Application of the Canadian Aquatic Biomonitoring Network and Reference Condition Approach to Canada's Pacific Wild Salmon Policy

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APPLICATION OF THE CANADIAN AQUATIC BIOMONITORING NETWORK AND REFERENCE CONDITION APPROACH TO CANADA'S PACIFIC WILD SALMON POLICY

by

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TABLE OF CONTENTS

ABSTRACT

Branton, M.A., Manson, M.M., and Galbraith, R.V. 2006. Application of the Canadian Aquatic Biomonitoring Network and reference condition approach to Canada's Pacific Wild Salmon Policy. Can. Manuscr. Rep. Fish. Aquat. Sci. 2770: v + 29p.

The strategy for implementing Fisheries and Oceans Canada's Pacific Wild Salmon Policy (WSP) will involve the selection of indicators to assess the quantity and quality of fish habitat. Environment Canada's Canadian Aquatic Biomonitoring Network (CABIN) is a program that has been established to assess and monitor the biological condition of fresh water systems in Canada. The approach involves the use of benthic invertebrates as a biological indicator, which has been effective in many other monitoring programs. The CABIN program has established a large number of reference sites across DFO's Pacific Region (e.g. the Fraser/Georgia basin, Skeena River, and Yukon River) and is a valuable resource. Access to existing assessments, the standardized protocol, training program, analytical tools, and information delivery system are all consistent with the objectives of the WSP.

A case study involving the use of CABIN to assess fish habitat in Salmon and Bessette Creek in the British Columbia interior showed that the sampling protocol and analytical tools provide clear designations of ecological stress level at the sample sites, though the scale at which they measure perturbations could be too fine for the purposes of the WSP. There is also uncertainty regarding the relevance of the stress designations to fish habitat condition. Also, some risk is associated with relying on a program that is currently transitioning from a research project to an applied biomonitoring program.

Reference Condition Approach based biomonitoring following the CABIN protocol has the potential to serve as a site specific stress indicator in a tiered approach to habitat monitoring under the WSP. Low cost options for leverage between the two programs and possible others would have to be employed, given the funding level of the WSP. At minimum, the development of the CABIN program should be tracked as the WSP monitoring program evolves.

RÉSUMÉ

Branton, M.A., Manson, M.M., and Galbraith, R.V. 2006. Application of the Canadian Aquatic Biomonitoring Network and reference condition approach to Canada's Pacific Wild Salmon Policy. Can. Manuscr. Rep. Fish. Aquat. Sci. 2770: v + 29p.

La stratégie de mise en œuvre de la Politique concernant le saumon sauvage (PSS) du Pacifique de Pêches et Océans Canada prévoit le choix d'indicateurs pour évaluer la quantité d'habitats du poisson disponibles et la qualité de ceux-ci. Le Réseau canadien de biosurveillance aquatique (RCBA) d'Environnement Canada est un outil qui nous permet d'évaluer et de suivre l'état biologique des systèmes d'eau douce au Canada en utilisant les invertébrés benthiques comme indicateurs biologiques. Un grand nombre de sites de référence ont établis par le RCBA dans la Région du Pacifique du MPO (p. ex., le bassin Fraser/Georgia, la rivière Skeena et le fleuve Yukon). Le RCBA s'est aussi révélé efficace dans nombre d'autres programmes de surveillance. L'accès aux évaluations, le protocole normalisé, le programme de formation, les outils d'analyse et le système de prestation de renseignements sont conformes aux objectifs de la PSS.

Dans une étude de cas où l'on s'est servi du RCBA pour évaluer l'habitat du poisson dans les ruisseaux Salmon et Bessette (intérieur de Colombie-Britannique), on a démontré que le protocole d'échantillonnage et les outils d'analyse permettent de désigner clairement le niveau de stress écologique présent aux sites témoins, même si l'échelle à laquelle les perturbations sont mesurées est trop petite pour les besoins du PSS. Il existe toutefois des incertitudes quant à l'applicabilité des désignations du niveau de stress aux conditions régnant dans l'habitat du poisson. Qui plus est, le fait de compter sur un programme en pleine transition entre un projet de recherche et un programme de biosurveillance appliquée comporte certains risques.

La biosurveillance fondée sur des conditions de référence (selon le protocole du RCBA) peut servir d'indicateur du stress à un site donné dans le cadre d'une approche de surveillance multi-niveaux de l'habitat conforme à la PSS. Des options à faible coût nous permettant de tirer le maximum des deux programmes et d'autres programmes éventuels devraient être utilisées étant donné le niveau de financement du PSS. À tout le moins, il faudrait assurer un suivi de l'évolution du programme du RCBA au fur et à mesure que le programme de surveillance de la PSS évolue.

1.0 INTRODUCTION

Canada's Policy for Conservation of Wild Pacific Salmon was implemented in 2005 to "restore and maintain healthy and diverse salmon populations and their habitat for the benefit and enjoyment of the people of Canada in perpetuity" (Fisheries and Oceans Canada 2005). A cornerstone objective of the Wild Salmon Policy (WSP) is to safeguard the genetic diversity of salmon "Conservation Units" (CUs), defined as "group[s] of wild salmon sufficiently isolated from other groups that, if extirpated, it is very unlikely to re-colonize naturally within an acceptable timeframe, such as a human lifetime" (Fisheries and Oceans Canada 2005). In conjunction with this, the policy seeks to maintain salmon habitat and ecosystem integrity, while managing fisheries in a sustainable manner. Six strategies have been applied to fulfill the objectives of the WSP. Strategy 2 of the WSP, the assessment of habitat status, entails the identification of the habitat necessary for conservation of the CUs, and continuing assessment of changes in this habitat. The fulfillment of this strategy requires a systematic approach to habitat assessment that can document the current status of habitat and changes in that status over time relative to benchmarks. Towards this end, Fisheries and Oceans Canada is in the process of identifying indicators and benchmarks of habitat quality and quantity that can be used in their assessment program. These indicators can then be used to assess habitat status within CUs and to monitor habitat status.

Biomonitoring (or bioassessment) methods, which use living organisms to assess the condition of biological systems, have the potential to be useful indicators in the WSP assessment program. These methods may be particularly useful in conjunction with the Reference Condition Approach (RCA) in which indicators from potentially impaired sites are compared to those at a group of regional "reference" sites that have had minimal human impact. Based on this comparison, the status of the potentially impaired site is determined (e.g. unstressed, severely stressed). The Canadian Aquatic Biomonitoring Network (CABIN) is a program that uses the RCA and has been established by Environment Canada to develop a network of reference sites that can be used in assessing and monitoring the biological condition of fresh water systems in Canada (Environment Canada 2006). The online CABIN tools are used to assess aquatic habitat quality compared to reference locations. In British Columbia, the CABIN database contains reference sites for the Fraser River Basin (Reynoldson et al. 1997, Rosenberg et al. 1999), the Georgia Basin (Sylvestre et al. 2005) and the Skeena River watershed. Reference sites are also being established in the Yukon River watershed.

An overview of the use of benthic invertebrates in bioassessment, the RCA, and the analytical tools used in CABIN is provided in Section 2.0. In Section 3 a case study is presented to demonstrate how CABIN is used to evaluate habitat quality. The potential for CABIN to be used as a tool for habitat assessment under the WSP is discussed in Section 4.

