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Reference Condition Approach Bioassessment of Yukon River Basin Placer Mining Streams Sampled in 2006

By

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1. Introduction

An Integrated Regulatory Regime for Yukon Placer Mining was the final report of the Yukon Placer Implementation Steering Committee, submitted to the Minister of Fisheries in 2005. Under a proposed new management regime, the Yukon's placer mining industry will be managed through an adaptive management framework, with the aim of striking a balance between maintaining a viable placer industry and the protection and conservation of aquatic ecosystem integrity and fish populations. The effectiveness of the regime at achieving this balance will be monitored and assessed with appropriate adjustments to the requirements as required. The report recommended that a number of protocols be prepared and implemented in order to monitor the effectiveness of the new management system and among these is one with the primary objective of assessing and monitoring watershed health.

A draft Watershed Health Monitoring protocol was completed July 1, 2006, and is currently being reviewed and considered by first nation, territorial and federal government agencies, industry and conservation organizations, and the general public. The draft protocol aims to provide for a process to help assess how effective the new management regime is for maintaining watershed health and to generate monitoring results that will be used to guide the adaptive management framework assessment and adjustment phases.

After consideration of a number of methods, the Reference Condition Approach (RCA) was selected for assessing and monitoring watershed health under the draft protocol. There were a number of reasons for this choice:

- It is the most robust of many biomonitoring methods
- It is the basis of regional programs in Canada (it is an accepted design under the federal Environmental Effects Monitoring program), and programs in other countries, several USEPA programs in the United States, national programs in Australia and the United Kingdom, and has been adopted under the European Water Directive.
- An RCA program has been underway in the Yukon for a number of years that could be immediately applied to the placer mining areas and augmented by future fieldwork.

When the draft protocol was in preparation in the spring of 2006, meetings were held among those already conducting some type of stream sampling program associated with the Yukon placer mining industry. This included The University of Western Ontario, the federal Department of Fisheries & Oceans, and Environment Yukon Fisheries section. These three groups agreed to collaborate and carry out RCA sampling in 2006 in a manner consistent with that provided for in the draft Watershed Health Monitoring Protocol in order to "test drive" the methodology and assess its effectiveness at achieving the new management regime's objectives. Follow-up Geographical Information System

(GIS) data collection and data analysis were also carried out as provided for in the draft protocol. In addition, reference sites were subjected to simulated impacts and then the RCA models were applied to these “Simpacted” sites in order to demonstrate the ability of the RCA models to detect a known degree of disturbance in streams.

The purpose of this report is to summarize the results of the RCA analysis of the placer mining stream sampling data collected in 2006. The three main components of the report are: the construction of Classification and Regression RCA models using 87 reference sites sampled in 2004-2006; application of the models to 50 test sites on placer mining streams in three sub-watersheds; and assessment of the power and sensitivity of the RCA models using simulated disturbance imposed on reference sites. In addition, there is a discussion of the ability for the models to detect temporal change and recommendations are provided respecting future sampling and analysis exercises.

2. Data Collection and Preparation

The data analyzed for this report are a consolidation of those collected by The University of Western Ontario (UWO) in 2004-2006 and by Department of Fisheries & Oceans (DFO) and Yukon Government Fisheries (YTG) in 2006.

In the spring of 2006, the three sampling groups agreed to adopt the sampling protocol provided in the draft *Yukon Placer Mining Watershed Health Assessment and Monitoring Protocol* an excerpt of which follows:

1.3.3 Data Collection

Field data collected during sampling visits include fish (number and species), benthic macroinvertebrates (samples collected for laboratory identification and enumeration), basic water chemistry (pH, temperature, conductivity, dissolved oxygen), stream dimensions (width, depth and flow) and an in-stream and riparian zone habitat assessment. A water sample was also collected for laboratory analysis for nutrients, physical and chemical properties and metals.

There are many techniques available for field data collection. Consistency in methods is key and when sampling, care must be taken to adhere closely to the details. A critical component of programs is written documentation of the methods used. Most sites sampled over the past four years (and virtually all reference sites) have been sampled using the methods detailed in Appendix 1 and these are to be used in this program. It is critical that all samplers are proficient in the use of this methodology, and training and training review should be a program component.

All data collected should be checked, transferred to a database and routinely backed-up for subsequent analysis. This database should be updated with data generated after the sampling visit (e.g. invertebrate identification, water analysis, GIS data, placer mining activity verification).

A considerable amount of data for sites can be assembled before field data collection takes place, including GIS data available through Yukon Geomatics, such as catchment morphology, forest fire history, bedrock and surficial geology, and land cover (e.g. percent of the catchment that is forest, meadow, alpine, etc.). Assuming the catchments *for potential sites have already been delineated in the site selection process, it is a relatively simple matter to collect these other data, either before or after the sampling season. A protocol for delineation of watersheds and determining other characteristics is provided in Appendix 2.*

The appendices referred to in the above excerpt are provided in this report as Appendices 1 & 2. Also, see Yates and Bailey (2006), Stanfield (2003), and Parsons *et al.* (2001).

Adoption of the draft protocol methodology allowed for the analysis of 2006 data to include reference site data collected by UWO in 2004 and 2005 (61 sites) as well as data from three test sites on known placer mining streams collected in those years.

It was also agreed that the UWO sampling in 2006 would focus on test sites on known placer mining streams in the 60-Mile River, Klondike River and Indian River areas, while the aim of the DFO and YTG sampling would be to add to the reference sites used to develop the RCA models. In total, 91 reference sites (Appendix 3) and fifty test sites on known placer mining streams from three areas corresponding to the new placer regime sub-watersheds: Klondike River (21 sites), 60-Mile River (13 sites) and Indian River (16 sites) (Appendix 4) were initially selected for the RCA analysis presented here. Four reference sites were removed due to either the unique nature of their BMI community or absence of key data, so 87 reference sites were used for the final analyses.

Sites and data were catalogued in Excel spreadsheets. Environmental variables included on-site measurements (site dimensions, flow, basic water chemistry, EPA habitat scores) and GIS data (catchment area and perimeter, stream density, catchment vegetation, catchment bedrock geology, climate, forest fire activity, roads, mining claims past and present). Fish species sampled, fish species richness and abundance were recorded. BMI taxa and numbers were listed as were the corresponding calculated metrics for each site (Taxon Richness, Simpson's Diversity, Shannon-Weiner Evenness and the Hilsenhoff Biotic Index). Data were carefully crosschecked and anomalies investigated and corrected where appropriate.

3. Statistical Methods

a. Selection of Candidate Predictor Variables

When selecting candidate predictor variables for building a model that relates the biota and its environment in reference streams, it is important to choose variables that are not affected by the stressor of interest (placer mining in this case) (Bailey *et al.* 2004). In other RCA studies, such as that for the Fraser River, using a combination of local and landscape habitat variables generated the best models (Reynoldson *et al.* 2001, Rosenberg *et al.* 2000). This was not appropriate for this study, however. Placer mining activity can introduce sediment to stream systems and may change the chemical and physical properties of the streams. Consequently, water chemistry variables were not selected as candidate predictors. Similarly, the physical streambed and riparian zone at sampling sites are often altered during placer mining and therefore the EPA habitat scores and site dimensions were also not candidates. Accordingly, landscape-scale environmental variables were considered the most appropriate predictor variables for this analysis. These include catchment area and perimeter, stream density, vegetation, climate and bedrock geology.

b. BEAST RCA model development and application.

- Percent composition of the BMI community at each site was used to classify reference sites into groups of sites that had similar community composition. This was done using several clustering methods. The final classification was based on K-means analysis derived using Systat for 4 groups. Figure 1 shows the cluster groupings and test site locations.

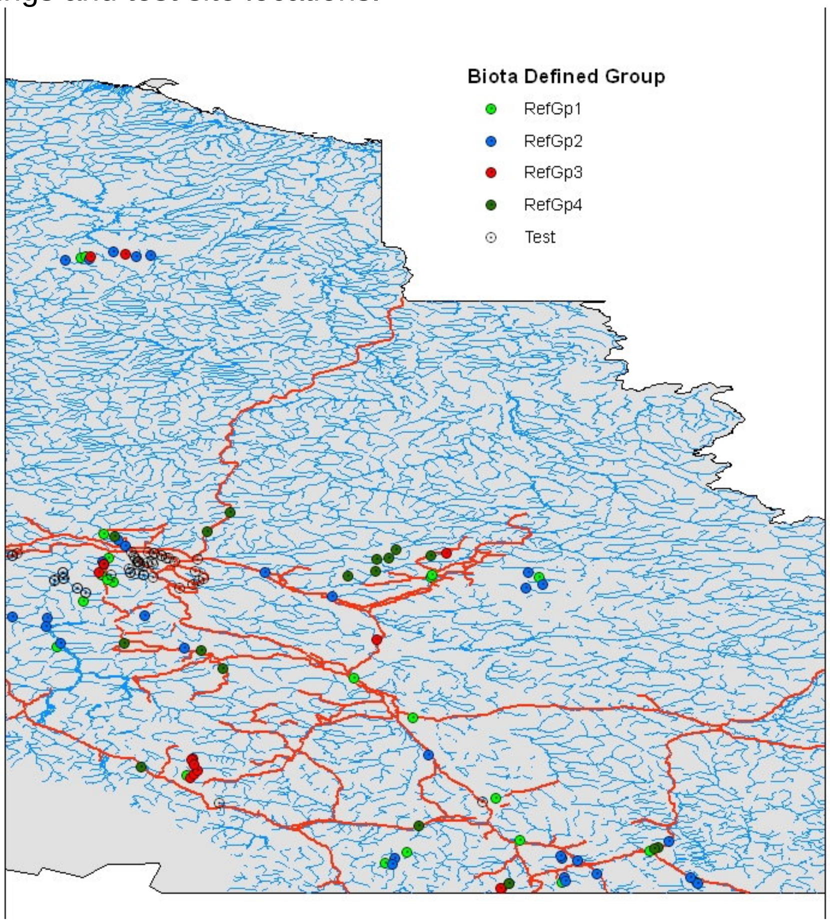

Figure 1. K-means cluster groupings of 4 groups for reference sites and test site locations.

- The Group to which each site was classified based on the community composition was used as the categorical variable in a Discriminant Function Analysis (DFA) with environmental (landscape scale) descriptors (catchment area and perimeter, stream density, vegetation and bedrock geology). This method selects the optimal set of habitat variables that show the greatest difference among the biologically defined groups. The method creates a predictive model that can be used to assign a probability of a site belonging to one of the biological groups based only on its environmental data. The number of reference sites that are placed in their correct biologically defined groups using only their environmental data determines the performance of the model. Figure 2 shows groupings predicted by the DFA for reference sites.

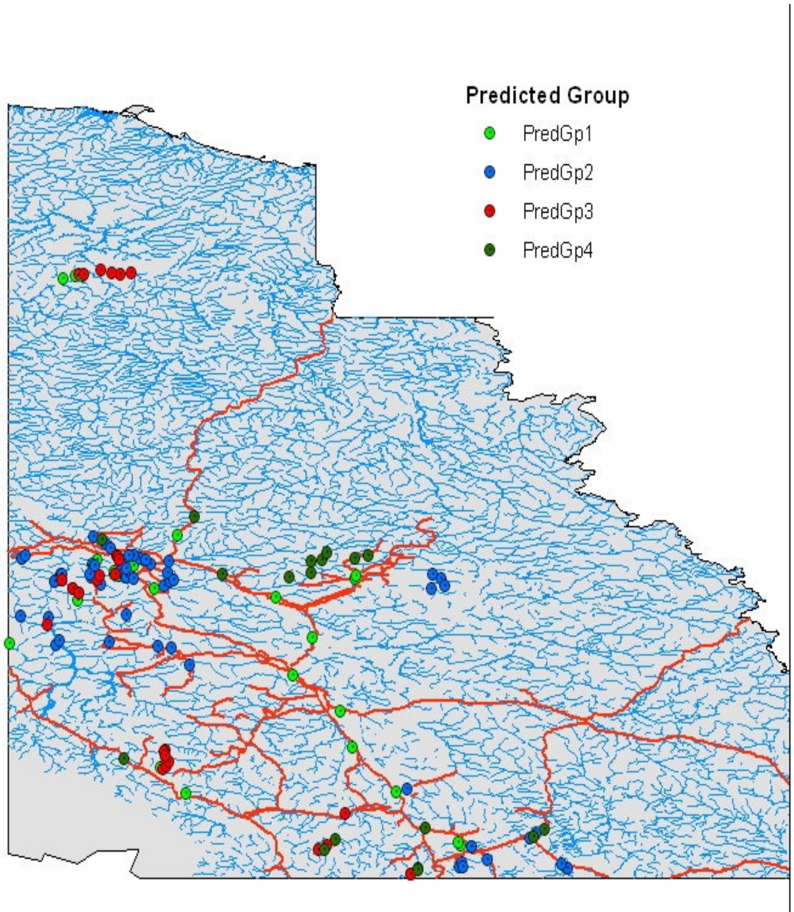

Figure 2. Groupings of reference sites predicted by DFA model.

- The predictive model is then used with environmental data to assign test sites to one of the biologically defined groups. This group characterizes the community that the test site is expected to have if it is in reference condition.

- Test sites are then compared to the group of reference sites to which they are matched. The degree of difference between the test site and the reference sites in its predicted group is a measure of the level of disturbance of the test site.

- The BEAST assessment approach uses ordination to capture the information in the community. The composition of the community is used to generate new variables (ordination axes) that capture the information and variability contained in the original taxa site data matrix, reducing this to two new variables that can be used in a scatter plot. In such a plot of sites the closer sites are to each other then the more similar they are. The location of the test sites is compared to that of the reference sites in ordination space. If the test site is within the “cloud” of reference sites then it has the same community as the reference site. The further a test site is from the cloud of reference sites then the greater the difference to reference. Probability ellipses constructed around the reference sites are used to establish levels of difference from reference. The probability ellipses used in the BEAST method are 90, 99, and 99.9%, resulting in corresponding Type 1 error probabilities of 10, 1 and 0.1% respectively, and thus providing 4 quality bands (Figure 3). However in this study 95% and 75% ellipses (Type 1 error probability =

5% and 25% respectively) were used for comparison with the regression approach. This means, for example, that with a decision point of 95%, there is a 5% chance of mistakenly concluding that a test site that is truly in reference condition is not in reference condition.

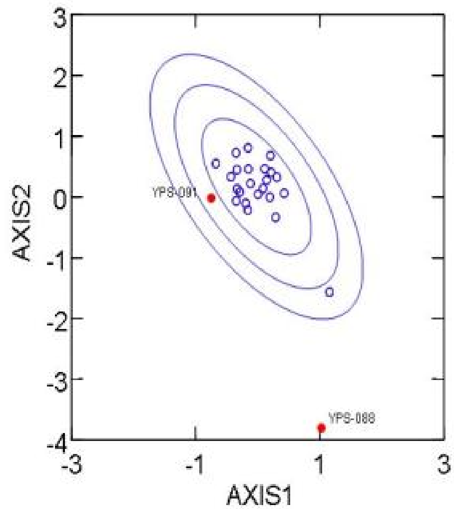

Figure 3. Assessment of Yukon River sites predicted to Group 1 reference community. Reference sites (open) have 90, 99 and 99.9% ellipses. Using BEAST method, test site YPS 091 is in Band 2 and YPS 088 is ion Band 4. A modification of this approach (with 95% and 75% ellipses) was used to assess all test sites.

