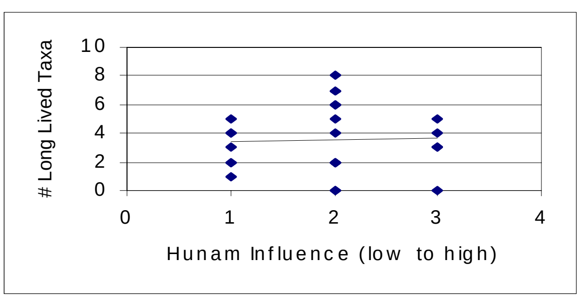
13) Relative Abundance of Clingers



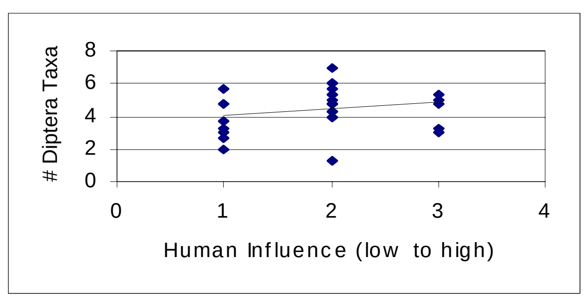
14) Relative Abundance of Dipterans and Non-insects



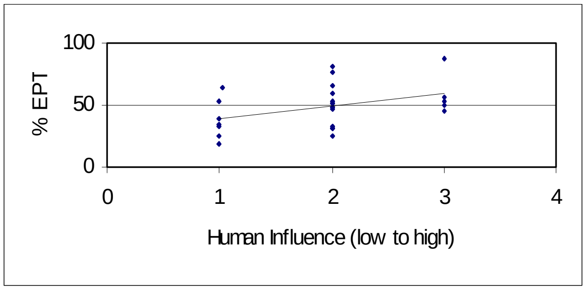
15) Total Long Lived Taxa



16) Total Dipteran Taxa



17) Relative Abundance of Ephemeroptera, Plectoptera and Tricoptera Taxa Combined



18) Relative Abundance of Tolerant Individuals.

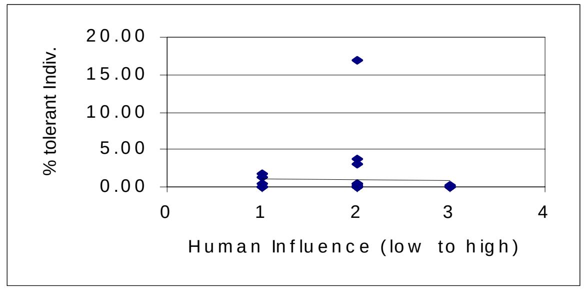


Figure 3: Benthic invertebrate metrics across a gradient of human influence

As presented in Figure 3, four metrics did not respond to increasing human influence as predicted. Of the fourteen metrics tested which did respond as predicted three indicated a statistically valid response to increasing human influence while eleven failed the variance test.

Table: 3 Results of Regression Analysis

Metric	d.f.	f-value	p-value
# Intolerant Taxa	26	9.6276	0.0047
% Dipteran	26	8.6502	0.0069
# of Plecoptera	26	4.0273	0.0547
# of Ephemeroptera	26	0.3763	0.5451
# of Tricoptera	26	3.2909	0.0817
# Clinger Taxa	26	0.7868	0.3835
% Predator	26	0.1942	0.6632
% Shredders	26	0.9568	0.3374
% Non-Insects	26	0.1437	0.7079
% Oligochaetes	26	0.1614	0.6914
Total # Taxa	26	0.3264	0.5711
# Long Lived Taxa	26	0.0174	0.8962
% Tolerant Indiv	26	0.0089	0.9257
% Dominance	26	0.3356	0.5675

Although only three of the metrics showed a statistically significant response to increasing human influence, a total of ten were selected for incorporation into the final genus level 10 Metric B-IBI. The remaining seven were selected based on their ability to “reasonably”, although not statistically, discriminate between low and high influenced sites within the Morice and Lakes TSAs as well as provide adequate representation of the four broad categories identified as key components in a balanced multimetric index (Karr and Chu 1999; Barbour et. al 1999). Karr and Chu 1999 show that the use of statistical relationships alone for determining the effectiveness of a particular metric to distinguish between low influence and high influence is not recommended. Weak statistical correlation can miss important biological patterns when the distribution of data does not lend itself to tests based on standard correlation techniques that detect linear relationships (Karr and Chu 199).