2.0 BIOMONITORING

Biomonitoring programs are increasingly relied upon by those charged with managing freshwater systems to assess current habitat status, changes due to perturbations, and trends in recovery. However, the complexity of ecological systems and their response to potential stressors present a multitude of possibilities for program design. In response, researchers have evaluated the best way to design and implement biomonitoring programs. Mazor et al. (2006) briefly review some of the key issues and relevant literature including which biological assemblages to monitor (e.g., Rosenberg and Resh 1993, Barbour et al. 1999, Sonneman et al 2001), how to account for natural variability in reference sites (e.g., Reynoldson et al 1997, Hawkins et al 2000a, Norris and Hawkins 2000), and how to make comparisons between disturbed and reference sites (e.g., Karr 1991, Reynoldson et al. 1997, Hawkins et al. 2000b). Similarly, there are numerous possibilities regarding which techniques should be used to analyze benthic data. These analyses vary in terms of their accuracy, precision and sensitivity, as well as their rationale and implementation (e.g., Bonada et al. 2006, Cao and Hawkins 2005, Fore et al. 1996, Mazor et al. 2006). Benthic biomonitoring is used to assess aquatic habitat quality in a number of national assessment programs, including the United States (Barbour et al. 1999), the United Kingdom (Wright et al. 2000) and Australia (Norris and Hawkins 2000).

The suite of indicators for a biomonitoring program may include community structure and diversity, or individual species measures such as abundance, density, condition or growth. The advantage of using community-based measures is that they integrate the different sensitivities, niches and life cycles of the species that comprise that community. A single species biomonitoring program will often focus on species of specific concern, or those that are uniquely sensitive to a potential perturbation at the site. Single species may be monitored either alone or together with other community indices. Although different biotic groups, including periphyton and fish (Barbour 1999, Karr 1991, Pearson et al. 2005) have been used in biomonitoring programs for freshwater systems, one of the most useful and widely used groups is benthic (bottom-dwelling) invertebrates. Benthic invertebrates are relatively sessile and therefore reflect local site conditions. They respond rapidly to changes in their environment, including water quality and physical habitat, and can integrate exposure to stressors over time and through multiple life stages, including sensitive embryo-larval stages. In addition, it is possible to evaluate community assemblages, which can include organisms with a range of sensitivities to different impacts. Standardized protocols are also available for sampling and analysis that are straightforward enough to be adopted for routine monitoring by stream stewardship groups and sophisticated enough to be used in advanced site assessments. Periphyton has similar characteristics to benthic invertebrates and is used increasingly in biomonitoring programs (Barbour et al. 1999, Pearson et al. 2005).

Fish have also been widely used in biomonitoring programs (e.g. Index of Biotic Integrity – IBI) (Karr 1991). However, they are not suited for use in areas with low species diversity, such as British Columbia and the Territories (Pearson et al. 2004). The use of anadromous salmon in biomonitoring programs which have the assessment of habitat in a localized area as their objective is, at best, challenging. These fish are mobile throughout their lifecycle, a portion of which is spent in both freshwater and marine systems. Indicators that have been used to assess the quality of freshwater habitat for salmon are the number of fry per unit area of habitat, the number of outmigrating fry and smolts, and the number of returning spawners (e.g., Bustard and Narver 1975, Morley et al. 2005). While these measures may provide some indication of habitat quality, they are extremely difficult to interpret. Ten or more years of monitoring records may be needed to detect trends (Bisson et al. 1992, Reeves et al. 1997). A number of factors can affect fish densities, including marine conditions, fishing pressure, lack of habitat connectivity or other production bottlenecks that may reduce spawner returns (Pearson et al. 2005). Moreover, a simple measure of fry per unit area to assess habitat quality may not be accurate if no other suitable habitat is available, resulting in low quality habitat with relatively high fry densities. Alternatively, a high quality habitat may not the have expected fry densities if, for instance, spawner returns were low or if there is abundant suitable habitat available nearby lowering the densities measured per unit area.

2.1 REFERENCE CONDITION APPROACH

The RCA is an approach to biomonitoring that has been developed to provide a powerful alternative to traditional field study designs (Bailey et al. 2004, Reynoldson et al. 1997). For the RCA, a three step process to assessment is typically employed:

1. A database of "minimally disturbed" regional reference sites is established, representing a range of physical, chemical, and biological characteristics (Reynoldson et al. 1997). These sites are classified into homogeneous groups which define the "reference condition" in terms of biological assemblage across the range of natural variability in the study area. The reference sites do not necessarily represent pristine conditions; instead the RCA assumes that the group of reference sites represents a range of normal or unimpaired conditions. Together they provide an "envelope" of reference conditions which incorporate the natural variability that might be expected between sites.
2. A model is developed to predict the biological assemblage from a set of environmental variables that were measured at the reference sites. These variables are chosen to be independent of anthropogenic influence, to the best extent possible.
3. Test sites are assigned to a reference group (or a probability of belonging to a reference group) based on the predictive model. Deviation of the biological assemblage at the test sites from their predicted reference group is assessed. The degree to which the invertebrate assemblage is similar (or dissimilar) to the predicted assemblage determines its classification on a gradient of perturbation (e.g., unstressed to severely stressed) relative to the reference sites.

A number of analytical techniques, including multivariate, multimetric or regression analyses can be used at each step of the RCA (Bailey et al. 2004), but the general approach is consistent with the above steps. The different analytical techniques for the RCA will not be described here, but a detailed description of one analytical example is provided for CABIN in section 2.2.

In contrast, the traditional approach to biomonitoring studies (e.g. Before After Control Impact (BACI) design) has been to compare the indicator at various treatment sites to baseline values at the site and to only one or a few sites representing “reference” conditions (i.e. control sites). A difference in the indicator between baseline, control and treatment sites is used to infer some degree of ecological change. A well designed RCA study circumvents the requirement for baseline data, as the treatment site is compared to the natural variability which occurs across the study area at a range of temporal scales. Further, the selection of control sites in a BACI design introduces the possibility that the detected differences do not reflect the impact of interest, as no control site is ever perfectly matched to a study site, particularly where few control sites are available for comparison. The RCA offers an important advantage in this regard, as it does not require control sites specific to each treatment site, alleviating the difficulty associated with the identification and selection of control sites and the large investment in resources required to sample a unique set of control sites for each study.

2.2 CANADIAN AQUATIC BIOMONITORING NETWORK (CABIN)

CABIN has been established by Environment Canada to develop a network of reference sites that can be used in RCA based biomonitoring studies. These sites represent a wide range of freshwater habitat and benthic invertebrate assemblages in different regions of Canada. To date, this has been developed for flowing waters only, but efforts are underway to expand this to include wetlands. In British Columbia, the CABIN database contains reference sites for the Fraser River Basin (Reynoldson et al. 1997, Rosenburg et al. 1999), the Georgia Basin (Sylvestre et al. 2005), and the Skeena River drainage. Considerable effort has also been invested in the development of a reference database for the Yukon River. It has also more recently been expanded to the Mackenzie River and the southern Okanagan (S. Sylvestre, Environment Canada, pers. comm.). In total, there are currently 274 sites in the Fraser/Georgia Basin reference database, and more than 100 in each of the Skeena and Yukon databases (see Figure 1 for all B.C. reference sites).

Making CABIN widely accessible to all potential users, including governments, academic researchers and community groups is one of Environment Canada’s goals. To this end they offer annual training to participants in stream sampling and appropriate field protocols, training and certification in the identification of stream organisms, as well as quality assurance and control of the data and taxonomic identifications (Environment Canada 2006). CABIN provides web accessible tools for data storage, management and analysis. The spatially referenced site reports are served to the internet via an Open GIS Consortium (OGC) compatible web map server (Figure 1). This service can be directly accessed by other OGC compatible internet applications.