- To minimize the influence of the test sites on the ordination when comparing to reference, the analysis was conducted with a ratio of 90% reference sites to 10% test sites (Reynoldson and Wright 2000).

c) Regression model development and application.

- Using Systat software, five stepwise multiple regressions were run on the reference site data, with each of four BMI metrics as the dependent variable (BMI Taxon Richness, Simpson's Diversity Index, Shannon-Weiner Evenness Index and the Hilsenhoff Biotic Index; Hauer and Lamberti, 1996), and a fourth using Fish Species Richness as the dependent variable. Candidate environmental predictor variables used in each regression were catchment area and perimeter, stream density, climate (annual precipitation and mean January and June temperatures), catchment vegetation cover type and catchment bedrock geology.

- Results of the stepwise regressions were subjected to bootstrap re-sampling. One hundred runs of the regression were performed using random sub-samples of 44 reference sites. Coefficients from the stepwise regression falling outside the 95% confidence interval of the bootstrap coefficients were removed to produce the final regression models. This insured that the stepwise regression models obtained were not the result of "over fitting" to the particular observations available.

- The regression models were applied to all reference and test sites to predict values for the dependent variables if a test site was in reference condition. These values were subtracted from the observed values for each site (i.e. O – P value). Thus, a positive value for this residual indicated that the dependent variable's observed value was higher than expected if the site was in reference condition, while a negative value indicated that the dependent variable's value was lower than expected if the site was in reference condition.

- The middle 75% and 90% of the reference site values for Observed-Predicted were used to determine the decision points for what would be considered in reference condition for the Fish Richness, BMI Richness, Simpson's and Shannon-Weiner models. The upper 75% and 90% of the O-P values for the Hilsenhoff model was used to determine these points. This corresponds to Type 1 error probabilities of 25% and 10% respectively for these two decision points.

- The decision points derived from the reference O-P values were applied to the test sites to determine which sites the models found to be in and out of reference condition.

4. Simpact Analysis

Objective

The objective of the Simpact analysis is to demonstrate the ability and sensitivity of the RCA models in detecting disturbance. A simulated impact (Simpact) was applied to the BMI data from reference sites and then the RCA models were applied to assess how they perform at detecting the Simpacted sites not being in reference condition.

Analysis

- The data set included benthic macroinvertebrate taxa at the family level. Planktonic taxa (e.g., Cladocera and Copepoda) and meiofauna (e.g., Ostracoda) were removed.

- Simulated data sets consisted of manipulations of 87 reference sites as described below. Three sites were removed from the original reference site collection of 91as their BMI communities were unique. One was removed because key data was unavailable.

- Two simulated data sets representing an enrichment stress response and a sediment stress response were created.

- Simpact disturbances for every reference site were created:

    - Taxa were categorized for the specific stress to one of three response classes: sensitive, insensitive, or tolerant.

  - Sensitive taxa declined in increasing number at different disturbance levels in response to the stress.
  - Insensitive taxa did not respond at low disturbance but then declined in number at increasing levels of disturbance.
  - Tolerant taxa increased in abundance at the low disturbance levels and then declined in number at higher levels of disturbance.

- Enrichment Simpact taxa categories were based on Hilsenhoff Tolerance values. Families that did not have tolerance values were categorized as insensitive. There were 14 sensitive taxa (e.g., Chloroperlidae, Ephemerellidae), 35 insensitive taxa (e.g., Leptophlebidae, Tipulidae), and 21 tolerant taxa (e.g., Chironomidae, Lumbriculidae).

- Sediment Simpact taxa were assigned to categories based on preferred habitat type and feeding behaviour. Taxa associated with soft sediment such as burrowing species (e.g. Oligochaeta and Bivalvia) or those that are deposit feeders (e.g. Chironomidae) were considered tolerant. Species with gills or predatory taxa (e.g. most Plecoptera and Ephemeroptera, but not for example Ephemeridae – burrowing mayflies) were considered sensitive. Other taxa were categorized as insensitive. There were 51 sensitive taxa, 5 insensitive taxa, and 14 tolerant taxa.

- The actual manipulations at each disturbance levels are summarized in Table 1, with increasing disturbance from level one to level nine. These nine levels correspond to *extremely modest disturbance* at the lower levels of disturbance (levels 1-4) where no taxa are lost and that would be well within the range of natural variation in a reference site, to *severe disturbance* (levels 6-9) where all sensitive taxa are lost and there is substantial reduction in abundance. Some perspective on the degree of disturbance can be gained from examination of the natural range in variation in taxa richness and abundance of the four most abundant taxa in each of the reference groups. For example in reference Group 1 (Table 2) the taxa richness in reference sites has a mean of 11.1 but is as low as 2 at some reference sites, in the case of the abundance of the more common taxa the abundance range is over three orders of magnitude and three of the four common taxa are not present at 25% of the sites. Thus undisturbed reference sites are very variable and the absence of taxa is not unusual. This provides some context for the Simpacts that have been imposed on the reference sites. The absence of one or two species has little effect and community-based approaches are not designed to look at single species. Rather, it is changes in the overall structure and assemblage complexity that such approaches are designed to address. Somewhat counter-intuitively, this ecological level is more robust and thus more useful than measuring and predicting change at the population level that examine single taxa.

Table 1. Summary of degree and direction of disturbance for two types of stress at nine increasing levels of disturbance (1 mild to 9 severe) to three categories of taxa (+ abundance increased from reference site value, - abundance reduced from reference site value, 0 means abundance changed to 0).

Level of disturbance	**Enrichment**	**Suspended sediment**
1	Sensitive unchanged Insensitive unchanged Tolerant + 25%	Sensitive -10% Insensitive unchanged Tolerant unchanged
2	Sensitive -10% Insensitive unchanged Tolerant +50%	Sensitive -25% Insensitive unchanged Tolerant unchanged
3	Sensitive – 25% Insensitive unchanged Tolerant +75%	Sensitive – 50% Insensitive unchanged Tolerant +50%
4	Sensitive -50% Insensitive -25% Tolerant +100%	Sensitive -75% Insensitive -15% Tolerant +25%
5	Sensitive -75% Insensitive -50% Tolerant -25%	Sensitive 0 Insensitive -15% Tolerant unchanged
6	Sensitive 0 Insensitive -50% Tolerant -50%	Sensitive 0 Insensitive -25% Tolerant -25%
7	Sensitive 0 Insensitive -75% Tolerant -50%	Sensitive 0 Insensitive -50% Tolerant -50
8	Sensitive 0 Insensitive -75% Tolerant -75%	Sensitive 0 Insensitive -75% Tolerant -75%
9	Sensitive 0 Insensitive 0 Tolerant -75%	Sensitive 0 Insensitive 0 Tolerant -75%

Table 2. Range in natural variation for taxon richness and the four most common taxa in each of four reference communities.

	Gp 1 (mn (min-max)	**Gp 2 (mn (min-max)**	**Gp 3 (mn (min-max)**	**Gp 4 (mn (min-max)**
Richness	**11 (2-18)**	**23 (11-40)**	**9 (6-14)**	**12 (9-18)**
Chironomidae	**175 (8-270)**	**42 (0-112)**	**67 (17-232)**	**52 (13-125)**
Baetidae	**20 (0-99)**	**16 (0-61)**	**92 (0-242)**	**33 (0-123)**
Simulidae	**14 (0-76)**	**9 (0-64)**	**74 (0-186)**	
Nemouridae	**12 (0-102)**	**10 (0-87)**	**18 (0-68)**	**39 (0-165)**
Heptageniidae				**62 (2-185)**

BEAST Simpact Analysis

- At each disturbance level for each community type the reference and matched Simpact site were ordinated. Each of these ordinations were plotted and a 95% and 75% probability ellipse was constructed around the reference sites, the number of test sites outside this ellipse was defined as the number of Simpacted sites detected (i.e., power). The number of reference sites outside the ellipse was defined as the Type 1 error rate, and the number of Simpacted sites inside the ellipse as the Type 2 error. Figure 4 shows an example of a comparison of sediment Simpacted and reference sites for the four community types. Figure 5 shows a comparison of the enrichment Simpact and reference sites at four levels of disturbance for the Group 1 community type.

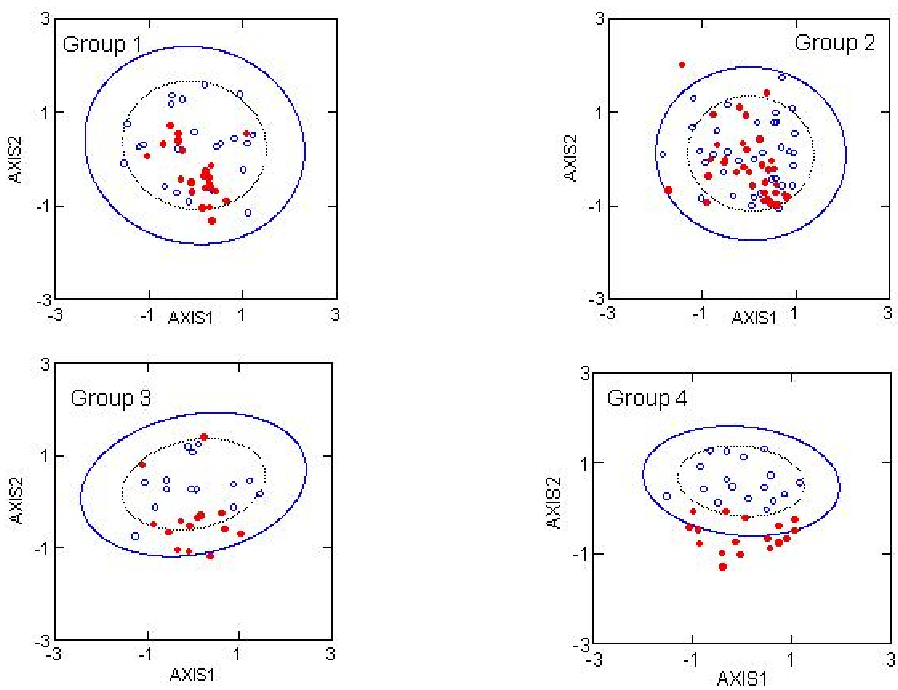

Figure 4. Comparison of sediment Simpact (solid) and reference (open) sites at disturbance level 4, for the four community types. Probability ellipses for 75% (hatched) and 95% (solid) are used to determine if a Simpact site is different to reference.

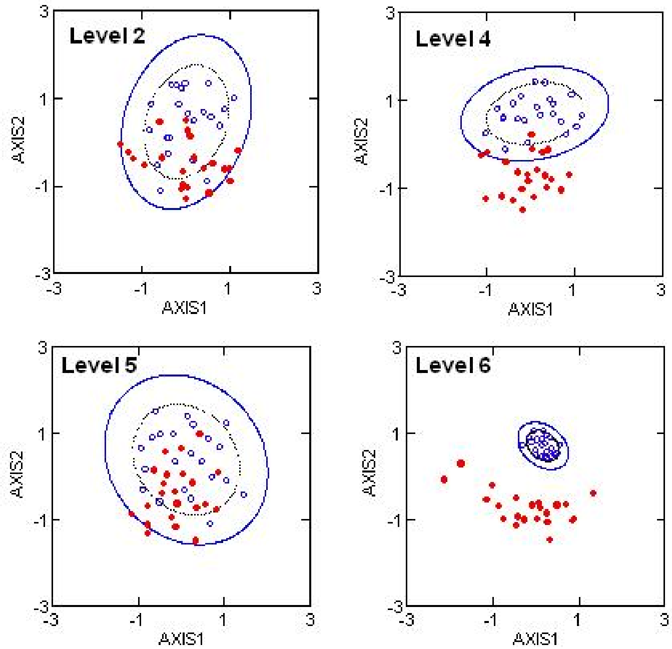

Figure 5. Comparison of enrichment SIMPACT (solid) and reference (open) sites at four disturbance levels for the Group 1 community type. Probability ellipses for 75% (hatched) and 95% (solid) are used to determine if a Simpact site is different to reference.

Regression Simpact Analysis

- Regression models for BMI Taxon Richness and Hilsenhoff Index were applied to the sediment Simpact sites at levels 1 through 9 at 75%, 90% and 95% probabilities (25%, 10% and 5% Type 1 error rates).

5. Results of RCA for Test Sites

BEAST Analysis Results

- 50 test sites were examined, from three river systems. Thirteen from the Sixty Mile River, 16 from the Indian River and 21 from the Klondike River.

- The predictive model was used to determine the reference site group with which the test site would be compared (Table 3).

Table 3. Number of sites predicted to reference communities using DFA model in three river systems.

Sixty Mile River	Indian River	Klondike River
Gp 1 - 3 sites Gp 2 - 6 sites Gp 3 - 4 sites	Gp 1 - 5 sites Gp 2 - 9 sites Gp 3 - 2 sites	Gp 1 - 4 sites Gp 2 - 14 sites Gp 3 - 3 sites

- Most sites (29) were predicted to Group 2, which is also the largest reference Group. No sites were predicted to Group 4, which is the reference Group with the smallest number of sites.
- Group 2 is also the most biologically variable and the least sensitive in detecting disturbance.
- Sites were compared to reference sites at a ratio of 9:1 reference to test sites (Reynoldson and Wright 2000).
- A site was assigned to a disturbance band by examining the location of test sites relative to the appropriate reference sites in ordination space
- The results for each test site are presented in Table 4

Table 4. Individual assessment of test sites. Where 0= inside 75 % ellipse, 1, inside 90% ellipse, 2 between 90-99% ellipses, 3 between 99 and 99.9% ellipses, and 4 outside 99.9% ellipse.

Group 1	Assessment	Group 2	Assessment	Group 2	Assessment	Group 3	Assessment
YPS-098	0	YPS-100	0	YPS-099	1	YPS-094	0
YPS-092	0	YPS-117	0	YPS-114	1	YPS-081	0
YPS-109	1	YPS-096	0	YPS-118	1	YPS-085	0
YPS-091	2	YPS-103	0	YPS-095	1	YPS-106	0
YPS-093	2	YPS-111	0	YPS-097	1	YPS-087	1
YPS-080	2	YPS-016	0	YPS-102	1	YPS-089	1
YPS-113	3	YPS-077	0	YPS-104	1	YPS-115	1
YPS-101	3	YPS-078	0	YPS-112	1	YPS-090	1
YPS-110	3	YPS-079	0	YPS-151	1	YPS-116	2
YPS-084	3	YPS-082	0	YPS-016.2	1		
YPS-108	3	YPS-083	0	YPS-051	1		
YPS-088	4	YPS-105	0	YPS-051.2	1		
		YPS-107	0	YPS-052	1		
		YPS-140	0	YPS-052.2	1		
		YPS-086	1				

Summary by Sub-watershed

- In the Sixty Mile River using BEAST 10 sites were in reference condition, 1 was possibly disturbed (YPS 116 Band 2), 1 disturbed (YPS 113 Band 3), and 1 very disturbed (YPS 088 Band 4). Based on 75% ellipses, 10 sites were disturbed.
- In the Indian River, using BEAST 12 sites were in reference condition, 2 were possibly disturbed (YPS 091, 093 - Band 2), and 2 disturbed (YPS 101, 110 - Band 3). Based on 75% ellipses, 5 were in reference condition and 11 sites were disturbed.

- In the Klondike R., using BEAST 18 sites were in reference condition, 1 was possibly disturbed (YPS 080 - Band 2) and 2 disturbed (YPS 84, 108 - Band 3). Based on 75% ellipses 12 were in reference condition and 9 sites were disturbed.

Regression Analysis Results

Five regression models were created and are described in Table 5.