The ranking graphs used to subjectively determine the cutoffs for the delineation of low, medium and high influence are presented in Figure 4.

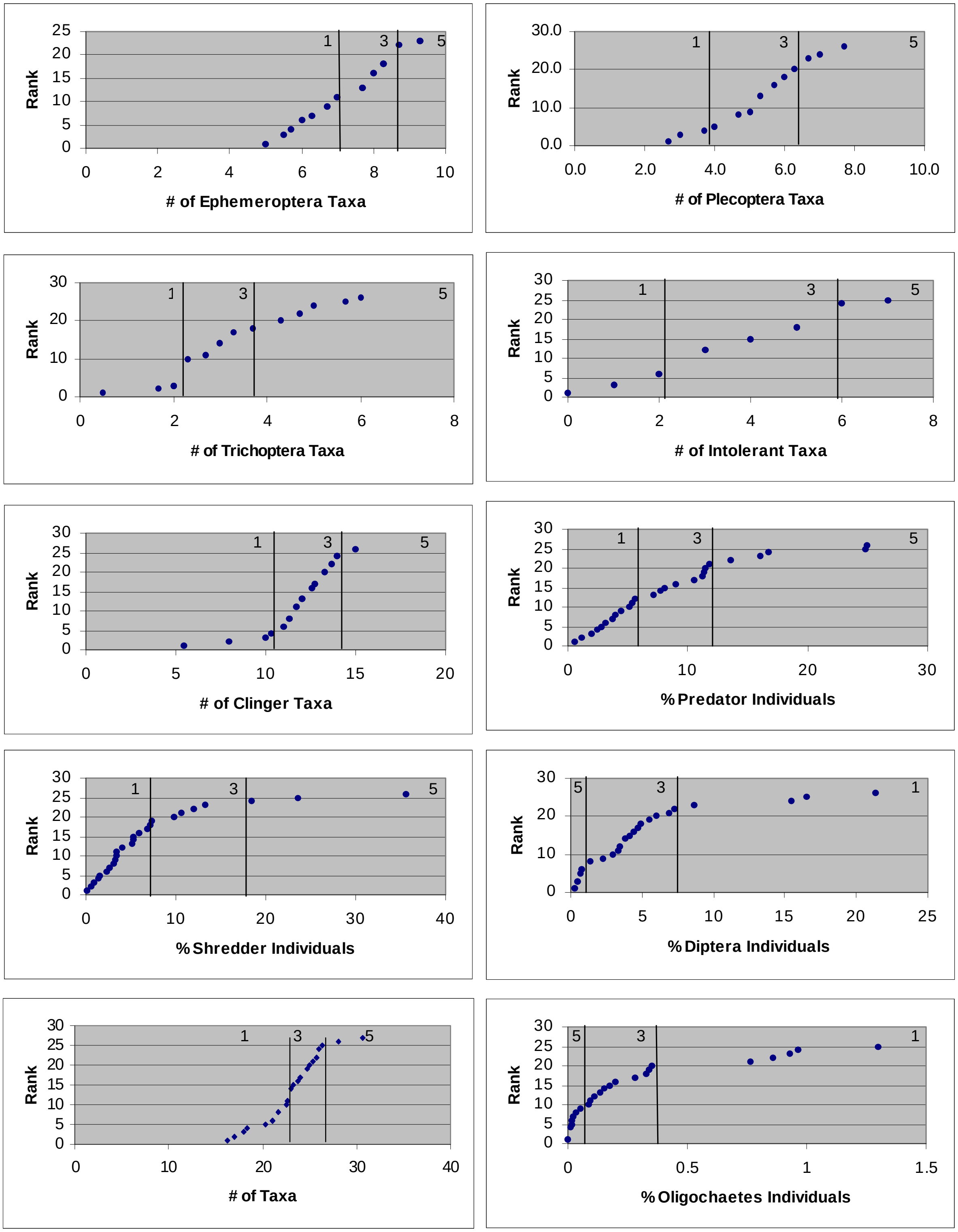


Figure 4: Scoring for each metric based on rank distribution of scores for Morice and Lakes TSA streams selected with a human influence gradient.