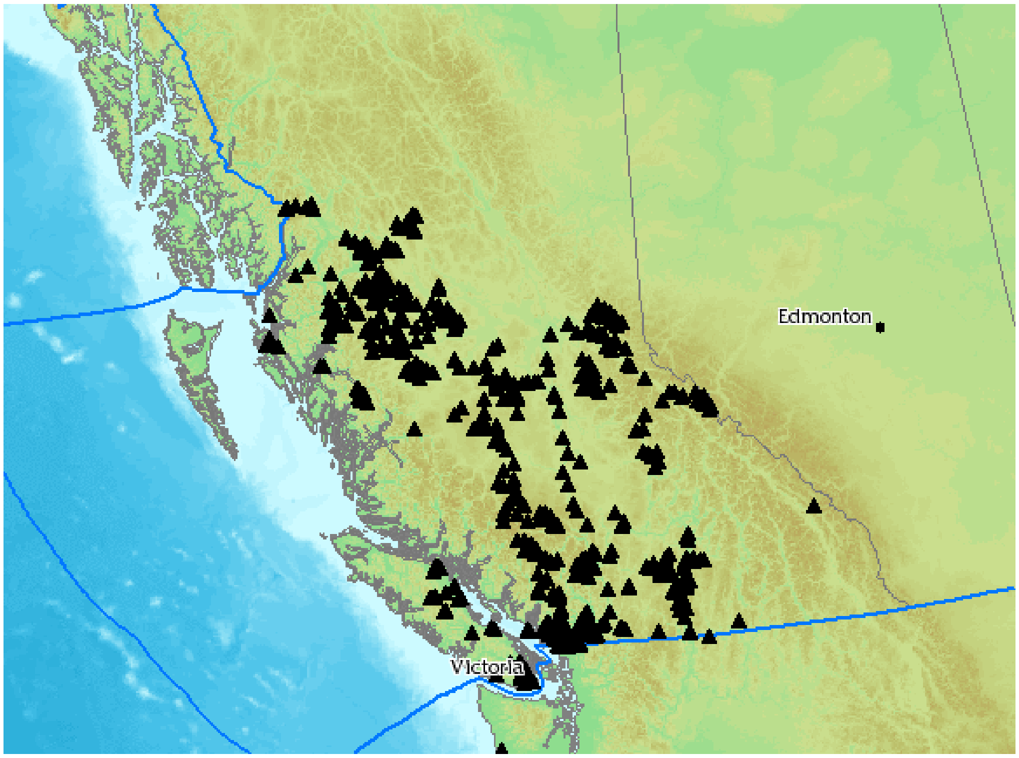


Figure 1. Reference sites sampled in the Fraser, Georgia and Skeena basins of British Columbia. Source: **http://excise.pyr.ec.gc.ca/chameleon/waterquality/wq_enhanced.phtml**

2.2.1 Model Development and Interpretation

The general steps to the RCA described in Section 2.1 were applied in the development of the CABIN Fraser/Georgia Basin model. Details for each step (adapted from Sylvestre et al. 2005) are presented in the following subsections to provide a more complete example of the process.

Reference Group Development: Family level invertebrate data from reference sites were classified using cluster analysis and plotted in ordination space using non-metric multidimensional scaling (Clarke and Warwick 1994), providing a description of the variability between sites. Reference sites were assigned to the reference group they were most similar to based on their classification in the cluster analysis. In other words, sites were grouped together based solely on the similarity of their benthic invertebrate communities.

Fraser/Georgia Basin Predictive Model: Principal axis correlation was then used to determine which environmental variables were significantly correlated with each group of reference sites. The best combination of predictor variables were selected by an iterative process of discriminant function analysis (DFA) and are now used as the default in the CABIN predictive model for the Fraser River (Sylvestre et al. 2005). All 27 environmental variables that were used in this analysis are listed in Table 1 and the predictor variables for the Fraser/Georgia Basin model are italicized.

Table 1. Environmental variables used in the Principal Axis Correlation with biological data to determine the best combination of predictor variables for the Fraser/Georgia Basin Model

Geographic Variables	Channel Characteristics	Riparian Vegetation	Substrate Characteristics	Water Chemistry
Stream Order	Bankfull width (m)	*Coniferous trees %*	Macrophyte coverage	Alkalinity (mg/L)
Ecoregion	*Channel (wetted) width (m)*	Deciduous trees %	*Embeddedness*	Conductivity (uS/cm)
Latitude	*Slope*	Grasses %	*Dominant substrate*	*pH*
Longitude	*Avg Channel Depth (m)*	Shrubs %	Surrounding material	
Altitude (fasl)	Max channel depth (m)		Gravel %	
	Avg velocity (m/s)		Sand %	
	Max Velocity (m/s)		Silt %	
			Clay %	

Test Site Assessment: CABIN uses a multivariate approach to test site assessment dubbed BEAST (i.e. the BEnthic Assessment of SedimenT) (Reynoldson et al. 1995), in which relative abundance counts of invertebrates identified to family level observed at test sites are compared with those of the most appropriate group of RCA reference sites. Using the default predictor environmental variables, or a subset of those variables if some predictor variables have been altered due to an anthropogenic disturbance, a test site is assigned a probability of belonging to a group of reference sites. When the probability of group membership is moderate (e.g., 35% to Group 3 and 39% to Group 5), it is recommended that the investigator reviews the environmental variables associated with the test site and most probable reference groups, to ensure the best match between test and reference has been achieved. Sylvestre et al. (2005) provide a detailed description of the habitat features of all of the reference sites.

There is potential for the classification of sites to the wrong reference group (misclassification error). If sites are misclassified and they are compared with the wrong reference group, the site stress classification may be incorrect. This may be exacerbated by the fact that some of the environmental variables used to assign sites to reference groups may in fact be influenced by human impacts, for instance changes in riparian vegetation and substrate. This illustrates why it is important to use CABIN as a tool that facilitates the interpretation of site data and not simply take the site classification without further evaluation of other indicators.

Following reference group classification, the expected invertebrate fauna is then predicted based on reference group membership. The invertebrate data from the test site and reference sites are then merged and plotted in an ordination plot using non-metric hybrid multi-dimensional scaling. The ordination plot provides a visual display of the expected and observed invertebrate communities and their abundance and uses the difference between the two to determine the degree of stress. Four categories of stress (e.g. unstressed, potentially stressed, stressed or severely stressed) are delineated based on the 90%, 99% and 99.9% confidence ellipses around the reference sites based on the similarity of the test site to the reference sites (e.g., see Figure 2). This ordination is done on three ordination axes, representing a three-dimensional space, each of which may indicate a different distance to the reference community. The overall assessment is based on the greatest difference between the test and reference sites.

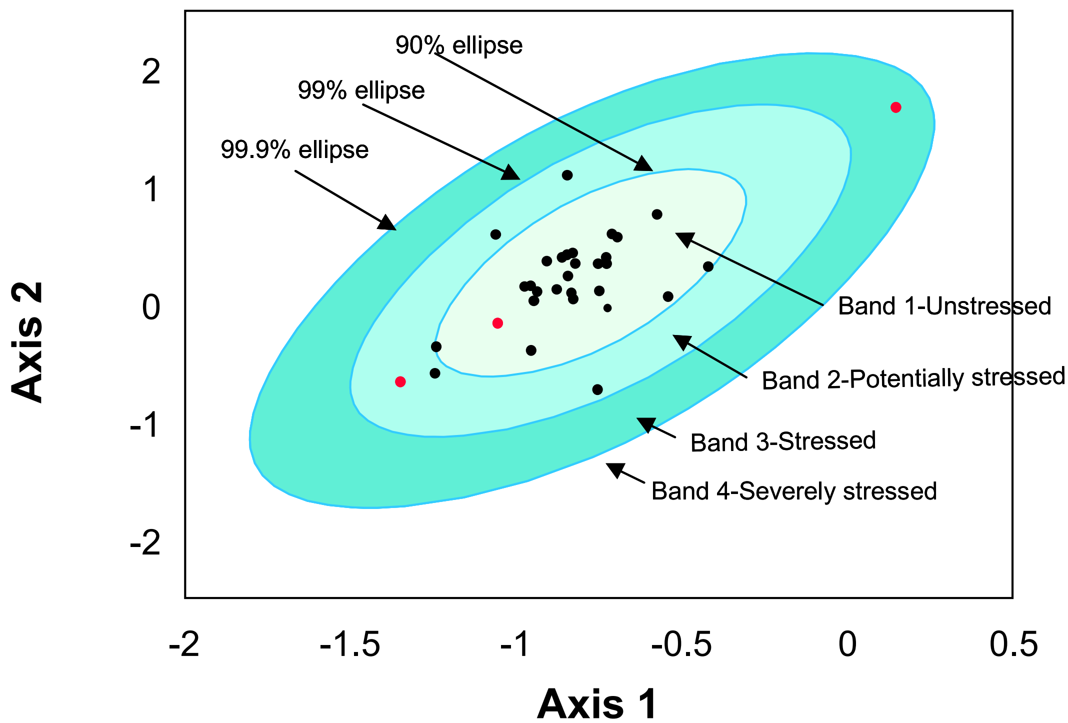


Figure 2. Confidence ellipses around reference sites (reproduced from Environment Canada (2006)).