Table 5. Regression models showing model biotic variable, habitat predictor variables and their function in the model and the R^2 value.

Model Biota Variable	Predictor Variables	R^2
Fish Species Richness	**+** stream density **-** tundra, clastic/chert, clastic/limestone/dolomite, clastic/ volcanic/metamorphic, dolomite, limestone	0.214
BMI Taxon Richness	**+** catchment perimeter, annual precipitation, clastic volcanic feldspar **-** catchment area, January temperature, conifer, clastic/chert limestone, clastic limestone, clastic/limestone/dolomite,	0.454
BMI Simpson's Diversity	**+** Jan. & June temp., shrub, tundra, clastic dolomite, dolomite **-** conifer, mixed, clastic limestone, clastic limestone dolomite	0.208
BMI Shannon's Evenness	**+** catchment area, clastic dolomite **-** catchment perimeter, mixed, clastic/chert dolomite, clastic/limestone, clastic/volcanic/felsic	0.229
BMI Hilsenhoff Index	**+** catchment perimeter, clastic/chert/dolomite, clastic/limestone **-** catchment area, shrub, tundra, clastic/volcanic/metamorphic, dolomite	0.416

Each of the models was applied to 49 test site on placer mining streams (see Appendix 4) at 75% and 90% levels (2-tailed for Fish Species Richness, BMI Taxon Richness, BMI Simpson's Diversity and BMI Shannon's Evenness and 1-tailed for BMI Hilsenhoff).

The determination of whether test sites were in reference condition for each model and level is shown in Tables 6 and 8.

Table 6. Determination of whether test sites were in reference condition (Y) or not (N) under each of the 5 models at the 75% level. Fish S =Fish Species Richness, BMI S=BMI Taxon Richness, BMI D=Simpson's Diversity, BMI E=Shannon's Evenness, BMI BI=Hilsenhoff Index.

YPS No.	SITE	Fish S 75%	BMI S 75%	BMI D 75%	BMI E 75%	BMI BI 75%
YPS-016	YRB-37_04	N	Y	N	Y	Y
YPS-016.2	YRB-37_06	Y	Y	Y	Y	Y
YPS-051	YRB-96_05	Y	Y	N	N	Y
YPS-051.2	YRB-96_06	Y	N	Y	N	Y
YPS-052	YRB-97_05	Y	Y	Y	N	Y
YPS-052.2	YRB-97_06	Y	Y	N	N	N
YPS-070	YRB-115	Y	N	N	N	Y
YPS-077	YRB-122	Y	N	Y	Y	Y
YPS-078	YRB-123	N	N	N	N	Y
YPS-079	YRB-124	N	Y	N	N	N
YPS-080	YRB-125	Y	N	Y	N	Y

YPS-081	YRB-126	N	N	Y	Y	Y
YPS-082	YRB-127	N	Y	Y	Y	Y
YPS-083	YRB-128	N	Y	Y	Y	Y
YPS-084	YRB-129	Y	Y	Y	Y	Y
YPS-085	YRB-130	Y	N	Y	N	Y
YPS-086	YRB-131	N	Y	Y	N	N
YPS-087	YRB-132	Y	N	Y	N	N
YPS-088	YRB-133	N	N	Y	N	N
YPS-089	YRB-134	Y	N	Y	N	Y
YPS-090	YRB-135	N	N	Y	N	N
YPS-091	YRB-136	Y	N	N	N	Y
YPS-092	YRB-137	Y	Y	N	Y	Y
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YPS-096	YRB-141	Y	Y	N	Y	Y
YPS-097	YRB-142	N	N	Y	N	Y
YPS-098	YRB-143	Y	Y	Y	N	N
YPS-099	YRB-144	Y	Y	Y	Y	Y
YPS-100	YRB-145	Y	N	N	Y	Y
YPS-101	YRB-146	N	Y	Y	N	Y
YPS-102	YRB-147	N	N	N	N	Y
YPS-103	YRB-148	Y	N	Y	N	N
YPS-104	YRB-149	Y	Y	N	N	Y
YPS-105	YRB-150	Y	N	N	N	N
YPS-106	YRB-151	N	Y	Y	Y	Y
YPS-107	YRB-152	Y	Y	Y	Y	Y
YPS-108	YRB-153	N	Y	Y	N	Y
YPS-109	YRB-154	N	Y	Y	Y	Y
YPS-110	YRB-155	N	Y	Y	Y	Y
YPS-111	YRB-156	Y	N	Y	N	N
YPS-112	YRB-157	Y	Y	Y	Y	Y
YPS-113	YRB-158	Y	N	Y	Y	Y
YPS-114	YRB-159	Y	N	Y	N	N
YPS-115	YRB-160	N	Y	Y	Y	Y
YPS-116	YRB-161	N	N	Y	Y	Y
YPS-117	YRB-162	N	N	Y	Y	Y
YPS-118	YRB-163	Y	Y	N	N	Y

Summary of 75% level Regressions (49 test sites)

- Fish Species Richness Model – 19 sites not in reference; BMI Taxon Richness Model – 22 sites not in reference; BMI Simpson's Index Model – 16 sites not in reference; BMI Shannon's Evenness Index Model – 27 sites not in reference; BMI Hilsenhoff Index Model – 11 sites not in reference

- Number of sites all models determine to be in reference condition – 5; sites all models determine not to be in reference – 0; sites 4 of 5 models determine not to be in reference – 6; sites 3 of 5 models determine not to be in reference – 10; sites 2 of 5 models determine not to be in reference - 16; sites 1 of 5 models determine not to be in reference – 12. Photos of the sites that all models concluded were in reference condition are shown in Appendix 3.

- The performance of the Fish and BMI Richness models were compared to see how many sites they agreed on. There is concordance of 24 sites, non-concordance of 25. This comparison is shown in Table 7.

Table 7. Comparison of the Performance of the Fish Species Richness and BMI Taxon Richness Models at 75% level.

		Fish Species Richness Model		
		In Reference	Not in Reference	Total
BMI Taxon Richness Model	In Reference	16	11	27
	Not in Reference	14	8	22
	Total	30	19	49

Table 8. Determination of whether test sites were in reference condition (Y) or not (N) under each of the 5 models at the 90% level. Fish S =Fish Species Richness, BMI S=BMI Taxon Richness, BMI D=Simpson's Diversity, BMI E=Shannon's Evenness, BMI BI=Hilsenhoff.

YPS No.	SITE	Fish S 90%	BMI S 90%	BMI D 90%	BMI E 90%	BMI BI 90%
YPS-016	YRB-37_04	Y	Y	Y	Y	Y
YPS-016.2	YRB-37_06	Y	Y	Y	Y	Y
YPS-051	YRB-96_05	Y	Y	Y	N	Y
YPS-051.2	YRB-96_06	Y	N	Y	N	Y
YPS-052	YRB-97_05	Y	Y	Y	N	Y
YPS-052.2	YRB-97_06	Y	Y	Y	N	Y
YPS-070	YRB-115	Y	Y	Y	N	Y
YPS-077	YRB-122	Y	N	Y	Y	Y
YPS-078	YRB-123	N	N	N	N	Y
YPS-079	YRB-124	N	Y	N	N	Y
YPS-080	YRB-125	Y	Y	Y	N	Y
YPS-081	YRB-126	Y	N	Y	Y	Y
YPS-082	YRB-127	Y	Y	Y	Y	Y
YPS-083	YRB-128	N	Y	Y	Y	Y
YPS-084	YRB-129	Y	Y	Y	Y	Y
YPS-085	YRB-130	Y	N	Y	Y	Y
YPS-086	YRB-131	N	Y	Y	Y	Y
YPS-087	YRB-132	Y	N	Y	N	Y
YPS-088	YRB-133	Y	Y	Y	N	Y
YPS-089	YRB-134	Y	N	Y	N	Y

YPS-090	YRB-135	N	N	Y	N	Y
YPS-091	YRB-136	Y	N	N	N	Y
YPS-092	YRB-137	Y	Y	Y	Y	Y
YPS-093	YRB-138	Y	Y	N	N	Y
YPS-094	YRB-139	Y	Y	Y	Y	Y
YPS-095	YRB-140	Y	Y	Y	Y	Y
YPS-096	YRB-141	Y	Y	Y	Y	Y
YPS-097	YRB-142	Y	N	Y	N	Y
YPS-098	YRB-143	Y	Y	Y	N	Y
YPS-099	YRB-144	Y	Y	Y	Y	Y
YPS-100	YRB-145	Y	N	N	Y	Y
YPS-101	YRB-146	N	Y	Y	Y	Y
YPS-102	YRB-147	N	Y	N	N	Y
YPS-103	YRB-148	Y	N	Y	N	N
YPS-104	YRB-149	Y	Y	N	N	Y
YPS-105	YRB-150	Y	Y	N	N	Y
YPS-106	YRB-151	N	Y	Y	Y	Y
YPS-107	YRB-152	Y	Y	Y	Y	Y
YPS-108	YRB-153	N	Y	Y	Y	Y
YPS-109	YRB-154	N	Y	Y	Y	Y
YPS-110	YRB-155	N	Y	Y	Y	Y
YPS-111	YRB-156	Y	N	Y	N	N
YPS-112	YRB-157	Y	Y	Y	Y	Y
YPS-113	YRB-158	Y	N	Y	Y	Y
YPS-114	YRB-159	Y	N	Y	N	N
YPS-115	YRB-160	N	Y	Y	Y	Y
YPS-116	YRB-161	N	Y	Y	Y	Y
YPS-117	YRB-162	Y	N	Y	Y	Y
YPS-118	YRB-163	Y	Y	Y	Y	Y

Summary of 90% level Regressions (49 test sites)

- Fish Species Richness Model – 13 sites not in reference; BMI Taxon Richness Model – 16 sites not in reference; BMI Simpson's Index Model – 8 sites not in reference; BMI Shannon's Evenness Index Model – 22 sites not in reference; BMI Hilsenhoff Index Model – 3 sites not in reference.

- Number of sites all models determine to be in reference condition – 12; sites all models determine not to be in reference – 0; sites 4 of 5 models determine not to be in reference – 1; sites 3 of 5 models determine not to be in reference – 7; sites 2 of 5 models determine not to be in reference - 8; sites 1 of 5 models determine not to be in reference – 21.

- The performance of the Fish and BMI Richness models were compared to see how many sites they agreed on. There is concordance of 24 sites, non-concordance of 25. This comparison is shown in Table 9.

Table 9. Comparison of the Performance of the Fish Species Richness and BMI Taxon Richness Models at 90% level.

Fish Species Richness Model

BMI Taxon Richness Model		In Reference	Not in Reference	Total
	In Reference	22	11	33
	Not in Reference	14	2	16
	Total	36	13	49

6. Simpact Analysis Results

BEAST Sediment Simpact Results

- Ability of the BEAST method to detect impairment was undertaken using sites with known levels of disturbance. As described above, nine disturbance levels were used with taxa responding in one of three ways (Table 1).

- To determine power (number of sites defined as different to reference) we used the number of Simpact sites either outside the 75% ellipse or outside the 95% ellipse. Type 1 error (i.e. concluding incorrectly that a site in reference condition was not in reference condition) was defined as the proportion of reference sites outside the ellipse. Type 2 error (i.e. concluding incorrectly that a site that had been degraded from levels 1-9 was in reference condition) was defined as the proportion of degraded sites within the ellipse. It is important to note that the two types of error have very different implications. Type 1 error is the risk to "industry" where a site is declared disturbed if it is not. Conversely, the risk to the environment is the Type 2 error rate that defines a disturbed site as being in reference. Finally, the power (the ability to detect difference where it exists) is the inverse of the Type 2 error.

- Simpact sites were matched with the group to which the same reference site belonged. So for each disturbance level four ordinations were conducted.

- The results are summarized in Table 10 and Figure 7. This shows both the total number and percentage of disturbed sites and Type 1 errors for 75 and 95% levels. In addition the number of sites per group are indicated in parentheses.

Table 10. Power of 75% and 95% probability levels in detecting disturbed (sediment Simpact) sites and the Type 1 error rates at 9 different levels of disturbance. Number of sites defined as disturbed or indicating Type 1 errors per community type are shown in parentheses: (Gp 1+Gp2+Gp3+Gp4). Taxa adjusted are: Sensitive 51 taxa, Insensitive 5 taxa, and Tolerant 14 taxa

Disturbance	75 % probability		95 % probability	
	POWER (Proportion of Detected Simpacts)	Type 1 error	POWER (Proportion of Detected Simpacts)	Type 1 error
1	(4+5+1+2)=12 13.8%	(4+5+1+3)= 13 14.9%	(0+0+0+0)=0	(0+0+0+0)=0
2	(3+7+1+2)=13 14.9%	(4+6+1+3)=14 16.1%	(0+1+0+0)=1 1.1%	(0+0+0+0)=0
3	(9+6+3+5)=23 26.4%	(4+6+1+3)=14 16.1%	(0+1+0+0)=1 1.1%	(0+0+0+0)=0
4	(1+4+7+16)=28 32.2%	(3+7+2+1)=13 14.9%	(0+1+1+12)=14 16.1%	(0+0+0+0)=0
5	(3+3+14+17)=37 42.5%	(4+5+3+3)=15 17.4%	(0+0+13+17)=30 34.5%	(0+1+2+0)=3 3.4%
6	(6+16+14+17)=53 60.9%	(4+5+3+3)=15 17.4%	(0+6+14+17)=37 42.6%	(0+3+0+0)=3 3.4%
7	(22+6+14+17)=59 67.8	(5+3+2+3)=13 14.9%	(19+2+14+17)=52 59.8%	(0+2+0+0)=2 2.3%
8	(22+32+14+17)=85 97.7%	(6+6+3+3)=18 20.7%	(22+22+14+17)=74 86.2%	(0+1+0+0)=1 1.1%
9	(22+33+14+17)=86 98.8%	(4+5+3+3)=15 17.4%	(22+21+14+17)=74 85.0%	(0+2+0+0)=2 2.3%

- Type 1 error rates vary from 14.9-20.7% for 75% level, and 0-3.4% for the 95% level.

- Power ranges from 13.8-98.8% for 75% level and 0 – 85.0% for 95% level, depending on the level of disturbance.

- As expected, there is a balance between power and error with the choice depending on where the importance of error lies. In fact, Type 1 error rates are very stable (Figure 7) over the disturbance range, and the detection level determines the severity. The Type 2 error and power are determined more by the distribution of the data and of course there is a direct relationship between the power and the Type 2 error (as Type 2 error is simply the inverse of the power). For the sediment Simpact, Type 2 errors and power are in the order of 50% where disturbance starts to become of concern (level 6) and gradually improve as the degree of disturbance becomes more severe (Figure 7). Again the same balance exists between the ability to detect disturbance (power) and error – the choice depends on where the importance of error lies. The only way to improve power (but increase Type 1 and 2 errors) is to change the significance level by using a different ellipse size.

- There are considerable differences from community to community. For example, at the 95% level, Simpacts are not detected in Group 1 until disturbance level 7, but are detected at disturbance level 4 for Group 4. This is dependent on type of organisms present and the variability of the Group.

BEAST Enrichment Simpact Results

- Results of the enrichment Simpact are summarized in Table 11 and Figure 6.

Table 11. Comparison of 75% and 95% probability levels in detecting disturbed (enrichment Simpact) sites and the Type 1 error rates at 9 different levels of disturbance. Number of sites defined as disturbed or indicating Type 1 errors per community type are shown in parentheses: (Gp 1+Gp2+Gp3+Gp4). Taxa adjusted are: Sensitive 14 taxa, Insensitive 35 taxa, and Tolerant 21 taxa.