The identified cut-off points in Figure 3 were used to calculate a score for each of the core metrics at every sample site. Individual metric scores were then summed up to provide a final index score for each site sampled. There were ten metrics included in the index, each of which had a maximum potential score of 5 and a minimum potential score of 1. The value of 5 was given to results that were indicative of undisturbed sites while the value of 1 indicates a site that has experienced significant human influence. Therefore, the maximum index score for any one site was 50 with a minimum score of 10.

Table 4: Ten metrics and scoring cutoffs points selected for inclusion in the Morice and Lakes B-IBI

	Scoring Criteria		
Metric	**1**	**3**	**5**
Taxa Richness and Composition			
Number of Ephemeroptera taxa	≤7.0	7.1-8.5	>8.6
Number of Plecoptera taxa	<4.0	4.1-6.5	≥6.6
Number of Trichoptera taxa	<2.5	2.6-4.0	>4.1
Number of Taxa	<22.7	22.8-26.3	>26.4
% Diptera individuals	>7.5	1.0-7.4	<1.0
Tolerance			
Number of intolerant taxa	<3.0	3.1-5.0	>5.1
% Oligochaetes	>0.40	0.06-0.39	<0.06
Feeding Ecology			
% of predator individuals	<6.0	6.0-12.0	>12.0
% Shredder individuals	<7.0	7.0-15.0	>15.0
Number of clinger taxa	<10.5	10.5-14.0	>14.0

A final stream condition description was determined for each sample stream by corresponding the final index score calculated for each sample site with the scoring ranges taken from the Salmonweb internet site (Table 5).

Table 5: Genus Level 10 Metric B-IBI scores and associated Stream Condition

Genus Level B-IBI Score	Stream Condition
46-50	Excellent
38-45	Good
28-37	Fair
18-27	Poor
10-17	Very Poor

The final index scores indicated that the majority of the sample sites examined were of fair to poor stream condition. Gerow Creek scored within the range of good stream condition while Lamprey Creek at the recreation site scored within the range of very poor stream condition. Two streams scored exactly on the cut-off points between fair and poor (Hill Tout Cr & Pinkut Cr Upper) while Thompson Creek scored right on the cut-off between poor and very poor.

Table 6: Summary of final index scores and associated stream condition

Site	B-IBI Total	Stream Condition	Human Influence Type	Land-use Degree	Human Influence	ASCI Totals	ASCI Condition
Decker Creek	Unk	Dry	Non Forestry/Forestry	High	3	N/A	N/A
Tatalrose Creek	Unk	Dry	Non Forestry/Forestry	High	3	N/A	N/A
Gerow Cr.	42	Good	Reference	Low	1	208	Optimal
Pierre Cr.	30	Fair	Reference	Low	1	194	Suboptimal
Unnamed Cr.(R2)	32	Fair	Reference	Low	1	242	Optimal
4 Mile Cr.	34	Fair	Reference	Low	1	226	Optimal
Twain Cr.	34	Fair	Forestry	Low	1	177	Suboptimal
Parrot @ Ford	30	Fair	Non Forestry/Forestry	Moderate	2	225	Optimal
John Cr.	24	Poor	Forestry	Moderate	2	212	Optimal
Tachek Cr.	34	Fair	Forestry	Moderate	2	214	Optimal
Unnamed Cr.(4)	32	Fair	Forestry	Moderate	2	220	Optimal
Unnamed Cr.(5)	32	Fair	Forestry	Moderate	2	223	Optimal
Hill Tout Cr.	28	Poor/Fair	Forestry	Moderate	2	229	Optimal
No Mans Cr.	30	Fair	Forestry	Moderate	2	225	Optimal
Endako R. Upper	26	Poor	Non Forestry/Forestry	Moderate	2	195	Suboptimal
Guess Cr.	24	Poor	Forestry	Low	1	220	Optimal
Outlet No Mans Lk	24	Poor	Forestry	Moderate	2	217	Optimal
Parrot Cr. Lower	28	Fair	Non Forestry/Forestry	Moderate	2	176	Suboptimal
Pinkut Cr. Lower	22	Poor	Forestry	Moderate	2	236	Optimal
Tildesley Cr.	24	Poor	Forestry	Low	1	232	Optimal
Pinkut Cr. Upper	28	Poor/Fair	Forestry	Moderate	2	223	Optimal
Tangelchain Cr.	20	Poor	Forestry	Moderate	2	228	Optimal
Andrew's Cr.	26	Poor	Forestry	Moderate	2	227	Optimal
Buck Cr.*	26	Poor	Non Forestry/Forestry	Moderate	2	N/A	N/A
Thompson Cr.	18	Poor/VP	Non Forestry/Forestry	High	3	193	Suboptimal
Owen Cr. Lower	26	Poor	Non Forestry/Forestry	High	3	198	Optimal
Nadina R.	20	Poor	Non Forestry/Forestry	Moderate	2	238	Optimal
Owen Cr. Upper	24	Poor	Non Forestry/Forestry	High	3	225	Optimal
Lamprey Rec Site	14	Very Poor	Forestry	Moderate	2	163	Suboptimal
Vallee Creek	Unk	Dry	Non Forestry/Forestry	High	3	N/A	N/A