In addition to the BEAST assessment, another multivariate approach to test site assessment dubbed RIVPACS (i.e. the River Invertebrate Prediction and Classification System) (Wright 1995), is also included in CABIN. The RIVPACS approach is widely used in the United Kingdom (Wright et al. 2000) and Australia (AusRivAS, Parsons and Norris 1996). With RIVPACS the probability of group membership for all reference groups (not just the most probable reference group as in BEAST) and the frequency of taxa occurrence in each reference group is used to predict the taxa that should be observed at each test site. The probability of occurrence is summed for all reference groups resulting in a summed probability of a taxon being present at the test site (e.g., see Table 2). The sum of the probability of occurrence for each taxa is then used to calculate the expected taxa richness for that test site. An observed to expected ratio (O:E) ratio is calculated by summing the total number of observed taxa and dividing that by the expected number of taxa. This ratio is calculated given a 50% or 70% probability of a taxon occurring. A low O:E score indicates that there were fewer taxa observed than would have been expected based on the reference groups indicating the presence of a stressor (or stressors) at the site. A high O:E score (e.g., >1.3) may indicate enrichment. In contrast to the BEAST approach, these ratios rely simply on presence and absence data and can be used to detect changes in the number of taxa present but not to detect changes in the relative abundance of the taxa present (Bonada et al. 2006, Mazor et al. 2006, Reynoldson et al. 1997). The advantage of this approach is that the probability of occurrence is based on all reference sites and not just the most probable reference site, providing a valuable check on the results of the BEAST analysis, particularly when the probability of group membership is moderate.

Table 2. Calculation of the probability of *Baetidae* being present at test site FRA12. The probability of group membership for FRA12 is derived from discriminant function analysis and the frequency of *Baetidae* occurrence in each group is derived from the reference group.

Test Site FRA12	Group 1	Group 2	Group 3	Group 4	Group 5	Summed probability of a taxon being present at test site
Probability of group membership	0.0018	0.9396	0.0003	0.0580	0.0001	
Frequency of occurrence in reference group (%)	94.51	75	88.75	63.16	92.65	
Combined probability (%)	0.17	70.47	0.027	3.66	0.0096	74.34

Table from Sylvestre et al. 2005

CABIN also calculates the individual bioassessment metrics (Plafkin 1989) listed in Table 3 to provide insight into the BEAST results. This set of metrics has been chosen to capture relevant ecological measures, including diversity, evenness and pollution tolerance. In some bioassessment programs, these metrics are combined into indices to assess habitat quality (e.g., Barbour et al. 1999), but they are evaluated separately in CABIN to provide insight into some of the potential mechanisms behind the RCA site stress designation. For instance, a low EPT metric could indicate a toxic stress, or enrichment could be indicated by a high % Dominance or % Chironomidae (Sylvestre et al. 2005).

Table 3. Individual bioassessment metrics and the rationale for their use in bioassessment studies.

Metric	Rationale	Reference
Abundance	Some environmental stresses may cause abundance to be reduced.	Resh and Jackson 1993
Total Richness	Reflects the health of a community by the variety of taxa present.	Plafkin et al. 1989
EPT richness (Ephemeroptera Plecoptera Trichoptera)	In general, the taxa from the orders Ephemeroptera, Plecoptera, and Trichoptera are pollution sensitive. Each one of these orders can be represented in their own richness metric as each has specific tolerances to oxygen, temperature and habitat complexity.	Lenat 1988, GVRD 2004
% Dominance (top 3 taxa)	Indicates balance in the community where the total of the 3 most abundance taxa are expressed in terms of total community contribution. A community dominated by relatively few taxa would indicate environmental stress.	Plafkin et al. 1989
% Chironomidae	The composition of Chironomidae tends to increase when disturbance increases as many genera are highly tolerant and opportunistic relative to the more sensitive insect groups.	Plafkin et al. 1989
Simpson's Diversity	Accounts for both abundance and richness. In some cases, a low diversity may be indicative of poor environmental quality.	Begon et al. 1990
Simpson's Evenness	Represents how evenly the taxa are distributed in the community where D_{max}=S, the maximum number that Simpson's diversity could be. An inequitable community (unbalanced) may be indicative of poor environmental quality.	Begon et al. 1990
Bray-Curtis dissimilarity measure.	A community with exactly the same structure as the median community will have a Bray-Curtis distance measure of 0 while a value of 1 indicates a totally different community.	Belbin 1993

Table adapted from Sylvestre et al. 2005.

2.2.2 Standard Protocols

CABIN's field and laboratory protocols, stream sampling field sheets and laboratory bench sheets are provided online at http://cabin.cciw.ca/Main/cabin_online_resources.asp. These protocols provide a detailed, step by step description of all methods and materials to be used in field sampling. As long as participants in CABIN follow these protocols, all methods and data collected are standardized, providing some level of quality control, and facilitating comparison with the reference database. While not the focus of the protocols, a brief description of study design is also provided.

Field Data: Following the CABIN protocol sampling is conducted once a year in the autumn. The following data are collected for each sampling location:

- General information: ecoregion, latitude, longitude, GPS coordinates
- Reach/Site characteristics: stream order, instream habitat types present, canopy coverage, macrophyte coverage, riparian vegetation present
- Photographs: upstream, downstream, across the stream, substrate
- Benthic invertebrate samples collected using a kick net with 400 um mesh; timed kicknet samples are collected in transects across the stream in an upstream direction thereby integrating the multiple habitats present
- Substrate composition: particle size and embeddedness
- Channel measurements: slope, bankfull and wetted width, water velocity
- Water chemistry: temperature and dissolved oxygen

Taxonomic Identification: Identifications are made to family or the lowest practical level which will vary with the expertise of the taxonomist (amateur or professional). Samples are stored in preservative until taxonomic identification and specific protocols are provided for sub-sampling and quality assurance (i.e., sampling efficiency and taxonomic verification).

Data Management: Environment Canada has established a web accessible data management system for CABIN projects. This is a geographically referenced data entry system. Data entry is facilitated with a series of menus and forms, with a master list of all taxon names which accelerates data entry and eliminates spelling errors and is current with taxonomic changes. All data are input to this database. Taxonomic data is input at the lowest taxonomic level identified for that sample and a taxon coding system allows all data to be generated at a number of different taxonomic levels (Rosenberg et al. 1999).

Data Interpretation: The primary way that data is interpreted for CABIN is using the multivariate technique BEAST to compare test sites with reference sites as described in Section 2.2.1. The RIVPACS and bioassessment metric tools are also calculated to aid in the interpretation of the BEAST analysis.