Disturbance	75 % probability		95 % probability	
	POWER (Proportion of Detected Simpacts)	**Type 1 error**	**POWER (Proportion of Detected Simpacts)**	**Type 1 error**
1	(8+8+1+3)= 20 23.0%	(3+6+1+2)=12 13.8%	(0+1+0+0)=1 1.1%	(0+1+0+0)=0 0%
2	(14+7+1+2)= 24 27.6%	(3+4+1+2)=10 11.5%	(2+0+0+0)=2 2.2%	(0+0+0+0)=0 0%
3	(18+7+1+3)= 28 32.2 %	(3+8+2+3)= 16 18.4%	(13+0+0+0)=13 14.9%	(0+1+0+0)=1 1.1%
4	(21+12+1+9)= 43 49.4 %	(5+4+2+3)= 14 16.1%	(17+1+0+1)=19 21.8%	(0+0+0+0)=0 0%
5	(7+9+3+1)= 20 23.0%	(4+6+1+2)= 13 14.9%	(1+0+0+0)=1 1.1%	(0+1+0+0)=0 0%
6	(22+34+14+15)=85 97.7%	(4+6+2+1)= 13 14.9%	(22+34+14+8)=78 89.6%	(0+0+0+0)=0 0%
7	(22+34+13+12)=81 93.1%	(3+6+1+1)= 11 12.6%	(22+34+8+4)=68 78.2%	(1+0+0+0)=1 1.1%
8	(22+34+14+13)=83 95.4%	(3+6+1+3)= 13 14.9%	(22+34+14+10)=80 92.0%	(0+0+0+0)=0 0%
9	(22+34+14+17)= 87 100 %	(3+7+2+3)= 15 17.2%	(22+34+14+17)=87 100%	(0+0+0+0)=0 0%

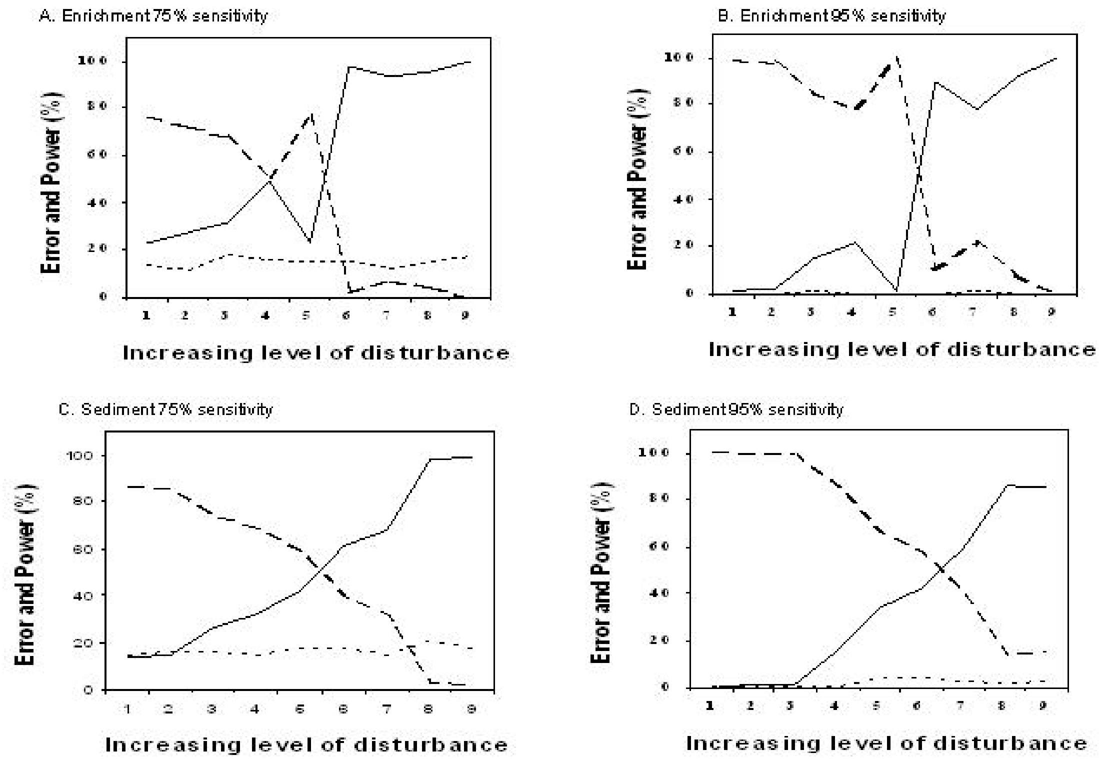

Figure 6. Effect of increasing level of enrichment disturbance (A & B) and sediment disturbance (C & D) on Type 1 (dots) and Type 2 (dash) errors and Power (solid), using sensitivity of 75 and 95%

- Type 1 error rates vary from 11.5-17.2% for 75% level, and 0-1.1% for the 95% level (Table 11, Figure 6).

- Power ranges from 23.0 - 100% for 75% level and 1.1 - 100% for 95% level, depending on the level of disturbance (Table 11, Figure 6).

- Again the same balance exists between power and Type 2 error where the choice depends on where the importance of error lies. It is noteworthy that again the Type 1 errors are stable over the disturbance range (Figure 6) and Type 2 errors drop (and power increases) where disturbance would start to be of concern (level 6).

- There are again differences from community to community e.g., at 95% level Simpacts are first detected in Group 1 at disturbance level 3, but not until level 6 in Group 4 (Table 11). This is the exact opposite to the sediment Simpact where 1 was the least sensitive and Group 4 the most sensitive (Table 10).

- Again, the type of organisms present and the variability of the Group determine this**.** In effect this means that different community types have different sensitivities to various types of disturbance, which we would argue is a benefit of this approach, that it tailors the decision to the sensitivity of the in-stream community.

- Figure 5 shows the response in Group 1 sites to the enrichment Simpact at four levels. Simpacted sites are first detected as different to reference at level 2, where tolerant taxa have increased in abundance by 50% and sensitive taxa declined by 10%. The effect continues to increase (more Simpact sites detected) through to level 4. However at level 5 there is a decline in the number detected. This is a consequence of the typical response of tolerant taxa to enrichment, of initial increase and then decline, so that in fact numbers of these organisms are more similar to reference at this level of disturbance. The Simpact at level 4 was to increase their abundance by 100%, but at level 5 the change from the reference sites was only 25% (but now a decline). This is a typical enrichment response and demonstrates the caution that must be taken in interpreting data. At level 6, when taxa disappear, the difference between reference and Simpact sites becomes very clear.

- Figure 6 shows this two-step response. The initial increase in detection being due to change in relative abundance. The steeper second stage response is to loss of taxa.

Regression Model Simpact Results

The regression models for BMI Taxon Richness and BMI Hilsenhoff Index were applied to the Sediment Simpacted sites at levels 1 – 9 with a Type 1 error at 25% and 5%. The results are summarized in Tables 12-15.

Table 12. Results of the application of the BMI Taxon Richness model with Type 1 error set at 25% for Sediment Simpact Levels 1 - 9. Red indicates sites determined not to be in reference condition while blue indicates a reference condition determination.

YPS No.	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9
YPS-018	-9.25	-9.25	-9.25	-9.25	-15.57	-15.57	-15.57	-15.57	-16.57
YPS-041	-6.23	-6.23	-6.23	-6.23	-14.21	-14.21	-14.21	-14.21	-14.21
YPS-033	-5.05	-5.05	-5.05	-5.05	-13.48	-13.48	-13.48	-13.48	-13.98
YPS-128	-4.57	-4.57	-4.57	-4.57	-13.09	-13.09	-13.09	-13.09	-13.91
YPS-020	-4.45	-4.45	-4.45	-4.45	-13.00	-13.00	-13.00	-13.00	-13.48
YPS-155	-4.21	-4.21	-4.21	-4.21	-12.98	-12.98	-12.98	-12.98	-13.26
YPS-045	-4.01	-4.01	-4.01	-4.01	-12.26	-12.26	-12.26	-12.26	-13.09
YPS-143	-3.97	-3.97	-3.97	-3.97	-12.21	-12.21	-12.21	-12.21	-13.00
YPS-071	-3.97	-3.97	-3.97	-3.97	-11.97	-11.97	-11.97	-11.97	-12.87
YPS-126	-3.86	-3.86	-3.86	-3.86	-11.97	-11.97	-11.97	-11.97	-12.45
YPS-003	-3.80	-3.80	-3.80	-3.80	-11.92	-11.92	-11.92	-11.92	-12.21
YPS-038	-3.50	-3.50	-3.50	-3.50	-11.87	-11.87	-11.87	-11.87	-11.97
YPS-049	-3.33	-3.33	-3.33	-3.33	-11.84	-11.84	-11.84	-11.84	-11.97
YPS-138	-3.25	-3.25	-3.25	-3.25	-11.37	-11.37	-11.37	-11.37	-11.92
YPS-057	-3.09	-3.09	-3.09	-3.09	-11.21	-11.21	-11.21	-11.21	-11.84
YPS-031	-3.01	-3.01	-3.01	-3.01	-11.21	-11.21	-11.21	-11.21	-11.80
YPS-123	-2.97	-2.97	-2.97	-2.97	-10.91	-10.91	-10.91	-10.91	-11.61
YPS-058	-2.73	-2.73	-2.73	-2.73	-10.76	-10.76	-10.76	-10.76	-11.37
YPS-043	-2.64	-2.64	-2.64	-2.64	-10.61	-10.61	-10.61	-10.61	-11.21
YPS-059	-2.55	-2.55	-2.55	-2.55	-10.59	-10.59	-10.59	-10.59	-11.21
YPS-167	-2.48	-2.48	-2.48	-2.48	-10.55	-10.55	-10.55	-10.55	-11.00
YPS-026	-2.43	-2.43	-2.43	-2.43	-10.45	-10.45	-10.45	-10.45	-10.76
YPS-150	-2.27	-2.27	-2.27	-2.27	-10.43	-10.43	-10.43	-10.43	-10.59
YPS-004	-2.21	-2.21	-2.21	-2.21	-10.40	-10.40	-10.40	-10.40	-10.55

YPS-137	-1.92	-1.92	-1.92	-1.92	-10.25	-10.25	-10.25	-10.25	-10.54
YPS-040	-1.39	-1.39	-1.39	-1.39	-10.25	-10.25	-10.25	-10.25	-10.43
YPS-014	-1.26	-1.26	-1.26	-1.26	-10.05	-10.05	-10.05	-10.05	-10.40
YPS-013	-1.21	-1.21	-1.21	-1.21	-10.00	-10.00	-10.00	-10.00	-10.30
YPS-121	-1.12	-1.12	-1.12	-1.12	-9.80	-9.80	-9.80	-9.80	-10.25
YPS-136	-1.03	-1.03	-1.03	-1.03	-9.73	-9.73	-9.73	-9.73	-10.25
YPS-015	-1.00	-1.00	-1.00	-1.00	-9.63	-9.63	-9.63	-9.63	-10.05
YPS-066	-0.92	-0.92	-0.92	-0.92	-9.33	-9.33	-9.33	-9.33	-9.84
YPS-069	-0.84	-0.84	-0.84	-0.84	-9.30	-9.30	-9.30	-9.30	-9.73
YPS-076	-0.80	-0.80	-0.80	-0.80	-9.28	-9.28	-9.28	-9.28	-9.63
YPS-025	-0.76	-0.76	-0.76	-0.76	-9.27	-9.27	-9.27	-9.27	-9.33
YPS-067	-0.73	-0.73	-0.73	-0.73	-9.26	-9.26	-9.26	-9.26	-9.33
YPS-154	-0.64	-0.64	-0.64	-0.64	-9.03	-9.03	-9.03	-9.03	-9.28
YPS-022	-0.59	-0.59	-0.59	-0.59	-9.01	-9.01	-9.01	-9.01	-9.27
YPS-005	-0.59	-0.59	-0.59	-0.59	-8.80	-8.80	-8.80	-8.80	-9.26
YPS-127	-0.58	-0.58	-0.58	-0.58	-8.64	-8.64	-8.64	-8.64	-9.25
YPS-068	-0.57	-0.57	-0.57	-0.57	-8.57	-8.57	-8.57	-8.57	-9.20
YPS-034	-0.31	-0.31	-0.31	-0.31	-8.54	-8.54	-8.54	-8.54	-9.09
YPS-062	-0.28	-0.28	-0.28	-0.28	-8.52	-8.52	-8.52	-8.52	-9.09
YPS-007	-0.26	-0.26	-0.26	-0.26	-8.31	-8.31	-8.31	-8.31	-9.03
YPS-008	-0.09	-0.09	-0.09	-0.09	-8.25	-8.25	-8.25	-8.25	-9.01
YPS-039	-0.03	-0.03	-0.03	-0.03	-8.23	-8.23	-8.23	-8.23	-9.01
YPS-037	-0.01	-0.01	-0.01	-0.01	-8.09	-8.09	-8.09	-8.09	-8.86
YPS-144	0.00	0.00	0.00	0.00	-8.09	-8.09	-8.09	-8.09	-8.80
YPS-074	0.02	0.02	0.02	0.02	-8.01	-8.01	-8.01	-8.01	-8.64
YPS-035	0.14	0.14	0.14	0.14	-8.00	-8.00	-8.00	-8.00	-8.64
YPS-129	0.15	0.15	0.15	0.15	-7.86	-7.86	-7.86	-7.86	-8.57
YPS-027	0.16	0.16	0.16	0.16	-7.86	-7.86	-7.86	-7.86	-8.52
YPS-163	0.16	0.16	0.16	0.16	-7.83	-7.83	-7.83	-7.83	-8.34
YPS-064	0.17	0.17	0.17	0.17	-7.75	-7.75	-7.75	-7.75	-8.31
YPS-063	0.25	0.25	0.25	0.25	-7.64	-7.64	-7.64	-7.64	-8.23
YPS-134	0.37	0.37	0.37	0.37	-7.59	-7.59	-7.59	-7.59	-8.12
YPS-056	0.48	0.48	0.48	0.48	-7.54	-7.54	-7.54	-7.54	-8.01
YPS-162	0.66	0.66	0.66	0.66	-7.50	-7.50	-7.50	-7.50	-8.00
YPS-073	0.70	0.70	0.70	0.70	-7.33	-7.33	-7.33	-7.33	-7.86
YPS-021	1.00	1.00	1.00	1.00	-7.20	-7.20	-7.20	-7.20	-7.83
YPS-012	1.09	1.09	1.09	1.09	-7.12	-7.12	-7.12	-7.12	-7.82
YPS-142	1.12	1.12	1.12	1.12	-7.03	-7.03	-7.03	-7.03	-7.75
YPS-044	1.34	1.34	1.34	1.34	-6.84	-6.84	-6.84	-6.84	-7.59
YPS-120	1.53	1.53	1.53	1.53	-6.82	-6.82	-6.82	-6.82	-7.54
YPS-002	1.80	1.80	1.80	1.80	-6.36	-6.36	-6.36	-6.36	-7.50
YPS-141	1.91	1.91	1.91	1.91	-6.34	-6.34	-6.34	-6.34	-7.36
YPS-065	2.30	2.30	2.30	2.30	-6.34	-6.34	-6.34	-6.34	-7.33
YPS-139	2.39	2.39	2.39	2.39	-6.12	-6.12	-6.12	-6.12	-7.03
YPS-072	2.60	2.60	2.60	2.60	-6.01	-6.01	-6.01	-6.01	-6.56
YPS-036	2.66	2.66	2.66	2.66	-5.96	-5.96	-5.96	-5.96	-6.39
YPS-135	2.79	2.79	2.79	2.79	-5.85	-5.85	-5.85	-5.85	-6.34
YPS-122	2.88	2.88	2.88	2.88	-5.84	-5.84	-5.84	-5.84	-6.12
YPS-130	3.04	3.04	3.04	3.04	-5.58	-5.58	-5.58	-5.58	-6.01
YPS-060	3.18	3.18	3.18	3.18	-5.39	-5.39	-5.39	-5.39	-5.96
YPS-047	3.44	3.44	3.44	3.44	-5.01	-5.01	-5.01	-5.01	-5.85
YPS-157	3.63	3.63	3.63	3.63	-4.97	-4.97	-4.97	-4.97	-5.84
YPS-046	3.64	3.64	3.64	3.64	-4.92	-4.92	-4.92	-4.92	-5.58

YPS-156	3.67	3.67	3.67	3.67	-4.73	-4.73	-4.73	-4.73	-4.97
YPS-048	3.67	3.67	3.67	3.67	-4.57	-4.57	-4.57	-4.57	-4.92
YPS-019	3.75	3.75	3.75	3.75	-4.56	-4.56	-4.56	-4.56	-4.73
YPS-006	4.13	4.13	4.13	4.13	-4.47	-4.47	-4.47	-4.47	-4.57
YPS-017	4.46	4.46	4.46	4.46	-4.33	-4.33	-4.33	-4.33	-4.48
YPS-131	4.46	4.46	4.46	4.46	-3.88	-3.88	-3.88	-3.88	-4.47
YPS-042	4.52	4.52	4.52	4.52	-3.48	-3.48	-3.48	-3.48	-3.88
YPS-075	5.43	5.43	5.43	5.43	-2.70	-2.70	-2.70	-2.70	-3.66
YPS-061	5.99	5.99	5.99	5.99	-2.66	-2.66	-2.66	-2.66	-2.70

- Detection rates range from 28% for Simpact levels 1-4 to 98% for levels 5-8 and 99% for level 9. This jump occurs because it is at Simpact level 5 that BMI taxa begin to disappear.