* Buck Cr Data obtained from Shauna Bennett, *Expansion and Recalibration of a B-IBI for the Upper Bulkley River, 2001*

DISCUSSION

In 2002 the development of a B-IBI biomonitoring system in the Morice and Lakes TSAs focused on defining biological condition in minimally disturbed areas (i.e. what the natural, uninfluenced condition in the area is), and the identification and defining of metrics that predictably change across a gradient of human influence.

The results of the 2002 sampling season and initial index development indicate that the natural uninfluenced stream condition in the area is not clearly defined. As presented in Rysavy 2000a, final B-IBI scores were plotted against relative human influence in the upstream catchment area (Figure 5).

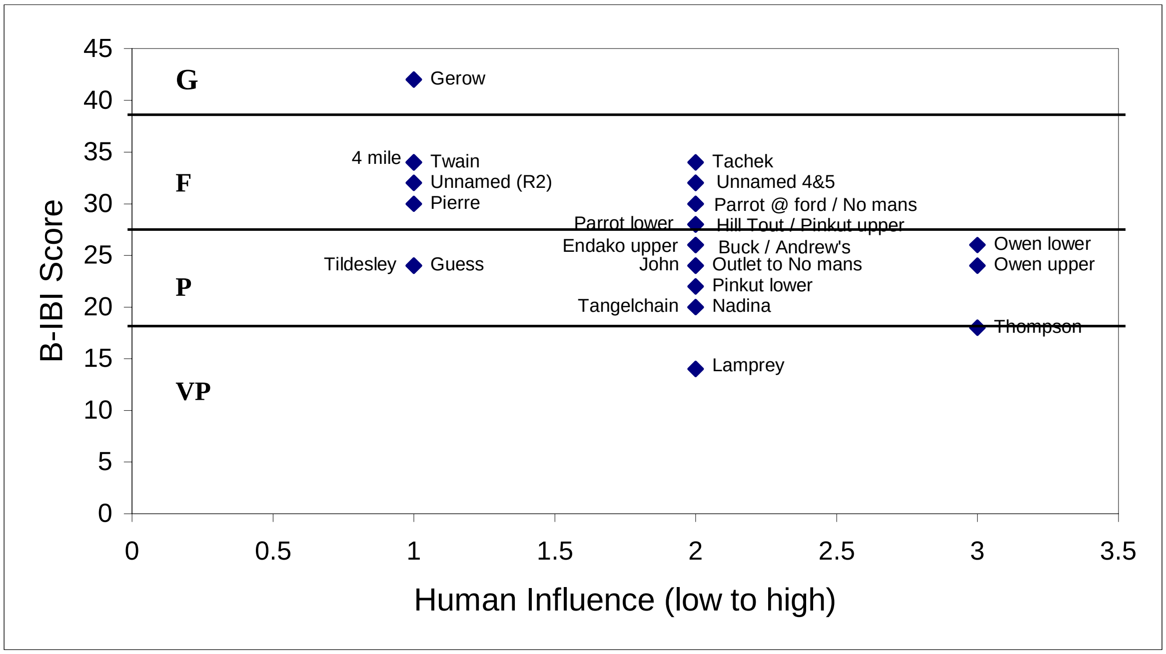


Figure 5: Final B-IBI Scores Plotted Against Degree of Human Influence in the Upstream Catchment Area

As shown in Figure 5 the majority of the sites sampled scored within the range of fair to poor stream condition with no significant differentiation between low influenced sites and moderately influenced sites. These results indicate that either the land use gradient is inadequate and unable to accurately predict the level of human influence or that there is very little variation in benthic community structure and diversity between low influenced and moderately influenced streams in the Morice and Lakes TSAs.