2.3 POTENTIAL USE OF RCA FOR FISH

Another potential application of the RCA approach would be to develop a program for fish that is analogous to that which has been developed for invertebrates. It could be used to predict habitat quality based on fish assemblages, for fish alone or for fish in combination with benthic invertebrates. An RCA model for fish and benthic invertebrates is currently being developed in the Yukon however results from this study have not yet been released (S. Sylvestre, Environment Canada, pers. comm.). A similar approach has been recommended for use by DFO in Yukon Placer Mining monitoring (Reynoldson et al. 2006). Using fish alone for the RCA approach would likely not be successful in British Columbia because there are few fish species present and it would likely be challenging to establish reference groups based on fish alone. A challenge of using fish either alone or with invertebrates is that it may be difficult to compare non-resident (i.e., salmon) fish communities in test sites with reference sites because abundance may vary substantially from year to year for reasons unrelated to site habitat. Developing a reference database which includes fish would also be resource intensive. It would not be possible to simply use the benthic invertebrate database as biota and habitat sampling needs to occur together to accurately use them in predictor models.

3.0 CASE STUDY - USING CABIN TO ASSESS THE HABITAT STATUS OF BESSETTE CREEK AND THE SALMON RIVER

Standard CABIN protocols were used to assess the habitat quality of two streams in the Southern Interior of British Columbia relative to reference conditions (Reynoldson et al. 2001, Sylvestre et al. 2005). Benthic invertebrate samples used in this analysis were collected in conjunction with an effectiveness monitoring study in the Salmon River and Bessette Creek where stream restoration activities have been carried out for more than 20 years (Cooperman M.E., UBC and Bennett, S.E., Fisheries and Oceans Canada, unpublished data). As no pre-project data were collected for the restoration sites, stress designations for individual study reaches were compared to determine if stream reaches that had undergone streambank stabilization were less stressed relative to reference conditions than those that had not been stabilized. The results of these analyses are presented below to demonstrate the application of CABIN and the RCA to Fisheries and Oceans Canada's fish habitat monitoring efforts.

3.1 DESCRIPTION OF THE STUDY AREAS

The Salmon River watershed encompasses an estimated drainage area of 1,510 km^2 and extends approximately 110 km from Douglas Lake Southwest of Westwold to Salmon Arm where it enters Shuswap Lake. Miles (1995) reported an estimated 40% removal of forest cover in the watershed since 1901. These forest practices, combined with agricultural land use, have led to loss of riparian habitat, bank erosion and loss of fish habitat, low flows, poor water quality and high water temperatures. A fire that impacted the lower Salmon River valley in 1998 created further disturbance. An estimated 19.9 km of the river's length is suffering from active bank erosion (Miles 1995). Restoration efforts for the Salmon River, ongoing since about 1990, have focused on the section downstream of Falkland to its confluence with Shuswap Lake. Restoration activities have included bank stabilization projects, livestock exclusion fencing and riparian plantings to improve water quality and mainstem fish habitat in the Salmon River.

Bessette Creek forms in Lumby at the confluence of Duteau and Harris Creeks. From Lumby, Bessette Creek flows approximately 38 km north east into the Middle Shuswap

River. Agriculture, forestry, urban development and other activities impact Bessette Creek and its tributaries. Riparian corridor fencing projects were first initiated in 1989, and since that time fencing has been constructed throughout much of the Lumby area along with bank stabilization, tree revetments, riparian planting, development of off-channel habitats and other habitat enhancement projects to improve water quality and mainstem fish habitat (S. Bennett, Fisheries and Oceans Canada, pers. comm.).

3.2 METHODS

In the summer of 2005, eight sites in Bessette Creek and 19 in the Salmon River were sampled. Of these, 16 of the sites had streambank stabilization projects and were considered as Treatments in the effectiveness component of this study. The remaining 11 had eroding banks and served as the Controls. Whenever possible, Control reaches were located just upstream of Treated reaches to achieve a pseudo-paired design. In the Salmon River, however, there were long stretches of river where most of the eroding banks have been treated or the banks upstream of the stabilization project were not degraded. In those instances Control banks were selected from elsewhere in the river to best represent the assumed pre-treatment condition of the Treated banks.

Figure 3. Treated Reach on Bessette Creek (BE-Mar-T1).

CABIN field protocols described in Section 2.2.2 were followed to document habitat conditions and to collect benthic invertebrate samples. Additional measurements taken at each site included riparian vegetation (percent coverage of bare ground, shrubs or trees and number of stems at breast height), streambed and bank profiles, in-stream habitat units and upstream habitat. In addition surber samples of benthic invertebrates were taken at the same time as the CABIN benthic kick sampling. The point of maximum inflection of the riverbend was the mid-point of each study site. Measurements were taken along three transects, one at the mid-point and one at the either end of the bend minus 10% of the total length of the bank (e.g., if the bank was 100m long transects would be at 10m, 50m and 90m). At Treated reaches, the physical state of the stabilization project was also noted although there was no quantitative assessment of the state of these projects. A detailed description of the methods and results for the non-CABIN portion of the study are available from Cooperman M.E., UBC and Bennett, S.E., Fisheries and Oceans Canada (unpublished data).

Current habitat status and baseline conditions for long term monitoring were determined using CABIN tools (Environment Canada 2006). CABIN was used to perform a multivariate analysis to classify test sites along a stress gradient from unstressed to severely stressed using the BEAST assessment approach. The RIVPACS O:E ratio and individual metrics listed in Table 2 were also calculated to provide further insight into the BEAST stress classification for each site tested. The non-parametric Wilcoxon paired two-sample test for rank comparisons was used to compare stress designations between treatments (Treatment of Control) or streams (SAS 9.1). Results were considered significant if they had p-values of ≤ 0.05. In addition, Control and Treated reaches were compared on the basis of the individual metrics from Table 2.

3.3 RESULTS

Individual reports which summarize the findings for each of the 27 test sites were generated using CABIN tools. An example of the report for one study site (BE-Hem-T2) is provided in Figure 4 and a summary table of the results for all sites is provided in Table 4. Each component of the results reports is briefly described here:

- Site metadata summarize basic site data (i.e., sample date, latitude, longitude, stream name and order).
- The BEAST prediction results report the probability of membership in each reference group and indicate which reference group the test site was assigned to, in this case reference group number 5 (56.8% probability).
- Habitat attributes for the test site and the reference group (mean value) are provided. This can be used to identify differences between the test site and the assigned reference group and may be used to refine the reference group assignment when there is a similar probability of belonging to two or more reference groups. If this occurs it is possible to run ordinations comparing the test site to a different reference group.
- The RIVPACS analysis indicates the probability of occurrence for each taxa from the reference groups and reports the observed abundance of that taxa.
- Site assessment graphs indicating where the test site falls relative to the cloud of reference sites are provided for up to three vector comparisons. The site is assigned a stress classification based on the greatest difference between the test site and reference sites. For BE-Hem-T2, each of the three site assessments

resulted in a different stress level, from unstressed to stressed, resulting in a final site classification of stressed.
- Finally, individual metrics are reported that can provide further insight into the reasons for the stress assessment.

For site BE-Hem-T2 the RIVPACS indicates that all taxa expected to be at the test site were observed which does not corroborate the severe stress rating. However some of the individual site metrics indicate there were substantial differences compared to the reference group (e.g., fewer EPT individuals and lower abundance) thus providing evidence to support the severe stress rating.