Table 13. Results of the application of the BMI Taxon Richness model with Type 1 error set at 5% for Sediment Simpact Levels 1 - 9. Red indicates sites determined not to be in reference condition while blue indicates a reference condition determination.

YPS No.	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9
YPS-018	-9.25	-9.25	-9.25	-9.25	-15.57	-15.57	-15.57	-15.57	-16.57
YPS-041	-6.23	-6.23	-6.23	-6.23	-14.21	-14.21	-14.21	-14.21	-14.21
YPS-033	-5.05	-5.05	-5.05	-5.05	-13.48	-13.48	-13.48	-13.48	-13.98
YPS-128	-4.57	-4.57	-4.57	-4.57	-13.09	-13.09	-13.09	-13.09	-13.91
YPS-020	-4.45	-4.45	-4.45	-4.45	-13.00	-13.00	-13.00	-13.00	-13.48
YPS-155	-4.21	-4.21	-4.21	-4.21	-12.98	-12.98	-12.98	-12.98	-13.26
YPS-045	-4.01	-4.01	-4.01	-4.01	-12.26	-12.26	-12.26	-12.26	-13.09
YPS-143	-3.97	-3.97	-3.97	-3.97	-12.21	-12.21	-12.21	-12.21	-13.00
YPS-071	-3.97	-3.97	-3.97	-3.97	-11.97	-11.97	-11.97	-11.97	-12.87
YPS-126	-3.86	-3.86	-3.86	-3.86	-11.97	-11.97	-11.97	-11.97	-12.45
YPS-003	-3.80	-3.80	-3.80	-3.80	-11.92	-11.92	-11.92	-11.92	-12.21
YPS-038	-3.50	-3.50	-3.50	-3.50	-11.87	-11.87	-11.87	-11.87	-11.97
YPS-049	-3.33	-3.33	-3.33	-3.33	-11.84	-11.84	-11.84	-11.84	-11.97
YPS-138	-3.25	-3.25	-3.25	-3.25	-11.37	-11.37	-11.37	-11.37	-11.92
YPS-057	-3.09	-3.09	-3.09	-3.09	-11.21	-11.21	-11.21	-11.21	-11.84
YPS-031	-3.01	-3.01	-3.01	-3.01	-11.21	-11.21	-11.21	-11.21	-11.80
YPS-123	-2.97	-2.97	-2.97	-2.97	-10.91	-10.91	-10.91	-10.91	-11.61
YPS-058	-2.73	-2.73	-2.73	-2.73	-10.76	-10.76	-10.76	-10.76	-11.37
YPS-043	-2.64	-2.64	-2.64	-2.64	-10.61	-10.61	-10.61	-10.61	-11.21
YPS-059	-2.55	-2.55	-2.55	-2.55	-10.59	-10.59	-10.59	-10.59	-11.21
YPS-167	-2.48	-2.48	-2.48	-2.48	-10.55	-10.55	-10.55	-10.55	-11.00
YPS-026	-2.43	-2.43	-2.43	-2.43	-10.45	-10.45	-10.45	-10.45	-10.76
YPS-150	-2.27	-2.27	-2.27	-2.27	-10.43	-10.43	-10.43	-10.43	-10.59
YPS-004	-2.21	-2.21	-2.21	-2.21	-10.40	-10.40	-10.40	-10.40	-10.55
YPS-137	-1.92	-1.92	-1.92	-1.92	-10.25	-10.25	-10.25	-10.25	-10.54
YPS-040	-1.39	-1.39	-1.39	-1.39	-10.25	-10.25	-10.25	-10.25	-10.43
YPS-014	-1.26	-1.26	-1.26	-1.26	-10.05	-10.05	-10.05	-10.05	-10.40
YPS-013	-1.21	-1.21	-1.21	-1.21	-10.00	-10.00	-10.00	-10.00	-10.30
YPS-121	-1.12	-1.12	-1.12	-1.12	-9.80	-9.80	-9.80	-9.80	-10.25
YPS-136	-1.03	-1.03	-1.03	-1.03	-9.73	-9.73	-9.73	-9.73	-10.25
YPS-015	-1.00	-1.00	-1.00	-1.00	-9.63	-9.63	-9.63	-9.63	-10.05
YPS-066	-0.92	-0.92	-0.92	-0.92	-9.33	-9.33	-9.33	-9.33	-9.84
YPS-069	-0.84	-0.84	-0.84	-0.84	-9.30	-9.30	-9.30	-9.30	-9.73
YPS-076	-0.80	-0.80	-0.80	-0.80	-9.28	-9.28	-9.28	-9.28	-9.63

YPS-025	-0.76	-0.76	-0.76	-0.76	-9.27	-9.27	-9.27	-9.27	-9.33
YPS-067	-0.73	-0.73	-0.73	-0.73	-9.26	-9.26	-9.26	-9.26	-9.33
YPS-154	-0.64	-0.64	-0.64	-0.64	-9.03	-9.03	-9.03	-9.03	-9.28
YPS-022	-0.59	-0.59	-0.59	-0.59	-9.01	-9.01	-9.01	-9.01	-9.27
YPS-005	-0.59	-0.59	-0.59	-0.59	-8.80	-8.80	-8.80	-8.80	-9.26
YPS-127	-0.58	-0.58	-0.58	-0.58	-8.64	-8.64	-8.64	-8.64	-9.25
YPS-068	-0.57	-0.57	-0.57	-0.57	-8.57	-8.57	-8.57	-8.57	-9.20
YPS-034	-0.31	-0.31	-0.31	-0.31	-8.54	-8.54	-8.54	-8.54	-9.09
YPS-062	-0.28	-0.28	-0.28	-0.28	-8.52	-8.52	-8.52	-8.52	-9.09
YPS-007	-0.26	-0.26	-0.26	-0.26	-8.31	-8.31	-8.31	-8.31	-9.03
YPS-008	-0.09	-0.09	-0.09	-0.09	-8.25	-8.25	-8.25	-8.25	-9.01
YPS-039	-0.03	-0.03	-0.03	-0.03	-8.23	-8.23	-8.23	-8.23	-9.01
YPS-037	-0.01	-0.01	-0.01	-0.01	-8.09	-8.09	-8.09	-8.09	-8.86
YPS-144	0.00	0.00	0.00	0.00	-8.09	-8.09	-8.09	-8.09	-8.80
YPS-074	0.02	0.02	0.02	0.02	-8.01	-8.01	-8.01	-8.01	-8.64
YPS-035	0.14	0.14	0.14	0.14	-8.00	-8.00	-8.00	-8.00	-8.64
YPS-129	0.15	0.15	0.15	0.15	-7.86	-7.86	-7.86	-7.86	-8.57
YPS-027	0.16	0.16	0.16	0.16	-7.86	-7.86	-7.86	-7.86	-8.52
YPS-163	0.16	0.16	0.16	0.16	-7.83	-7.83	-7.83	-7.83	-8.34
YPS-064	0.17	0.17	0.17	0.17	-7.75	-7.75	-7.75	-7.75	-8.31
YPS-063	0.25	0.25	0.25	0.25	-7.64	-7.64	-7.64	-7.64	-8.23
YPS-134	0.37	0.37	0.37	0.37	-7.59	-7.59	-7.59	-7.59	-8.12
YPS-056	0.48	0.48	0.48	0.48	-7.54	-7.54	-7.54	-7.54	-8.01
YPS-162	0.66	0.66	0.66	0.66	-7.50	-7.50	-7.50	-7.50	-8.00
YPS-073	0.70	0.70	0.70	0.70	-7.33	-7.33	-7.33	-7.33	-7.86
YPS-021	1.00	1.00	1.00	1.00	-7.20	-7.20	-7.20	-7.20	-7.83
YPS-012	1.09	1.09	1.09	1.09	-7.12	-7.12	-7.12	-7.12	-7.82
YPS-142	1.12	1.12	1.12	1.12	-7.03	-7.03	-7.03	-7.03	-7.75
YPS-044	1.34	1.34	1.34	1.34	-6.84	-6.84	-6.84	-6.84	-7.59
YPS-120	1.53	1.53	1.53	1.53	-6.82	-6.82	-6.82	-6.82	-7.54
YPS-002	1.80	1.80	1.80	1.80	-6.36	-6.36	-6.36	-6.36	-7.50
YPS-141	1.91	1.91	1.91	1.91	-6.34	-6.34	-6.34	-6.34	-7.36
YPS-065	2.30	2.30	2.30	2.30	-6.34	-6.34	-6.34	-6.34	-7.33
YPS-139	2.39	2.39	2.39	2.39	-6.12	-6.12	-6.12	-6.12	-7.03
YPS-072	2.60	2.60	2.60	2.60	-6.01	-6.01	-6.01	-6.01	-6.56
YPS-036	2.66	2.66	2.66	2.66	-5.96	-5.96	-5.96	-5.96	-6.39
YPS-135	2.79	2.79	2.79	2.79	-5.85	-5.85	-5.85	-5.85	-6.34
YPS-122	2.88	2.88	2.88	2.88	-5.84	-5.84	-5.84	-5.84	-6.12
YPS-130	3.04	3.04	3.04	3.04	-5.58	-5.58	-5.58	-5.58	-6.01
YPS-060	3.18	3.18	3.18	3.18	-5.39	-5.39	-5.39	-5.39	-5.96
YPS-047	3.44	3.44	3.44	3.44	-5.01	-5.01	-5.01	-5.01	-5.85
YPS-157	3.63	3.63	3.63	3.63	-4.97	-4.97	-4.97	-4.97	-5.84
YPS-046	3.64	3.64	3.64	3.64	-4.92	-4.92	-4.92	-4.92	-5.58
YPS-156	3.67	3.67	3.67	3.67	-4.73	-4.73	-4.73	-4.73	-4.97
YPS-048	3.67	3.67	3.67	3.67	-4.57	-4.57	-4.57	-4.57	-4.92
YPS-019	3.75	3.75	3.75	3.75	-4.56	-4.56	-4.56	-4.56	-4.73
YPS-006	4.13	4.13	4.13	4.13	-4.47	-4.47	-4.47	-4.47	-4.57
YPS-017	4.46	4.46	4.46	4.46	-4.33	-4.33	-4.33	-4.33	-4.48
YPS-131	4.46	4.46	4.46	4.46	-3.88	-3.88	-3.88	-3.88	-4.47
YPS-042	4.52	4.52	4.52	4.52	-3.48	-3.48	-3.48	-3.48	-3.88
YPS-075	5.43	5.43	5.43	5.43	-2.70	-2.70	-2.70	-2.70	-3.66
YPS-061	5.99	5.99	5.99	5.99	-2.66	-2.66	-2.66	-2.66	-2.70

- Detection rates range from 7% for Simpact levels 1-4 to 94% for levels 5-8 and 97% for level 9. Again, this jump occurs because it is at Simpact level 5 that BMI taxa begin to disappear.

Table 14. Results of the application of the BMI Hilsenhoff Index model with Type 1 error set at 25% for Sediment Simpact Levels 1 - 9. Red indicates sites determined not to be in reference condition while blue indicates a reference condition determination.

YPS No.	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9
YPS-076	1.507	1.565	1.775	1.932	2.781	2.781	2.781	2.781	2.781
YPS-073	1.382	1.454	1.687	1.865	2.756	2.756	2.756	2.756	2.756
YPS-045	1.231	1.302	1.677	1.775	2.697	2.697	2.697	2.697	2.697
YPS-018	1.052	1.094	1.545	1.758	2.573	2.573	2.573	2.573	2.573
YPS-129	1.027	1.073	1.458	1.717	2.374	2.374	2.374	2.374	2.374
YPS-048	0.981	1.054	1.389	1.627	2.336	2.336	2.336	2.336	2.336
YPS-037	0.958	0.986	1.288	1.539	2.244	2.244	2.244	2.244	2.244
YPS-059	0.901	0.986	1.275	1.525	2.233	2.233	2.233	2.233	2.233
YPS-041	0.900	0.892	1.238	1.464	2.132	2.132	2.132	2.132	2.132
YPS-063	0.820	0.891	1.212	1.342	2.127	2.127	2.127	2.127	2.127
YPS-136	0.816	0.871	1.152	1.335	2.032	2.032	2.032	2.032	2.032
YPS-121	0.761	0.845	1.147	1.332	2.008	2.008	2.008	2.008	2.008
YPS-042	0.726	0.802	1.059	1.259	1.950	1.950	1.950	1.950	1.950
YPS-005	0.716	0.787	1.038	1.254	1.922	1.922	1.922	1.922	1.922
YPS-027	0.679	0.769	1.025	1.189	1.888	1.888	1.888	1.888	1.888
YPS-003	0.660	0.762	1.001	1.189	1.788	1.788	1.788	1.788	1.788
YPS-019	0.652	0.731	0.971	1.162	1.773	1.773	1.773	1.773	1.773
YPS-141	0.622	0.727	0.931	1.150	1.771	1.771	1.771	1.771	1.771
YPS-002	0.611	0.683	0.929	1.060	1.765	1.765	1.765	1.765	1.765
YPS-156	0.599	0.661	0.891	1.053	1.757	1.757	1.757	1.757	1.757
YPS-138	0.566	0.644	0.890	1.026	1.745	1.745	1.745	1.745	1.745
YPS-157	0.419	0.515	0.882	1.009	1.668	1.668	1.668	1.668	1.668
YPS-057	0.407	0.480	0.869	1.006	1.663	1.663	1.663	1.663	1.663
YPS-047	0.360	0.440	0.867	0.991	1.649	1.649	1.649	1.649	1.649
YPS-031	0.359	0.439	0.862	0.967	1.624	1.624	1.624	1.624	1.624
YPS-015	0.328	0.423	0.802	0.939	1.587	1.587	1.587	1.587	1.587
YPS-068	0.302	0.381	0.747	0.918	1.546	1.546	1.546	1.546	1.546
YPS-036	0.295	0.381	0.740	0.905	1.526	1.526	1.526	1.526	1.526
YPS-013	0.281	0.376	0.725	0.886	1.509	1.509	1.509	1.509	1.509
YPS-126	0.281	0.368	0.723	0.871	1.488	1.488	1.488	1.488	1.488
YPS-139	0.271	0.365	0.710	0.866	1.483	1.483	1.483	1.483	1.483
YPS-163	0.246	0.355	0.709	0.862	1.449	1.449	1.449	1.449	1.449
YPS-020	0.243	0.325	0.687	0.859	1.417	1.417	1.417	1.417	1.417
YPS-142	0.242	0.285	0.679	0.835	1.405	1.405	1.405	1.405	1.405
YPS-007	0.190	0.278	0.645	0.815	1.372	1.372	1.372	1.372	1.372
YPS-061	0.181	0.271	0.638	0.804	1.347	1.347	1.347	1.347	1.347
YPS-143	0.170	0.266	0.595	0.796	1.335	1.335	1.335	1.335	1.335
YPS-128	0.156	0.213	0.589	0.795	1.302	1.302	1.302	1.302	1.302
YPS-120	0.121	0.212	0.589	0.769	1.287	1.287	1.287	1.287	1.287
YPS-135	0.094	0.186	0.582	0.768	1.274	1.274	1.274	1.274	1.274
YPS-062	0.086	0.167	0.577	0.767	1.239	1.239	1.239	1.239	1.239
YPS-046	0.073	0.167	0.460	0.726	1.238	1.238	1.238	1.238	1.238
YPS-130	0.065	0.158	0.445	0.705	1.226	1.226	1.226	1.226	1.226