The effectiveness of the land use gradient may be limited by the age of the input data. The GIS data used was approximately 5-8 years old and the accuracy associated with the measurements is unknown. The age of the data may affect watershed classification by inaccurately representing the level of human influence. This could be attributable to the green-up of older harvesting areas and the associated hydrological rebound since 1995 and the absence of recent harvesting impacts accumulated since 1998.

Another concern is that the selection criteria for low influenced sites (ie: little or no forest development within the upper catchment) may have been biased towards sub optimal habitats or stream conditions resulting in lower B-IBI scores. This is because there is often a number of significant ecological factors responsible for the selection or avoidance of a particular watershed by forest companies seeking development opportunities. These ecological factors may include low timber resources, which can reflect poor soil nutrient levels reducing the nutrient input in to streams, geomorphology which may make the watershed inoperable and influence riparian structure and characteristics, and terrain stability which may influence natural sedimentation levels in streams.

Locating road accessible watersheds with suitable stream characteristics and a low level of human influence was difficult. However, seven low influence sites were identified and sampled in 2002. The B-IBI scores associated with six of the sites (excluding Gerow Creek) scored within the range of fair to poor. The similarity between the scores associated with moderate influence sites and low influence sites indicates that the natural stream condition in the area is not clearly defined at this time. These conditions must be accurately defined in order to detect and understand change in biological systems that result from forest management activities. In order to understand change in biotic integrity we need to evaluate the change with respect to the natural condition. Accurate identification of reference conditions will also inform managers of the natural variability and allow for comparisons across watersheds.

The inability to clearly define these conditions may be attributable to the small sample size used; however, this assumes that the natural stream condition significantly varies between low influenced sites and moderately influenced sites in the Morice and Lakes TSAs. In order to capture a greater amount of the natural variability associated with low influenced streams in the area, future sampling should focus on increasing the number of reference sites which will have a greater potential of being uninfluenced. This may require accessing watersheds which do not currently have road access.

The summer of 2002 was one of significantly lower rainfall levels than usual in both the Morice and Lakes TSAs. This resulted in several of the streams selected for sampling being completely de-watered. This sampling limitation was most notable in the streams identified as having the highest degree of human influence (Decker Creek, Tatalrose Creek, Vallee Creek and an unnamed tributary to Nadina River). The absence of significant water flow in these streams during late August may indicate that these streams are being extremely degraded. However, without the ability to sample sites of this nature, the capture of highly impacted conditions is limited.

Of the high influence sites that could be sampled, Thompson Creek and Owen Creek had the highest levels of human influence in the upstream catchment, according to the human influence calculations. Lamprey Creek was classified as moderately influenced and scored significantly lower than both Owen and Thompson Creeks in terms of upstream influence; however, the final B-IBI score for this sample site was the lowest score calculated. This result is possibly attributable to the high level of influence associated with the British Columbia Forest Service Recreation site adjacent to the sample site. This area is heavily used by recreationalists for camping and experiences a significant amount of foot traffic during fishing season.

Three streams were sampled at more than one site including Owen, Pinkut and Parrot creeks in order to validate the index and examine spatial variability. In the case of Pinkut and Parrot creeks the upstream site scored higher than the downstream site reflecting the cumulative effects associated with land use between the two sites . Although the level of land use within the Pinkut watershed was significantly lower at (17) than the Parrot watershed at (28) the Pinkut creek sites showed the greatest variance in IBI scores with the upstream site scoring 28 and the downstream site scoring 22. The difference between the upstream site (30) and the downstream site (28) on Parrot Creek is probably not significant and may be limited by the fact that the upstream site was located 20 m downstream of the ford located at the outlet of Parrot Lake. This location experiences truck traffic at certain times of the year which may be responsible for a lower IBI score at the upstream site effectively reducing the difference between the upstream and downstream scores.