Site Assessment Report

Site Metadata

Site	BE-Hem-T2
Sample Date	Aug 29 2005
Latitude	N 50° 16' 21.16"
Longitude	W 118° 57' 8.32"
Feature Name	Bessette Creek
Stream Order	3

BEAST Prediction Results

Predictor Variables	Channel Depth (Avg),Channel Width,contrees,Dominant Substrate,ecoregion,Embeddedness,latitude,pH,Slope,stream order,Velocity (Max)
Predicted Group Number	5

Group	1	2	3	4	5
Probability	2.2%	0.0%	38.6%	2.4%	56.8%

Habitat Attributes

Variable	Site	Reference Mean
2nd Dominant Substrate (Category(0-9))	2	6
Bnkfl width (m)	16.7	42.8
Canopy (%)	1.00	0.71
Channel Depth (Avg) (cm)	43.1	26.6
Channel Depth (Max) (cm)	115.0	38.1
Channel Width (m)	13.3	19.7
Conductivity (uS/cm)	206.0000000	96.3624087
Contrees (None)	0	1
Dectrees (None)	0	1
DO (mg/L)	10.6000000	11.3560806
Dominant Substrate (Category(0-9))	4	6
Embeddedness (Category(1-5))	5	4
Grasses (None)	1	0
Macrophyte (None)	0	0
pH (pH)	14.6	7.5
Pool (%)	0	0
Rapid (%)	0	0
Riffle (%)	0	0
Run (%)	0	0
Shrubs (None)	1	1
Slope (m/m)	0.000	0.019
Surrounding Material (Category(0-9))	2	3
Velocity (Avg) (m/s)	0.00	0.40
Velocity (Max) (m/s)	0.00	0.58

Figure 4a. Site Metadata, BEAST prediction results and habitat attributes from the CABIN assessment report for study site BE-Hem-T2.

RIVPACS Analysis

Taxa	Probability Of Occurrence	Abundance
Baetidae	0.9	36
Capniidae	0.65	36
Ceratopogonidae	0.2	12
Chironomidae	0.99	1248
Chloroperlidae	0.75	12
Elmidae	0.43	60
Ephemerellidae	0.86	54
Haliplidae	0.01	18
Leptophlebiidae	0.52	30
Lumbriculidae	0.08	102
Naididae	0.34	174
Perlodidae	0.61	6
Tabanidae	0.01	6
Tipulidae	0.54	30

All species predicted to occur did occur.

Site Assessment Graphs

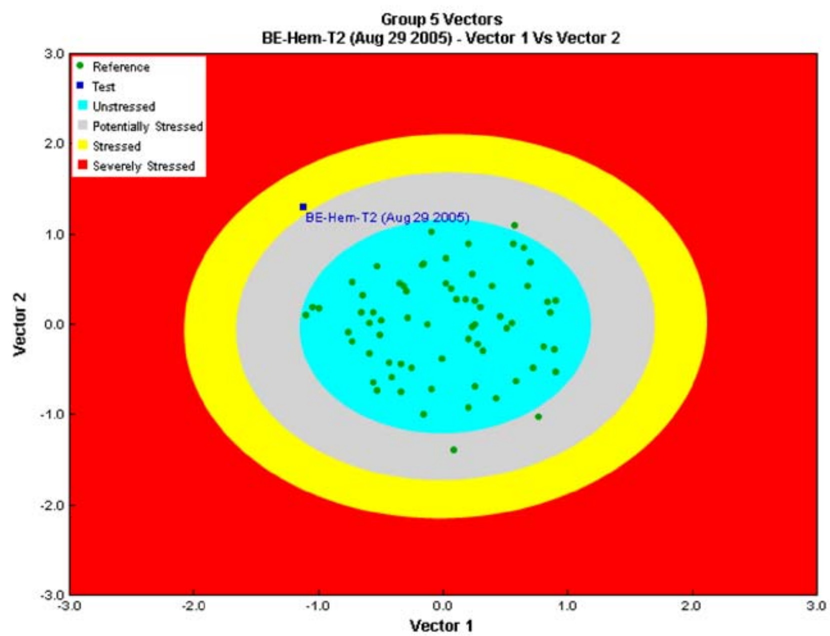
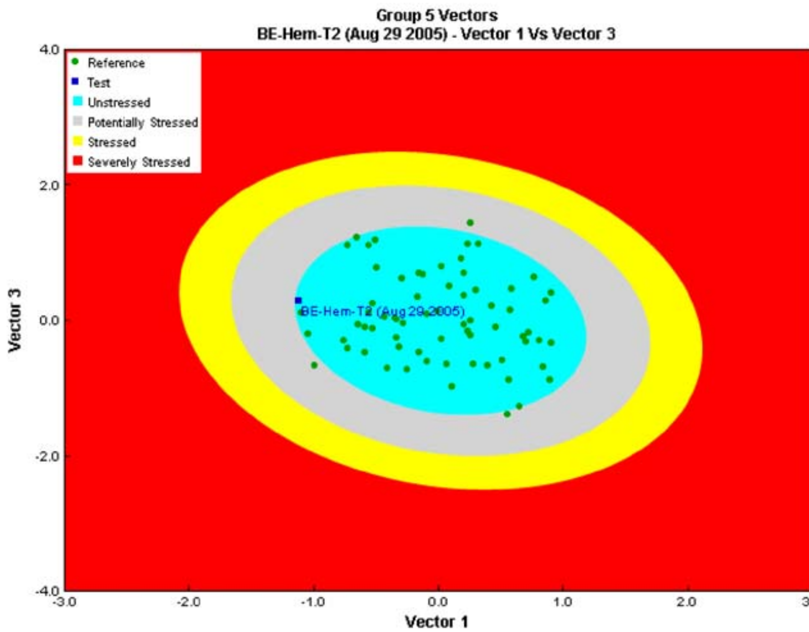


Figure 4b. RIVPACS analysis results and first site assessment graph (vector 1 vs. vector 2) from the CABIN site assessment report for site BE-Hem-T2.



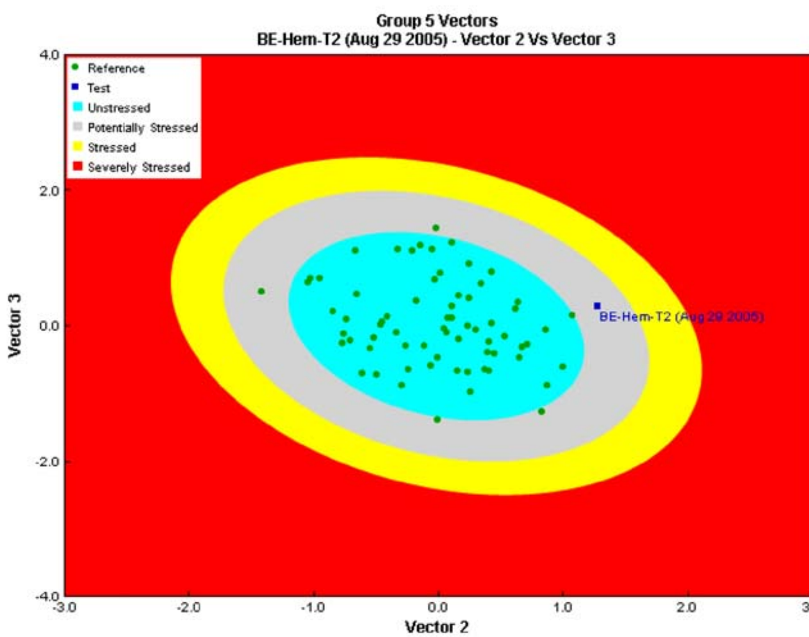


Figure 4c. Second and third site assessment graphs (vector 1 vs. vector 3, vector 2 vs. vector 3) from CABIN site assessment report for site BE-Hem-T2.

Site Assessment Vector Data

Assessment For The Test Site

Vector 1 Vs Vector 2	Stressed
Vector 1 Vs Vector 3	Unstressed
Vector 2 Vs Vector 3	Potentially Stressed
Overall	Stressed

Site Metrics

Metric Name	Reference Mean	Test Site	Significant
% Chironomidae	22.4217	68.4228	Yes
% of 2 Dominant Taxa	59.89	77.962	No
Ephemeroptera Taxa	3.4635	3.0	No
EPT Individuals	3425.4305	174.05	No
EPT Taxa	9.9124	6.0	No
Plecoptera Taxa	3.7774	3.0	No
Simpson's Diversity	0.747	0.5161	No
Simpson's Evenness	0.2933	0.1476	No
Total Abundance	5840.2264	1824.67	No
Total Numberof Taxa	16.1095	14.0	No
Trichoptera Taxa	2.6715	0.0	No

Summary

A significantly higher percentage of chironomids and numerically, not statistically significant, fewer EPT individuals and taxa support the BEAST assessment of impairment at this site.