YPS-014	0.031	0.126	0.422	0.681	1.224	1.224	1.224	1.224	1.224
YPS-167	0.027	0.104	0.399	0.662	1.203	1.203	1.203	1.203	1.203
YPS-122	-0.017	0.100	0.379	0.652	1.201	1.201	1.201	1.201	1.201
YPS-026	-0.024	0.079	0.364	0.630	1.181	1.181	1.181	1.181	1.181
YPS-137	-0.026	0.076	0.363	0.589	1.163	1.163	1.163	1.163	1.163
YPS-049	-0.065	0.028	0.363	0.587	1.143	1.143	1.143	1.143	1.143
YPS-040	-0.067	-0.011	0.337	0.537	1.142	1.142	1.142	1.142	1.142
YPS-006	-0.094	-0.012	0.333	0.531	1.134	1.134	1.134	1.134	1.134
YPS-069	-0.118	-0.043	0.333	0.485	1.127	1.127	1.127	1.127	1.127
YPS-022	-0.127	-0.064	0.332	0.483	1.099	1.099	1.099	1.099	1.099
YPS-012	-0.154	-0.082	0.321	0.479	1.076	1.076	1.076	1.076	1.076
YPS-008	-0.179	-0.095	0.273	0.466	1.063	1.063	1.063	1.063	1.063
YPS-044	-0.185	-0.097	0.263	0.413	1.061	1.061	1.061	1.061	1.061
YPS-144	-0.211	-0.107	0.259	0.399	1.038	1.038	1.038	1.038	1.038
YPS-134	-0.256	-0.168	0.254	0.399	1.013	1.013	1.013	1.013	1.013
YPS-065	-0.287	-0.202	0.245	0.383	0.994	0.994	0.994	0.994	0.994
YPS-034	-0.302	-0.202	0.220	0.374	0.979	0.979	0.979	0.979	0.979
YPS-058	-0.332	-0.204	0.199	0.369	0.955	0.955	0.955	0.955	0.955
YPS-039	-0.339	-0.233	0.176	0.365	0.919	0.919	0.919	0.919	0.919
YPS-127	-0.342	-0.279	0.116	0.354	0.911	0.911	0.911	0.911	0.911
YPS-038	-0.344	-0.293	0.072	0.349	0.908	0.908	0.908	0.908	0.908
YPS-150	-0.376	-0.323	0.063	0.292	0.905	0.905	0.905	0.905	0.905
YPS-154	-0.401	-0.351	0.014	0.252	0.859	0.859	0.859	0.859	0.859
YPS-043	-0.447	-0.356	0.010	0.251	0.846	0.846	0.846	0.846	0.846
YPS-035	-0.468	-0.378	-0.005	0.240	0.826	0.826	0.826	0.826	0.826
YPS-155	-0.476	-0.383	-0.014	0.191	0.801	0.801	0.801	0.801	0.801
YPS-072	-0.512	-0.419	-0.034	0.184	0.734	0.734	0.734	0.734	0.734
YPS-162	-0.522	-0.422	-0.034	0.081	0.614	0.614	0.614	0.614	0.614
YPS-131	-0.566	-0.477	-0.069	0.080	0.595	0.595	0.595	0.595	0.595
YPS-056	-0.641	-0.501	-0.129	0.062	0.588	0.588	0.588	0.588	0.588
YPS-060	-0.649	-0.548	-0.170	0.058	0.549	0.549	0.549	0.549	0.549
YPS-067	-0.664	-0.581	-0.204	0.040	0.545	0.545	0.545	0.545	0.545
YPS-033	-0.691	-0.594	-0.257	0.028	0.533	0.533	0.533	0.533	0.533
YPS-066	-0.695	-0.640	-0.261	0.008	0.498	0.498	0.498	0.498	0.498
YPS-123	-0.723	-0.658	-0.267	-0.018	0.468	0.468	0.468	0.468	0.468
YPS-074	-0.737	-0.674	-0.291	-0.024	0.455	0.455	0.455	0.455	0.455
YPS-071	-0.737	-0.687	-0.301	-0.066	0.437	0.437	0.437	0.437	0.437
YPS-004	-0.812	-0.751	-0.409	-0.138	0.388	0.388	0.388	0.388	0.388
YPS-075	-0.906	-0.794	-0.429	-0.161	0.385	0.385	0.385	0.385	0.385
YPS-064	-1.088	-0.983	-0.433	-0.261	0.343	0.343	0.343	0.343	0.343
YPS-025	-1.278	-1.241	-0.811	-0.438	0.315	0.315	0.315	0.315	0.315
YPS-017	-1.423	-1.329	-0.993	-0.750	0.248	0.248	0.248	0.248	0.248
YPS-021	-1.583	-1.570	-1.480	-1.381	0.169	0.169	0.169	0.169	0.169

- Detection rates range from 29% for Simpact level 1, 37% for level 2, 56% for level 3, 73% for level 4 and 95% for levels 5-9.

Table 15. Results of the application of the BMI Hilsenhoff Index model with Type 1 error set at 5% for Sediment Simpact Levels 1 - 9. Red indicates sites determined not to be in reference condition while blue indicates a reference condition determination.

YPS No.	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9
YPS-076	1.507	1.565	1.775	1.932	2.781	2.781	2.781	2.781	2.781
YPS-073	1.382	1.454	1.687	1.865	2.756	2.756	2.756	2.756	2.756
YPS-045	1.231	1.302	1.677	1.775	2.697	2.697	2.697	2.697	2.697
YPS-018	1.052	1.094	1.545	1.758	2.573	2.573	2.573	2.573	2.573
YPS-129	1.027	1.073	1.458	1.717	2.374	2.374	2.374	2.374	2.374
YPS-048	0.981	1.054	1.389	1.627	2.336	2.336	2.336	2.336	2.336
YPS-037	0.958	0.986	1.288	1.539	2.244	2.244	2.244	2.244	2.244
YPS-059	0.901	0.986	1.275	1.525	2.233	2.233	2.233	2.233	2.233
YPS-041	0.900	0.892	1.238	1.464	2.132	2.132	2.132	2.132	2.132
YPS-063	0.820	0.891	1.212	1.342	2.127	2.127	2.127	2.127	2.127
YPS-136	0.816	0.871	1.152	1.335	2.032	2.032	2.032	2.032	2.032
YPS-121	0.761	0.845	1.147	1.332	2.008	2.008	2.008	2.008	2.008
YPS-042	0.726	0.802	1.059	1.259	1.950	1.950	1.950	1.950	1.950
YPS-005	0.716	0.787	1.038	1.254	1.922	1.922	1.922	1.922	1.922
YPS-027	0.679	0.769	1.025	1.189	1.888	1.888	1.888	1.888	1.888
YPS-003	0.660	0.762	1.001	1.189	1.788	1.788	1.788	1.788	1.788
YPS-019	0.652	0.731	0.971	1.162	1.773	1.773	1.773	1.773	1.773
YPS-141	0.622	0.727	0.931	1.150	1.771	1.771	1.771	1.771	1.771
YPS-002	0.611	0.683	0.929	1.060	1.765	1.765	1.765	1.765	1.765
YPS-156	0.599	0.661	0.891	1.053	1.757	1.757	1.757	1.757	1.757
YPS-138	0.566	0.644	0.890	1.026	1.745	1.745	1.745	1.745	1.745
YPS-157	0.419	0.515	0.882	1.009	1.668	1.668	1.668	1.668	1.668
YPS-057	0.407	0.480	0.869	1.006	1.663	1.663	1.663	1.663	1.663
YPS-047	0.360	0.440	0.867	0.991	1.649	1.649	1.649	1.649	1.649
YPS-031	0.359	0.439	0.862	0.967	1.624	1.624	1.624	1.624	1.624
YPS-015	0.328	0.423	0.802	0.939	1.587	1.587	1.587	1.587	1.587
YPS-068	0.302	0.381	0.747	0.918	1.546	1.546	1.546	1.546	1.546
YPS-036	0.295	0.381	0.740	0.905	1.526	1.526	1.526	1.526	1.526
YPS-013	0.281	0.376	0.725	0.886	1.509	1.509	1.509	1.509	1.509
YPS-126	0.281	0.368	0.723	0.871	1.488	1.488	1.488	1.488	1.488
YPS-139	0.271	0.365	0.710	0.866	1.483	1.483	1.483	1.483	1.483
YPS-163	0.246	0.355	0.709	0.862	1.449	1.449	1.449	1.449	1.449
YPS-020	0.243	0.325	0.687	0.859	1.417	1.417	1.417	1.417	1.417
YPS-142	0.242	0.285	0.679	0.835	1.405	1.405	1.405	1.405	1.405
YPS-007	0.190	0.278	0.645	0.815	1.372	1.372	1.372	1.372	1.372
YPS-061	0.181	0.271	0.638	0.804	1.347	1.347	1.347	1.347	1.347
YPS-143	0.170	0.266	0.595	0.796	1.335	1.335	1.335	1.335	1.335
YPS-128	0.156	0.213	0.589	0.795	1.302	1.302	1.302	1.302	1.302
YPS-120	0.121	0.212	0.589	0.769	1.287	1.287	1.287	1.287	1.287
YPS-135	0.094	0.186	0.582	0.768	1.274	1.274	1.274	1.274	1.274
YPS-062	0.086	0.167	0.577	0.767	1.239	1.239	1.239	1.239	1.239
YPS-046	0.073	0.167	0.460	0.726	1.238	1.238	1.238	1.238	1.238
YPS-130	0.065	0.158	0.445	0.705	1.226	1.226	1.226	1.226	1.226
YPS-014	0.031	0.126	0.422	0.681	1.224	1.224	1.224	1.224	1.224
YPS-167	0.027	0.104	0.399	0.662	1.203	1.203	1.203	1.203	1.203
YPS-122	-0.017	0.100	0.379	0.652	1.201	1.201	1.201	1.201	1.201
YPS-026	-0.024	0.079	0.364	0.630	1.181	1.181	1.181	1.181	1.181

YPS-137	-0.026	0.076	0.363	0.589	1.163	1.163	1.163	1.163	1.163
YPS-049	-0.065	0.028	0.363	0.587	1.143	1.143	1.143	1.143	1.143
YPS-040	-0.067	-0.011	0.337	0.537	1.142	1.142	1.142	1.142	1.142
YPS-006	-0.094	-0.012	0.333	0.531	1.134	1.134	1.134	1.134	1.134
YPS-069	-0.118	-0.043	0.333	0.485	1.127	1.127	1.127	1.127	1.127
YPS-022	-0.127	-0.064	0.332	0.483	1.099	1.099	1.099	1.099	1.099
YPS-012	-0.154	-0.082	0.321	0.479	1.076	1.076	1.076	1.076	1.076
YPS-008	-0.179	-0.095	0.273	0.466	1.063	1.063	1.063	1.063	1.063
YPS-044	-0.185	-0.097	0.263	0.413	1.061	1.061	1.061	1.061	1.061
YPS-144	-0.211	-0.107	0.259	0.399	1.038	1.038	1.038	1.038	1.038
YPS-134	-0.256	-0.168	0.254	0.399	1.013	1.013	1.013	1.013	1.013
YPS-065	-0.287	-0.202	0.245	0.383	0.994	0.994	0.994	0.994	0.994
YPS-034	-0.302	-0.202	0.220	0.374	0.979	0.979	0.979	0.979	0.979
YPS-058	-0.332	-0.204	0.199	0.369	0.955	0.955	0.955	0.955	0.955
YPS-039	-0.339	-0.233	0.176	0.365	0.919	0.919	0.919	0.919	0.919
YPS-127	-0.342	-0.279	0.116	0.354	0.911	0.911	0.911	0.911	0.911
YPS-038	-0.344	-0.293	0.072	0.349	0.908	0.908	0.908	0.908	0.908
YPS-150	-0.376	-0.323	0.063	0.292	0.905	0.905	0.905	0.905	0.905
YPS-154	-0.401	-0.351	0.014	0.252	0.859	0.859	0.859	0.859	0.859
YPS-043	-0.447	-0.356	0.010	0.251	0.846	0.846	0.846	0.846	0.846
YPS-035	-0.468	-0.378	-0.005	0.240	0.826	0.826	0.826	0.826	0.826
YPS-155	-0.476	-0.383	-0.014	0.191	0.801	0.801	0.801	0.801	0.801
YPS-072	-0.512	-0.419	-0.034	0.184	0.734	0.734	0.734	0.734	0.734
YPS-162	-0.522	-0.422	-0.034	0.081	0.614	0.614	0.614	0.614	0.614
YPS-131	-0.566	-0.477	-0.069	0.080	0.595	0.595	0.595	0.595	0.595
YPS-056	-0.641	-0.501	-0.129	0.062	0.588	0.588	0.588	0.588	0.588
YPS-060	-0.649	-0.548	-0.170	0.058	0.549	0.549	0.549	0.549	0.549
YPS-067	-0.664	-0.581	-0.204	0.040	0.545	0.545	0.545	0.545	0.545
YPS-033	-0.691	-0.594	-0.257	0.028	0.533	0.533	0.533	0.533	0.533
YPS-066	-0.695	-0.640	-0.261	0.008	0.498	0.498	0.498	0.498	0.498
YPS-123	-0.723	-0.658	-0.267	-0.018	0.468	0.468	0.468	0.468	0.468
YPS-074	-0.737	-0.674	-0.291	-0.024	0.455	0.455	0.455	0.455	0.455
YPS-071	-0.737	-0.687	-0.301	-0.066	0.437	0.437	0.437	0.437	0.437
YPS-004	-0.812	-0.751	-0.409	-0.138	0.388	0.388	0.388	0.388	0.388
YPS-075	-0.906	-0.794	-0.429	-0.161	0.385	0.385	0.385	0.385	0.385
YPS-064	-1.088	-0.983	-0.433	-0.261	0.343	0.343	0.343	0.343	0.343
YPS-025	-1.278	-1.241	-0.811	-0.438	0.315	0.315	0.315	0.315	0.315
YPS-017	-1.423	-1.329	-0.993	-0.750	0.248	0.248	0.248	0.248	0.248
YPS-021	-1.583	-1.570	-1.480	-1.381	0.169	0.169	0.169	0.169	0.169

- Detection rates range from 7% for Simpact level 1, 9% for level 2, 20% for level 3, 29% for level 4 and 70% for levels 5-9.