In Owen Creek the upstream and downstream sites scored 26 and 24 respectively. While both sites are influenced by land use the upstream site had a greater degree of influence at the reach scale with the close proximity of the Morice Owen Road. The unexpected higher IBI score associated with the downstream site and the insignificant difference between upstream and downstream scores may also be attributable to fact that one replicate at the downstream site was not used during metric calculations. The sample size of the third replicate was less than 300 individuals. Samples less than 300 have been shown to affect taxa richness and relative abundance measurements (Karr et. al 1987). However, the use of only two replicates may have missed some of the high impacts expected at the downstream site.

CONCLUSION

The goal of this project was to develop and test a biomonitoring system that characterizes benthic invertebrate communities on a human disturbance gradient from highly disturbed to undisturbed within the Morice and Lakes Timber Supply Areas.

Although only three metrics were found to statistically vary across the gradient of human influence, a total of ten were chosen for inclusion in this genus level 10 metric index. The metrics included in the Morice and Lakes B-IBI are: Ephemeroptera Taxa Richness, Plecoptera Taxa Richness, Trichoptera Taxa Richness, Number of Intolerant Taxa, Number of Clinger Taxa, Relative Abundance of Predators, Relative Abundance of Shredders, Relative Abundance of Dipterans, Relative Total Taxa Richness, and Relative Abundance of Oligochaetes.

In general, B-IBI scores for the streams sampled, reasonably reflected the predicted level of human influence; however, there is a significant amount of overlap which indicates that more data is needed to increase the reliability of this tool. The development and calibration of this B-IBI should be an iterative process, with continual re-evaluation of the index as a whole as well as the individual metrics chosen for inclusion. More data is needed to better define the natural or uninfluenced stream conditions within the Morice and Lakes TSAs as well as capturing the greatest range of variability across the land use gradient by sampling the highest influenced sites.

An increased sample size as well as the re-evaluation of existing sample sites will provide a better foundation for the confirmation or rejection of the metric responses to increasing human influence. As well, we need to incorporate more recent land use data as it becomes available in order to more accurately calculate and define the quantitative influence gradient.

In order to aid the practice of sustainable forest management, metrics which respond specifically to forest development disturbances need to be identified. To identify these specific metrics and to increase the reliability of the information provided by the metrics, new sample sites should be included in areas where disturbances associated with forest management dominate, and should include the streams that are expected to be the most heavily impacted. In order to increase the probability of successfully obtaining samples at all sampling sites across the gradient, sampling should occur earlier in August.

The Benthic Index of Biological Integrity has the potential to be an effective biological monitoring tool; however, several improvements and further sampling needs to be conducted to define the natural stream condition in the area, identify the best possible metrics and validate their responses to increasing human influence.

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APPENDIX 1: Field Notes and Site Assessment Forms

Available at:

Gartner Lee Limited
1269 Hwy 16, Telkwa B.C.
ph: (250) 846-9411 fax: (250) 846-9418
email: ccroft@gartnerlee.com

APPENDIX 2: Habitat Assessment Forms

Stream Name:		EMS:
Site Description:		
Date:	Time:	Field Crew:
Comments:		
Air Temp: °C	Water Temp: °C	

Weather Conditions:

Now:
- ☐ storm (heavy rain)
- ☐ rain (steady rain)
- ☐ showers (intermittent)
- ☐ overcast
- ☐ clear/ sunny

Past 24 hours:
- ☐ storm (heavy rain)
- ☐ rain (steady rain)
- ☐ showers (intermittent)
- ☐ overcast
- ☐ clear/ sunny

Has there been a heavy rain in the past 7 days? ☐ Y ☐ N

Sample Site Location Map (Draw a diagram of the site and indicate the areas sampled, and estimate the length of channel assessed)

Record Time of Collection for each Benthic Sample:

Sample 1: Sample 2: Sample 3:

Disturbance Indicators: Check off the following disturbance indicators present at the site

Bed Characteristics
- ☐ Extensive areas of scour
- ☐ Large extensive sediment wedges
- ☐ Extensive riffle zones
- ☐ Extensive areas of (unvegetated) bar
- ☐ Elevated mid-channel bars
- ☐ Limited pool frequency and extent

Channel Pattern
- ☐ Multiple channels (braiding)