Figure 4d. Stress designations, site metrics and site overview from CABIN site assessment report for site BE_Hem-T2.

Table 4. Summary of BEAST classifications and RIVPACS Observed:Expected ratios for 8 Bessette Creek and 19 Salmon River sites. For each stream all sites are listed from upstream to downstream.

Metric	BEAST	RIVPACS					
	Site Classification	Expected taxa P>0.50	Observed taxa P>0.50	O:E (p > 0.5)	Expected taxa P>0.70	Observed taxa P>0.70	O:E (p > 0.7)
BE-Mar-C1	Unstressed	4.35	6	**1.38**	3.21	4	1.25
BE-Mar-T1	Potentially Stressed	3.52	5	**1.42**	1.71	2	1.17
BE-Hem-C2	Unstressed	3.93	5	1.27	2.64	3	1.14
BE-Hem-C1	Unstressed	2.23	3	**1.35**	1.00	1	1.00
BE-Hem--T1	Unstressed	2.27	3	**1.32**	1.00	1	1.00
BE-Hem--T2	Stressed	5.82	8	**1.37**	3.51	4	1.14
BE-Buf-T1	Potentially Stressed	6.95	9	**1.30**	4.61	5	1.08
BE-Buf-C1	Stressed	4.61	6	**1.30**	3.38	4	1.18
MS-Rot-T1	Stressed	4.81	6	1.25	3.66	4	1.09
MS-Fel-C2	Potentially Stressed	7.29	10	**1.37**	4.43	5	1.13
MS-Fel-C1	Potentially Stressed	6.21	8	1.29	4.48	5	1.12
MS-Fel-T1	Potentially Stressed	6.20	8	1.29	4.48	5	1.12
MS-Roy-T2	Potentially Stressed	6.83	9	**1.32**	4.47	5	1.12
MS-Roy-T1	Potentially Stressed	6.01	8	**1.33**	4.38	5	1.14
MS-Put-C1	Potentially Stressed	4.14	6	**1.45**	1.74	2	1.15
MS-Put-T2	Potentially Stressed	5.33	7	**1.31**	3.65	4	1.10
MS-Put-T1	Potentially Stressed	2.41	3	1.25	1.73	2	1.16
LS-Wil-T1	Potentially Stressed	5.77	7	1.21	4.52	5	1.11
LS-Wil-T2	Potentially Stressed	4.57	6	**1.31**	3.54	4	1.13
LS-Cro-C1	Potentially Stressed	3.91	5	1.28	2.74	3	1.09
LS-Cro-C2	Potentially Stressed	3.12	4	1.28	1.75	2	1.14
LS-Cro-C3	Potentially Stressed	3.26	4	1.23	3.26	4	1.23
LS-Tur-C1	Potentially Stressed	2.28	3	**1.32**	1.00	1	1.00
LS-Tur-T1	Potentially Stressed	4.21	5	1.19	3.62	4	1.11
LS-Tur-T2	Severely Stressed	2.59	3	1.16	2.59	3	1.16
LS-Viv-T1	Potentially Stressed	2.78	4	**1.44**	1.00	1	1.00
LS-Viv-T2	Unstressed	2.25	3	**1.33**	1.00	1	1.00

Values in **bold** indicate potential enrichment

Based on the results from the BEAST analysis, the stress designations for Bessette Creek were mixed. Four of the eight Bessette Creek sites were unstressed, two were potentially stressed and two were stressed. The Salmon River was generally classified as potentially stressed (n=16) with one site for each of the classifications unstressed, stressed and severely stressed. The difference in stress level between the streams was not significant (Wilcoxon 2 sample df=8, 19; p=0.20).

In no instance did the O:E ratio indicate fewer taxa than were expected. O:E ratios (p>0.5) greater than 1.3, which may indicate potential enrichment, were observed in 16 of 27 sites.

There was no significant difference in stress designation between restoration treatments (Wilcoxon 2 sample df=16, 11; p=0.29). Marginally significant differences were found between treatments for species richness (p=0.07) and number of trichoptera (caddisflies) (p=0.06) (Table 5). For these metrics, the values for the Control sites were slightly higher.

Table 5. Summary of the two way ANOVAs comparing the effect of treatment on individual metrics.

	Effect of Treatment d.f.=1		Mean (Standard Deviation)[2]	
Metric Evaluated	**F**	**P**	**Treated**	**Control**
Species Richness	77.44	**0.07**	14.56 (2.56)	16 (3.44)
Total Abundance[1]		0.19	12390 (7595)	9027 (7924)
Ephemeroptera Taxa	0.22	0.72	3.56 (0.89)	3.55 (0.93)
Plecoptera Taxa	2	0.17	1.94 (1.06)	2.55 (1.13)
Trichoptera Taxa	106.78	**0.06**	2 (1.55)	2.91 (1.9)
EPT Individuals[1]		0.34	5633 (5186)	7826 (6272)
EPT Taxa	9.72	0.2	7.5 (2.63)	9 (2.68)
log % Chironomidae	0.02	0.92	21.67 (16.64)	22.34 (15.23)
% 2 Dominant	12.51	0.18	60.39 (9.82)	58.49 (12.85)
log Simpson's Evennes	0.28	0.69	0.31 (0.10)	0.76 (0.09)
Simpson's Diversity[1]		0.54	0.76 (0.08)	0.76 (0.09)

[1] Nonparametric data analyzed using Wilcoxon paired two-sample test.
[2] Means and standard deviations shown are not transformed.

3.4 CONCLUSIONS

The BEAST assessment was clearly able to determine differences between the condition of test sites and the reference groups. This analysis overwhelmingly indicates that the Salmon River is potentially stressed. For Bessette Creek the stress designations are more varied but suggest that the stream is increasingly stressed as it moves downstream. A potential cause of this stress may be indicated by O:E ratios (p>0.5) greater than 1.3 in all but one location. These high ratios indicate enrichment and may be consistent with nutrient inputs due to agricultural activities. Almost half of the sites on the Salmon River (9 of 19) also have by O:E ratios (p>0.5) greater than 1.3 likely due to the same cause. These stress designations are generally consistent with expert opinion of the habitat status and state of the salmon populations in the creeks (S. Bennett, Fisheries and Oceans Canada, pers. comm.).

No differences were apparent in the BEAST assessment of the benthic invertebrate community in restoration Treatment and Control reaches. It is unlikely that the observed increase in species richness and Trichoptera taxa indicates a biological effect of the bank stabilization projects, particularly in the absence of differences in the other metrics. This is likely a function of the fact that individual bank stabilization projects, often separated by eroding and degraded banks, were not sufficient to improve habitat, at least not in the time frame that they were evaluated. Alternatively, the banks chosen for stabilization projects (i.e., Treated reaches) may have been impaired relative to Control reaches prior to treatment, and may since have improved. Without pre-restoration data it is not possible to determine one way or the other.

The BEAST analysis was sensitive enough to discern differences in site condition between reaches that were separated by only a few hundred meters (i.e., BE-Mar-C1 and BE-Mar-T1). An evaluation of other metrics calculated using CABIN tools, in this case the O:E ratio, suggests potential causes of the stress which could be used in management decisions in finding ways to improve habitat quality. While a single river could theoretically have sites classed at contrasting levels (e.g. unstressed, stressed), the results of this assessment, in which the two streams were sampled intensively, were readily interpretable. Specifically, the overall message for the Salmon River is that it is potentially stressed and Bessette Creek appears to have problems with habitat quality that are manifest in increasingly stressed conditions downstream. The challenge with this approach will be to determine what sample size is sufficient to obtain an assessment of habitat quality that reflects the condition of the stream. Power analysis which determines the sample size required to have a reasonably high probability of detecting a predetermined effect size statistically, if it exists, may be useful in this regard. However, this approach would not determine the exact locations to be sampled. Moreover, the number of samples required may vary by factors including stream size and the amount of variation in adjacent land use. Potential strategies that could be used for sample site collection would be random sampling (e.g., river kilometer) or using location knowledge to identify potentially degraded locations or reaches. A limitation of the latter approach is that impacts to habitat quality will not necessary be detectable in the location where the potential stressor occurs and predicting the location where cumulative effects may be detected is challenging.