7. Measuring temporal change

An issue for most agencies when investigating system response to anthropogenic factors is whether the assessment method can follow trends through time. This is the case with the new placer mining management regime, where it is important to be able to detect whether new allowable settlement discharge levels change the health of the stream system over a number of years.

To illustrate the suitability of the RCA approach in following temporal change, we have again used the Simpact data. We have investigated two scenarios, one of disturbance response to a new placer mine, the second the response to an improvement in an organic effluent discharge through reduction in organic load. In both scenarios, one Simpact site was selected at random and then the disturbance levels have been assessed against the matched reference sites, using the BEAST methodology. The assumption being that the change in the level of disturbance is analogous to system response in either a negative or positive way after a stress is released (recovery) or when a stress is imposed (disturbance). The Simpact disturbance levels are then surrogates for time intervals. Results are shown in Figure 7.

In the disturbance scenario (Figure 7A) the site before disturbance is well within the reference cloud and it can be seen to gradually move away from reference and follows a consistent trajectory through time (simulated by increasing level of disturbance). However, in this particular example, it does not move outside the reference cloud until the fifth sampling event (using 75% as the probability level). In the recovery scenario (Figure 7B) the pre-remediation condition is well outside the range observed at reference sites, but by the fourth sampling event the site is moving toward the target (the unSimpacted reference sites).

While illustrative only, these two scenarios clearly show the ability to track site response through time and that sites do follow consistent recovery or disturbance trajectories that would permit action triggers to be developed within a decision making framework (see e.g., Grapentine et al 2002).

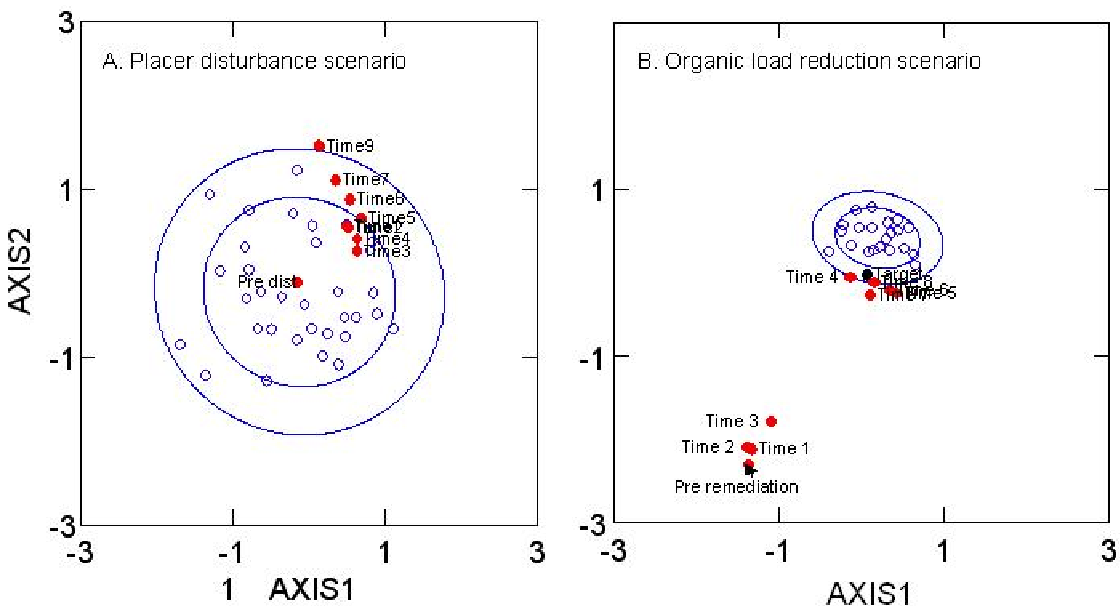

Figure 7. Assessment of temporal response to sites exposed to (A) sediment stress from placer activity and B) recovery after reduction in organic load (simulated data show response through time) where time 1 is first response and time 9 is full manifestation of effect) probability ellipses are 75 and 95%.

7. Discussion of Results

The Watershed Health Monitoring Protocol is intended to be only one piece in the larger management process for managing Yukon placer mining. It is intended that the RCA bioassessments of placer mining streams will provide indications of disturbance levels, with more focused study conducted where there may be problems. It is also intended that these bioassessments will be considered together with the results of water quality monitoring and other relevant sampling, in order to get as full a picture as possible of the effects placer mining may be having on these stream systems. Determinations of the state of aquatic systems and sources of impairment are generally supported by a preponderance of evidence rather than a single “silver bullet” and this will be the case under the new placer mining regime.

As additional stream sampling data is collected and analyzed, the RCA models will be re-calibrated and improved. Additional study will also result in a better general understanding of the stream systems of interest and provide more insight on linking the status of watershed health to specific activities. In the future, the program may also benefit from other bioassessment research conducted in the Yukon or elsewhere (e.g. sentinel fish studies). It is important to monitor other programs in order to identify and assess potentially useful bioassessment techniques that could augment the RCA program.

The key objectives of a watershed health monitoring program for the new placer mining regime are the ability to detect possible impacts from placer mining and to detect changes in watershed health over time that are attributable to the regulatory requirements of the new regime.

Analyzing BMI data with the BEAST model combined with the Fish Species Richness Regression is likely the best approach for achieving these objectives. There was no Simpact analysis conducted for the Fish Species Richness model. The small number of taxa and little tolerance variability make it difficult to generate realistic Simpact scenarios for fish communities. However, the Fish Species Richness model detected effects that the BMI-based models do not (Tables 7 & 9), suggesting that it is best to use both in a bioassessment program.

The BEAST method is the most appropriate of the BMI models for three reasons. First, by using different probability ellipses, a more nuanced determination and illustration of stream condition can be made (e.g. “undisturbed”, “possibly disturbed”, “disturbed”, and “very disturbed”. Second, the BEAST method is most effective for tracking and illustrating temporal changes in a given stream’s condition. Changes in the composition of a community from that expected if a site is in reference condition can be quantified and easily illustrated. Finally, the Canadian Bioassessment Network (CABIN) can provide the data analysis service for the BEAST method, which reduces the technical expertise requirement and provides the benefits of accessing a national program.

The BEAST Simpact analysis indicates that the best measure of sensitivity is probably the difference between the number of disturbed Simpact sites and Type 1 error sites. For example, the Sediment Simpact analysis summarized in Table 9 shows that at level 1, the 75% ellipse identifies 12 Simpact sites but there are 13 reference sites also identified as disturbed (Type 1 error). At level 3 the number of disturbed sites is greater than Type 1 error (23 v 14). Using the 95% level this does not happen until level 4, where 14 sites are identified as disturbed and there are 0 Type 1 errors. The 95% level is preferable as the number of Type 1 errors is low (close to 0), the difference between Type 1 errors and the number of detected sites is greater, but the number of disturbed sites detected (i.e., the power) is less, and the Type 2 error is greater. In the end this is not a scientific decision but a "societal" one, and requires determination of where the greater importance lies.

The Type 1 error policy decision generally depends on consideration of the implications of mistakenly concluding that a site that is not in reference condition when in fact it is (Bailey *et al.* 2004), and conversely the implications of concluding a site is not disturbed when it is (Type 2 error). There must also be consideration of available resources and priorities for field sampling, since it is often the case that sites that are judged to be possibly impaired are subject to more intense study and, if many of these sites are actually unimpaired, it may deflect valuable resources from where they may be more effectively used.

8. Conclusions & Recommendations

- The BMI BEAST model and Fish Species Richness Regression model appear to be the most effective approaches to data analysis for this program.

- In 2007, additional reference sites should be sampled or re-sampled and the BEAST and Regression analysis methods applied to re-calibrate and re-assess the performance of the models.

- Field samplers for 2007 should carefully review the sampling methodology to ensure sampling consistency. This should include particular attention to preparation, sample handling, labeling and record keeping.

- There should be efforts made to include the Yukon Placer Secretariat stream sampling program in the Canadian Bioassessment Network (CABIN) prior to the implementation on the new management regime.

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Appendix 1 – Field Sampling Methods

A sampling crew is ideally made up of 3 or 4 members, though 2 people if necessary can do the work. Most important is consistency in sampling and consequently, crewmembers should perform the same tasks at every sampling visit. It is particularly important that the same individual complete the EPA Habitat score sheets for all sites.

On arrival at a potential site location, it should be examined visually for suitability. A “site” is considered to be approximately 50 m. of the stream length, however, the most critical criterion is that there is a stream surface area of approximately 60 $m.^2$ within the site for collection of fish and benthic macroinvertebrates.

Fish sampling and water chemistry and sample collection are the first two tasks and can be done simultaneously if there are adequate crewmembers. Sampling benthic macroinvertebrates, measurement of stream dimensions and finally habitat assessment follows these. Notes should be taken regarding features of the site (e.g. existence of cabins, proximity to mining operation, etc.) and digital photographs of the site (up and downstream from the middle of the site and the substrate) should be taken.

The individual tasks are carried out using the following methods:

1. **Fish Sampling.**

   a) A section of approximately $60m^2$ at the site should be blocked off using ¼” seine nets. Natural barriers to fish movement may preclude the need for one or both nets. The blocked off section of the stream should contain all representative habitats for the stream site.

   b) Fish are sampled with a backpack electrofisher with a qualified operator and at least one netter catching shocked fish. The samplers enter the blocked off section of the site at its downstream end and fish upstream. The fishing duration is 600 seconds and should average 10 s/m^2. All habitats in the blocked off section should be fished with equal effort. Power and frequency settings on the electrofisher will vary, mostly depending on conductivity of the water in the stream. They should be adjusted to ensure all fish in the site are caught while minimizing mortality or effect on invertebrates. The netter catches shocked fish and transfers them to a bucket with stream water carried by the electrofisher operator. In some cases where fish are seen but not captured by the samplers, they should be identified and counted if possible. After the 600 seconds are complete, the downstream block net should be checked for fish that may have been shocked, but were not caught.

   c) After sampling, all collected fish are identified and counted, and returned to the stream. Voucher samples and unidentified fish are preserved for subsequent identification or verification. Retained samples should be preserved in a 10% formalin solution, unless they are to undergo genetic analysis, in which case they should be preserved in 95% ethanol.

2. Water Chemistry and sample collection.

a) Upstream of the fishing area, basic water chemistry is measured using electronic meters. pH, temperature, conductivity and dissolved oxygen. Two water samples are collected: one litre of untreated stream water and 250 ml. that is acidified with 3 drops of hydrochloric acid. These samples for laboratory analysis and must be chilled (on ice or in a refrigerator) until delivered to the laboratory.

b) Laboratory analysis includes chemistry (pH, conductivity, dissolved oxygen, alkalinity), physical properties (Total dissolved solids, total suspended solids), organic nutrient content and metals.

3. Benthic Macroinvertebrate (BMI) Sampling

a) BMI are sampled at the same site as the fish were sampled. A 500 µm kick-net is used and a 3-minute kick, sampling all represented habitats is carried out. Samples are cleaned of large debris and then preserved for identification in 10% formalin and transferred after at least 3 days to 70% ethanol unless otherwise specified by the identification laboratory.

b) BMI are sub-sampled in order to estimate abundance, picked and identified to lowest possible taxon group, with at least 200 specimens sub-sampled.

c) Site characteristics, stream measurements and habitat scores.

a. Complete sampling site field sheets.

b. Complete EPA Habitat scores.

Appendix 2 – Geographical Information System (GIS) Data

1. Determine the location (latitude and longitude) of potential sites and convert to a point file using ARCGIS 9.0 (ESRI 2005)

2. Assemble the required 1:50.000 digital elevation maps (DEMs) required to cover the anticipated catchment(s) of one or more potential sites (available from Yukon Geomatics).

3. Delineate upstream catchments using the ArcHydro 1.1 extension for ArcGIS 9.0 (ESRI 2005). ArcHydro can also delineate watersheds in every sub-basin (confluence of two streams) within the DEM as well as the outflow points of these catchment areas. This is another way of cataloguing potential reference and test sites in a given area.

4. Use Hawth's Tools with ARCGIS 9.0 to determine the perimeter and area of each delineated catchment. These are used as environmental descriptors of the site.

5. Overlay the shape files of the catchment areas of the potentially sampled sites onto layers with both natural (e.g. geology, stream network, climate) and potential stressor (e.g. roads, mining claims, forest fire history). Use ArcGIS with Microsoft Access to catalogue the landscape information for each potentially sampled catchment into a flat (spreadsheet) file.

6. Using ArcGIS, create a map with the potential sampling sites and other GIS information, and use this and other information (satellite imagery, local and regional knowledge, data from previously sampled sites) to determine which sites will be candidates for sampling.

Appendix 3 – Reference Site Locations.