Banks
- ☐ Eroding banks
- ☐ Isolated sidechannels or backchannels

Large Woody Debris
- ☐ Most LWD parallel to banks
- ☐ Recently formed LWD jams

Riparian Vegetation

Check off the dominant vegetation type:
- ☐ Unvegetated (much bare mineral soil is visible)
- ☐ Shrub / Herb
- ☐ Coniferous Forest
- ☐ Deciduous Forest
- ☐ Mixed Conifer - Deciduous Forest

Record the dominant species present:

Record the Structural Stage of the dominant vegetation in the Riparian Area:

- ☐ Non-vegetated or initial stage following disturbance, with less than 5% cover
- ☐ shrub / herb stage, less than 10% tree cover
- ☐ pole-sapling stage, with trees overtopping the shrub layer, usually less than 15-20 years old
- ☐ young forest (30- 80 years) - forest canopy is differentiating into distinct layers
- ☐ mature forest - well developed understory

Canopy Closure (proportion of the surface area of the stream covered by the projecting riparian canopy)

☐ 0 - 20% covered ☐ 20 - 40% covered ☐ 40 - 70% covered
☐ 70 - 90% covered ☐ >90% covered

Stream Characterization

- ☐ Glacial
- ☐ Clear
- ☐ Stained
- ☐ Other

Gradient (please estimate % gradient beside box)

- ☐ Steep
- ☐ Moderate
- ☐ Low

Predominant Surrounding Land Use

☐ Forest ☐ Field / Pasture ☐ Agricultural ☐ Residential
☐ Logging ☐ Mining ☐ Commercial / Industrial ☐ Other

Local Watershed Erosion

- ☐ Heavy
- ☐ Moderate
- ☐ None

Local Watershed NPS Pollution

- ☐ Obvious sources Comments:_______________
- ☐ Some potential Sources
- ☐ No evidence

Stream Parameters (Record 3 measurements)

Stream Wetted Width: ____m ____m _____m Stream Bankfull Width: _____m _____m _____m
Stream Wetted Depth: ____m ____m _____m Stream Bankfull Depth: _____m _____m _____m

Primary Habitat Units Present (check any habitats that occupy more than 50% of the wetted width of the main channel)

☐ Pools ☐ Glides ☐ Riffles ☐ Cascades ☐ Other

Sediment / Substrate

Odors

☐ Sewage ☐ Petroleum ☐ Anaerobic ☐ Chemical ☐ None ☐ Other

Oils

☐ Absent ☐ Slight ☐ Moderate ☐ Profuse

Bed Material

Substrate Type	Diameter	% composition in reach (=100%)
Sands, Silts, Clays & fine Organic materials	< 2mm	
Gravels	2 - 64 mm	
Cobbles	64 - 256 mm	
Boulder	> 256 mm	
Bedrock	> 4000 mm	

Cover = __________%

(% cover is the percent of the wetted surface area that is covered by woody debris, boulders, cutbanks, deep pools, overhanging vegetation (within 1 m of water surface) or instream vegetation)

Field Form Developed by: Shauna Bennett, Bio-Logic Consulting

Alaska Stream Condition Index (ASCI) Habitat Assessment Field Data Sheet

Major, E.B. and M.T. Barbour. 1997. *Standard Operating Procedures for the Alaska Stream Condition Index: A Modification of the U.S. EPA Rapid Bioassessment Protocols*. Prepared for Alaska Department of Environmental Conservation, Anchorage, Alaska.

Site Name:______________________________ Date/Time:__________________________________
Sampling Team:__________________________Comments:__________________________________

Habitat Parameter	Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate / Available Cover	Greater than 70% of substrate favorable for epifaunal colonization, mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (ie, logs/snags that are not new fall and not transient	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale)	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1 0**
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides substantial niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1 0**
3. Velocity-Depth Combinations	All four velocity-depth combinations present (slow-deep, slow-shallow, fast-deep, fast-shallow)	Only 3 of the 4 combinations present (if fast-shallow is missing, score lower than if missing other combinations)	Only 2 of the 4 habitat combinations present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity-depth combination (usually slow-deep).
SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1 0**
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% (<20% for low gradient streams) of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% (20-50% for low-gradient) of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% for low-gradient) of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% (80% for low-gradient) of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1 0**
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1 0**

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

APPENDIX 3: Benthic Invertebrate Sample Data

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