4.0 UTILITY OF THE RCA AND CABIN FOR WSP

The assessment of habitat status for the WSP will require a suite of indicators that reflect different components of habitat quality that are relevant to CUs. Potential indicators that have been considered for WSP habitat assessment include measurements of land use (e.g., percent land use type, density of roads), water quantity (e.g., flow hydrology), physical habitat (e.g., spawning habitat, impediments to accessibility to salmon habitat) and biological water quality (e.g., benthic invertebrates, phytoplankton) (G.A. Packman and Associates and Winsby Environmental Services 2006). One strategy that has been proposed is a tiered approach to habitat monitoring in which an initial broad scale habitat assessment would be performed remotely using a series of pressure indicators such as road density and percent forested land (M. Saunders, Fisheries and Oceans Canada, pers. comm.). Watersheds found to be spatially correlated with high levels of pressure could be further investigated at a second or third tier of investigation using site-specific status indicators (e.g. CABIN).

The benefit of using biological indicators to assess habitat is that they integrate exposure to, and stress from, many of the other parameters being measured and demonstrate that the stressors have triggered a biological response (although it is not always clear what the source of the perturbation is). Advantages to using benthic invertebrates as indicators include that they reflect local conditions, and that they integrate exposure over time and thus can reflect events that occurred in the past that may not be detected using other monitoring tools (e.g. chemical and physical measurements of water quality) (Barbour et al. 1999). Furthermore, benthic invertebrates are relatively sessile and are not subject to the many factors that influence the abundance and distribution of salmon in any stream in a given year (e.g., marine survival, fishing pressure etc.). Benthic invertebrates also form an important part of the aquatic food chain and thus impairment to that community may be reflected in other aquatic biota. Moreover, because the entire benthic community is assessed with measures such as abundance and richness, a range of species and life stage sensitivities are integrated in the habitat assessment.

There are limitations to using benthic invertebrates for WSP habitat assessment. Of particular relevance is the relatively small scale at which they measure perturbations. As indicated by the case study in Section 3.0, changes in stress designations (e.g., potentially stressed, severely stressed) can occur over very short distances and a single stream may have several different classifications. Although we were able to provide a reasonable explanation for this situation in Bessette Creek, interpreting the overall stress designation of fish habitat for a CU from numerous locations in other streams could prove to be more difficult. A further limitation is the cost, which would be magnified by the wide geographic extent of salmon habitat in BC. Statistical tools such as power analysis and existing knowledge about stream conditions may aid in developing study designs that would optimize sampling effort.

If benthic invertebrates are used as indicators for the WSP, the tools and reference site data available through the CABIN program provide an excellent resource. CABIN uses benthic invertebrate community data and the RCA with analytical techniques including BEAST and RIVPACS to classify the status of habitat quality relative to reference conditions. The reference conditions provide a benchmark of the range of natural conditions that would be expected given specific habitat features if there were no anthropogenic perturbations. This fulfils one of the primary goals of Strategy 2 of the WSP which is to assess quality of habitat relative to benchmarks. A further advantage to RCA is that sampling of different streams could be conducted on an “as needs” basis over a period of years. It also eliminates the problem of having to find specific control sites for comparison, and does not require the establishment of baseline or “pre-impact” data.

On the other hand, the extent to which the BEAST stress designations (which are derived from benthic invertebrate indicators) are relevant to fish has not been established. Though Gustavson and Brown (2002) argue that the greater the benthic invertebrate diversity the more “options” for ecosystem development and the greater the overall stream productivity, an alternative postulate would be that a decrease in diversity in previous years could represent a risk to fish sustainability. To determine the correlation between stress designations and the status of fish habitat in a particular stream, reference and test site assessments could be extracted from the CABIN database and compared to existing knowledge about fish and fish habitat in that stream (e.g., escapement, local and expert knowledge). If a good correlation exists, it would be reasonable to use CABIN and BEAST/RCA as one of the tiers for assessing fish habitat status under the WSP.

The CABIN database already includes over 270 reference sites for the Fraser/Georgia Basin and the program is expanding in the Skeena region of British Columbia and into the Yukon (although predictive models have not yet been developed for those regions) (S. Sylvestre, Environment Canada, pers. comm.). To date there is no coverage along the BC central coast, but interest in the CABIN program has been growing across BC and the goal is to have coverage throughout the province. The extent of this program provides an ongoing opportunity for leverage to the WSP monitoring strategy. The results from any CABIN study within the geographic range of a CU could be used directly for the WSP, because a standard set of field protocols have been used, and samples have been subject to the quality assurance and control program in CABIN. Furthermore, a standard training program has been implemented, and it would be easy to provide training to DFO staff or contractors (where resources are available) for directed assessment of priority CUs, and to collaborate with trained members of local stream stewardship groups.

The CABIN program also serves its reference and test site reports to the internet in an Open GIS compatible format. This format is consistent with existing internet spatial data delivery systems (e.g. Mapster, GeoPortal, COIN Pacific) that are hosted by DFO in the Pacific Region and nationally. WSP will almost certainly be using one of these systems to deliver its spatial information, so the CABIN information will integrate with the WSP information reporting framework.

While the availability of a database that is this extensive is rare and provides a unique opportunity to be able to both assess the status of varied habitats and serve as the basis for a long term monitoring program, it is important to recognize that CABIN is transitioning from being largely a research project to an applied biomonitoring program. In other words, Environment Canada is now entering a phase where stress classifications are being ground-truthed against other water quality measures and actual site conditions. Minor technical problems with the CABIN tools encountered during our case study reflect the fact that it is still being developed and fine tuned. Although Environment Canada has been extremely responsive in providing support and fixing bugs in the application, there is some risk associated with tying the WSP to an external program.

4.1 RECOMMENDATIONS

RCA based biomonitoring following the CABIN program has the potential to serve as a site-specific stress indicator in a tiered approach to the habitat monitoring strategy of the WSP. As funding levels for the implementation of the WSP would preclude the implementation of a widespread, site-specific sampling program, low cost options for integration would have to be adopted. CABIN's extensive, growing reference database provides a unique opportunity for leverage within the geographic areas relevant to the CUs. The following recommendations identify specific activities that will help to further clarify the utility of the CABIN program and the RCA to the WSP.

- A pilot study should be conducted to determine if the water quality stress designations, as determined using BEAST/RCA, provide a good indicator of habitat quality for salmon. To do this, the results of previous site assessments would be extracted from the CABIN database and compared to existing knowledge about fish and fish habitat (e.g., escapement, local and expert knowledge) at those sites to assess the correlation between the stress designations and the status of salmon in that particular stream.
- Low cost options for using the CABIN should be investigated, including: 1) determining the minimum sampling intensity that would be required to assess the overall health of a watershed or CU; 2) assisting non-governmental organizations to secure funding and implement CABIN based monitoring programs in geographic areas where little existing knowledge of fish habitat quality has been identified; 3) tracking new site

assessments in CABIN on an annual basis so they can be integrated with ongoing or future WSP habitat monitoring.

- Continue dialog between personnel from Fisheries and Oceans Canada and Environment Canada's CABIN program (e.g. Stephanie Sylvestre, Environment Canada, Pacific and Yukon) to track the development of the CABIN program and look for opportunities to benefit from it as the habitat monitoring strategy under the WSP evolves.

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