YPS No.	STUDY$	SITE	DATE	Status	LAT.	LONG.	Description
YPS-002	YRB	4	07/09/04	Ref	60.2330	-133.8994	Haunka Creek
YPS-003	YRB	5	07/10/04	Ref	60.5022	-133.2669	Unnamed Creek on S. Canol
YPS-004	YRB	6	07/10/04	Ref	60.5209	-133.2109	4-mile Creek
YPS-005	YRB	7	07/10/04	Ref	60.6138	-133.0456	Moose Creek (South)
YPS-006	YRB	15	07/07/04	Ref	61.6317	-135.8870	Klusha Creek
YPS-007	YRB	19	07/07/04	Ref	62.5361	-136.7658	McCabe Creek
YPS-008	YRB	20	07/07/04	Ref	63.0016	-136.4900	Willow Creek (South)
YPS-012	YRB	28	07/04/04	Ref	63.5084	-137.0208	Moose Creek (North)
YPS-013	YRB	31	07/06/04	Ref	63.7874	-137.8209	Willow Creek (North)
YPS-014	YRB	33	07/05/04	Ref	64.5054	-138.2244	North Klondike River
YPS-015	YRB	36	07/05/04	Ref	64.2788	-138.4909	Peasoup Creek
YPS-017	YRB	49	07/14/04	Ref	60.7990	-135.9988	Stony Creek
YPS-018	YRB	54	07/03/04	Ref	60.3885	-134.1274	Judas Creek (Above Highway)
YPS-019	YRB	54	07/15/04	Ref	60.3885	-134.1274	Judas Creek (Below Highway)
YPS-020	YRB	56	07/11/04	Ref	60.1286	-132.7202	Unnamed inflow to Teslin Lake
YPS-021	YRB	57	07/11/04	Ref	60.1166	-132.7031	Unnamed inflow to Teslin Lake
YPS-022	YRB	59	07/11/04	Ref	60.1830	-132.7915	Fox Creek (South)
YPS-023	YRB	61	07/11/04	Ref	60.3393	-133.0640	Deadman Creek
YPS-025	YRB	66	07/10/04	Ref	60.5457	-133.1709	Unnamed Creek on S. Canol
YPS-026	YRB	67	07/13/04	Ref	61.4891	-139.2750	Snafu Creek
YPS-027	YRB	70	07/13/04	Ref	61.3694	-138.6995	Unnamed inflow to Kluane L. N. of Gladstone
YPS-028	YRB	71	07/13/04	Ref	61.3871	-138.7437	Unnamed inf to Kluane L.N. of Gladstone w/cabin
YPS-031	YRB	76	07/10/05	Ref	62.0777	-136.0647	Inflow to Yukon River upstream of Carmacks
YPS-033	YRB	78	07/11/05	Ref	64.2496	-139.7261	Inf to Yukon R across from Chandindu R
YPS-034	YRB	79	07/11/05	Ref	64.2240	-139.5957	Inflow to Yukon River downstream of Dawson
YPS-035	YRB	80	07/11/05	Ref	64.1718	-139.5437	Québec Creek
YPS-036	YRB	81	07/11/05	Ref	64.1049	-139.4667	Deadwood Creek
YPS-037	YRB	82	07/12/05	Ref	63.7620	-139.7546	Inf to Yukon R ustream and across from Indian R
YPS-038	YRB	83	07/12/05	Ref	63.7923	-139.7754	Galena Creek
YPS-039	YRB	84	07/12/05	Ref	63.9186	-139.7403	Garner Creek
YPS-040	YRB	85	07/12/05	Ref	63.9641	-139.6620	Caribou Creek
YPS-041	YRB	86	07/13/05	Ref	67.5818	-139.6125	Porcupine River trib upstream Old Crow
YPS-042	YRB	87	07/13/05	Ref	67.5575	-139.4632	Porcupine River trib upstream Old Crow
YPS-043	YRB	88	07/13/05	Ref	67.5236	-139.3313	Porcupine River trib upstream Old Crow
YPS-044	YRB	89	07/13/05	Ref	67.5468	-139.1636	Porcupine River trib upstream Old Crow
YPS-045	YRB	90	07/14/05	Ref	67.5296	-139.8765	Porcupine River trib downstream Old Crow
YPS-046	YRB	91	07/14/05	Ref	67.5299	-139.9353	Porcupine River trib downstream Old Crow
YPS-047	YRB	92	07/14/05	Ref	67.5058	-139.8926	Porcupine River trib downstream Old Crow
YPS-048	YRB	93	07/14/05	Ref	67.5137	-139.9923	Porcupine River trib downstream Old Crow
YPS-049	YRB	94	07/14/05	Ref	67.4804	-140.1726	Porcupine River trib downstream Old Crow
YPS-050	YRB	95	07/14/05	Ref	67.4871	-140.2574	Bluefish River at Porcupine River
YPS-056	YRB	101	07/17/05	Ref	61.1164	-135.0914	Laurier Creek inflow to Lake Laberge
YPS-057	YRB	102	07/26/05	Ref	60.1154	-134.9255	Millhaven Creek inflow to Bennett L.
YPS-058	YRB	103	07/26/05	Ref	60.1100	-134.9241	Millhaven Creek inflow to Bennett L.
YPS-059	YRB	104	07/26/05	Ref	60.0505	-135.0222	Munroe Creek inflow to Bennett L.
YPS-060	YRB	105	07/26/05	Ref	60.0525	-135.0294	Latreille Creek inflow to Bennett L.
YPS-061	YRB	106	07/27/05	Ref	60.4883	-136.1446	Unnamed inflow to Kusuwa Lake
YPS-062	YRB	107	07/27/05	Ref	60.4135	-136.2791	Jo-Jo Creek inflow to Kusuwa Lake
YPS-063	YRB	108	07/27/05	Ref	60.3524	-136.4003	Unnamed inflow to Kusuwa Lake
YPS-064	YRB	109	07/27/05	Ref	60.3474	-136.3153	Unnamed inflow to Kusuwa Lake

YPS-065	YRB	110	07/28/05	Ref	61.4022	-138.6505	Kluane Lake Talbot Arm Inflow
YPS-066	YRB	111	07/28/05	Ref	61.4503	-138.6077	Kluane Lake Talbot Arm Inflow
YPS-067	YRB	112	07/28/05	Ref	61.5973	-138.6624	Kluane Lake Talbot Arm Inflow
YPS-068	YRB	113	07/28/05	Ref	61.5774	-138.6850	Kluane Lake Talbot Arm Inflow
YPS-069	YRB	114	07/28/05	Ref	61.5204	-138.6563	Kluane Lake Talbot Arm Inflow
YPS-071	YRB	116	07/30/05	Ref	60.1898	-134.2747	Tagish Lake inflow
YPS-072	YRB	117	07/30/05	Ref	60.1353	-134.2575	Tagish Lake inflow
YPS-073	YRB	118	07/30/05	Ref	60.1302	-134.3123	Tagish Lake inflow
YPS-074	YRB	119	07/30/05	Ref	60.4065	-134.2987	Kenny Creek inflow to Marsh Lake
YPS-075	YRB	120	07/30/05	Ref	60.4388	-134.3232	Monkey Creek inflow to Marsh Lake
YPS-076	YRB	121	07/31/05	Ref	60.6177	-134.8061	Inflow to Yukon River upstream of McCrae
YPS-120		RND-2	07/25/06	Ref	63.67257	-139.6088	Reindeer Creek
YPS-121		PED-1	07/26/06	Ref	62.89325	-138.7703	Pedlar Creek
YPS-122		ISL-1	07/26/06	Ref	62.86614	-138.5718	Unnamed Creek in Yukon South
YPS-123		SEL-1	07/26/06	Ref	62.65011	-138.3056	Selwyn River
YPS-126		LDCR-2	07/28/06	Ref	63.2487	-140.3833	Ladue Creek
YPS-127		RICE-2	07/28/06	Ref	63.26557	-140.8004	Rice Creek
YPS-128		LDCR-1	07/28/06	Ref	63.15334	-140.4080	Ladue Creek
YPS-129		MIK-1	07/28/06	Ref	62.95605	-140.2341	Mickey Creek
YPS-130		KAT-1	07/28/06	Ref	62.90939	-140.2777	Katerina Creek
YPS-131		TUSC-1	07/29/06	Ref	62.9316	-140.9591	Upper Scottie Creek in Tanana
YPS-132		TSW-1	07/29/06	Ref	62.98235	-140.9893	Swamp Creek in Tanana
YPS-133		TLLKY1	07/29/06	Ref	62.83801	-140.8934	Scottie Creek
YPS-134		LYX-1	07/30/06	Ref	63.986417	-135.8596	Lynx Creek
YPS-135		EDW-1	07/31/06	Ref	63.79775	-134.7017	Edwards Creek
YPS-136		LYX-2	07/30/06	Ref	64.02075	-135.6669	Lynx Creek
YPS-137		NEL-1	07/31/06	Ref	63.61212	-134.7322	Nelson Creek
YPS-138		NEL-2	07/31/06	Ref	63.655	-134.5339	Nelson Creek
YPS-139		EDW-2	07/31/06	Ref	63.73861	-134.5744	Edwards Creek
YPS-141		RED-1	08/01/06	Ref	63.96506	-136.3467	Red Creek
YPS-142		RND-1	07/25/06	Ref	63.70981	-139.6751	Reindeer Creek
YPS-143		TF-01	08/03/06	Ref	63.28212	-139.2385	Tenderfoot Creek
YPS-144		BAL-1	30/07/06	Ref	63.947192	-136.4988	Ballard Dreek
YPS-150		ENS-1	07/25/06	Ref	63.897046	-139.7152	Ensley Creek
YPS-154		IDP-1	07/28/06	Ref	62.951705	-139.4830	Independence Creek
YPS-155		M40-2	07/29/06	Ref	63.752664	-136.8334	40 Mile Creek
YPS-156		MUD-1	08/01/06	Ref	63.735813	-135.8604	Mud Creek
YPS-157		MUD-2	07/31/06	Ref	63.769366	-135.8436	Mud Creek
YPS-162		SES-2	07/26/06	Ref	63.458127	-139.9651	Sestat Creek
YPS-163		SUN-1	07/30/06	Ref	63.801209	-136.5119	Sunshine Creek
YPS-167		XMS-1	07/30/06	Ref	64.066383	-136.2641	Christmas Creek

Appendix 4 – Test Site Locations.

Klondike R.

YPS No.	SITE	SUBSITE$	DATE	Status	LAT.	LONG.	Description
YPS-016	YRB-37_04	X	07/06/04	Test	63.9274	-139.3250	Bonanza Creek (Discovery Claim)
YPS-016.2	YRB-37_06	X	07/15/06	Test	63.9274	-139.3250	Bonanza Creek (Discovery Claim)
YPS-051	YRB-96_05	X	07/15/05	Test	63.9918	-139.0410	Hunker Creek dstream of Hester Creek inf.
YPS-051.2	YRB-96_06	X	07/07/06	Test	63.9918	-139.0410	Hunker Creek dstream of Hester Creek inf.
YPS-052	YRB-97_05	X	07/15/05	Test	64.0189	-139.1275	Hunker Creek downstream of Hattie Gulch
YPS-052.2	YRB-97_06	X	07/15/06	Test	64.0189	-139.1275	Hunker Creek downstream of Hattie Gulch
YPS-077	YRB-122	X	07/07/06	Test	64.0327	-139.1999	Hunker Creek at Highway
YPS-078	YRB-123	X	07/08/06	Test	63.9225	-138.8839	Hunker Creek upstream of Ontario Cr.
YPS-079	YRB-124	X	07/08/06	Test	63.9617	-138.9562	Hunker Creek upstream of Gold Bottom Cr.
YPS-080	YRB-125	X	07/08/06	Test	63.9689	-138.9821	Hunker Creek dstream of Gold Bottom Cr.
YPS-081	YRB-126	X	07/08/06	Test	64.0306	-139.3885	Bonanza Creek at Highway
YPS-082	YRB-127	X	07/09/06	Test	63.8886	-139.2961	Eldorado Creek at Little Eldorado airstrip
YPS-083	YRB-128	X	07/09/06	Test	63.9194	-139.3138	Eldorado Creek at Bonanza Creek
YPS-084	YRB-129	X	07/09/06	Test	63.9196	-139.3133	Bonanza Creek ustream of Eldorado inf.
YPS-085	YRB-130	X	07/09/06	Test	63.9973	-139.3645	Bonanza Creek ustream of Sourdough G
YPS-105	YRB-150	X	07/14/06	Test	63.9432	-138.6177	All Gold Creek downstream of Hwy.
YPS-106	YRB-151	X	07/15/06	Test	63.9676	-139.3517	Bonanza Creek dstream of Mosquito G
YPS-107	YRB-152	X	07/15/06	Test	63.8623	-139.2468	Eldorado Creek top
YPS-108	YRB-153	X	07/15/06	Test	63.9126	-139.2095	Bonanza Creek-Park's Site
YPS-109	YRB-154	X	07/15/06	Test	63.9154	-139.1451	Tributary of Bonanza Creek
YPS-140	KR-3	DFO0912	08/04/06	Test	63.8697	-139.2620	Eldorado Creek

60-Mile River

YPS No.	SITE	SUBSITE$	DATE	Status	LAT.	LONG.	Description
YPS-086	YRB-131	X	07/10/06	Test	63.6086	-140.0387	10-Mile Creek at 60-Mile River
YPS-087	YRB-132	X	07/10/06	Test	63.6111	-140.0356	60-Mile River at 10-Mile Creek
YPS-088	YRB-133	X	07/10/06	Test	63.5571	-139.9377	unnamed Creek at 60-mile River
YPS-089	YRB-134	X	07/10/06	Test	63.5563	-139.9322	60-Mile River at unnamed Creek
YPS-098	YRB-143	X	07/12/06	Test	63.9884	-140.7922	Miller Creek at 60-Mile River
YPS-099	YRB-144	X	07/12/06	Test	63.9868	-140.7921	60-Mile Rive at Miller Creek
YPS-100	YRB-145	X	07/12/06	Test	64.0217	-140.7364	Big Gold Creek
YPS-113	YRB-158	X	07/16/06	Test	63.7008	-140.3033	inflow to upper Matson Creek
YPS-114	YRB-159	X	07/16/06	Test	63.7004	-140.3034	upper Matson Creek
YPS-115	YRB-160	X	07/16/06	Test	63.7169	-140.1960	Matson Creek at 60-Mile Rive
YPS-116	YRB-161	X	07/16/06	Test	63.7172	-140.1948	60-Mile River at Matson Creek
YPS-117	YRB-162	X	07/16/06	Test	63.7917	-140.2009	50-Mile Creek at 60-Mile River
YPS-118	YRB-163	X	07/16/06	Test	63.7920	-140.1999	60-Mile River at 50-Mile Creek

Indian River

YPS No.	SITE	SUBSITE$	DATE	Status	LAT.	LONG.	Description
YPS-090	YRB-135	X	07/10/06	Test	63.7694	-139.6299	Indian Rive at Water Resources Station
YPS-091	YRB-136	X	07/11/06	Test	63.8300	-139.4147	9-Mile Creek upper
YPS-092	YRB-137	X	07/11/06	Test	63.7741	-139.3439	Ophir Creek at Indian River
YPS-093	YRB-138	X	07/11/06	Test	63.7958	-139.4096	9-Mile Creek at Indian River
YPS-094	YRB-139	X	07/11/06	Test	63.7949	-139.4083	Indian River at 9-Mile Creek
YPS-095	YRB-140	X	07/11/06	Test	63.7577	-139.2484	Ruby Creek at Indian River
YPS-096	YRB-141	X	07/11/06	Test	63.7580	-139.2453	Indian River at Ruby Creek
YPS-097	YRB-142	X	07/11/06	Test	63.7428	-139.1393	Quartz Creek at Indian River
YPS-101	YRB-146	X	07/13/06	Test	63.6041	-138.8310	Eureka Creek near Indian River
YPS-102	YRB-147	X	07/13/06	Test	63.6493	-138.6749	inflow to Dominion Creek
YPS-103	YRB-148	X	07/13/06	Test	63.6913	-138.5978	Gold Run Creek
YPS-104	YRB-149	X	07/13/06	Test	63.8064	-138.6358	Dominion Creek Upstream of 72 Pup
YPS-110	YRB-155	X	07/15/06	Test	63.8920	-139.1298	Ready Bullion Gulch
YPS-111	YRB-156	X	07/15/06	Test	63.7165	-138.5447	Dominion Creek
YPS-112	YRB-157	X	07/16/06	Test	63.8970	-139.7151	Ensley Creek
YPS-151	ENS-2	YTG	07/25/06	Test	63.8849839	-139.6419	Ensley Creek

Appendix 5 – Photos of Sites all Regression Models determined to be in Reference Condition (all photos by R.C. Bailey)

YPS-099: 60-Mile River at Miller Creek

YPS-107: Upper Eldorado Creek

YPS-112: Lower Ensley Creek

YPS-084: Bonanza Creek upstream of Eldorado inflow

Appendix 6 – Photos of Sites 4/5 Regression Models Determined not to be in Reference Condition (all photos by R.C. Bailey)

YPS-90: Indian River at Water Resources Station

YPS-078: Hunker Creek upstream of Ontario Creek

YPS-079: Hunker Creek upstream of Gold Bottom Creek

YPS-088: Unnamed Creek at 60-Mile River

YPS-105: All Gold Creek downstream of Klondike Hwy.