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# Annual Report

# BPA Project 2002-011-00

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The overarching goals of the "Kootenai River Floodplain Ecosystem Operational Loss Assessment, Protection, Mitigation and Rehabilitation" Project (BPA Project # 2002-011-00) are to: 1) assess abiotic and biotic factors (i.e., geomorphologic, hydrological, aquatic and riparian/floodplain communities) in determining a definitive composition of ecological integrity, 2) develop strategies to assess and mitigate losses of ecosystem functions, and 3) produce a regional operational loss assessment framework. To produce a scientifically defensible, repeatable, and complete assessment tool, KTOI assembled a team of top scientists in the fields of hydrology, hydraulics, ornithology, entomology, statistics, and river ecology, among other expertise. This advisory team is known as the Research Design and Review Team (RDRT). The RDRT scientists drive the review, selection, and adaptive management of the research designs to evaluate the ecologic functions lost due to the operation of federal hydropower facilities. The unique nature of this project (scientific team, newest/best science, adaptive management, assessment of ecological functions, etc.) has been to work in a dynamic RDRT process. In addition to being multidisciplinary, this model KTOI project provides a stark contrast to the sometimes inflexible process (review, re-review, budgets, etc.) of the Columbia River Basin Fish and Wildlife Program.

The project RDRT is assembled annually, with subgroups meeting as needed throughout the year to address project issues, analyses, review, and interpretation. Activities of RDRT coordinated and directed the selection of research and assessment methodologies appropriate for the Kootenai River Watershed and potential for regional application in the Columbia River Basin. The entire RDRT continues to meet annually to update and discuss project progress. RDRT Subcontractors work in smaller groups throughout the year to meet project objectives.

Determining the extent to which ecological systems are experiencing anthropogenic disturbance and change in structure and function is critical for long term conservation of biotic diversity in the face of changing landscapes and land use. KTOI and the RDRT propose a concept based on incorporating hydrologic, aquatic, and terrestrial components into an operations-based assessment framework to assess ecological losses as shown in Figure E-1.

KTOI Operational Loss Assessment Project IEI Components

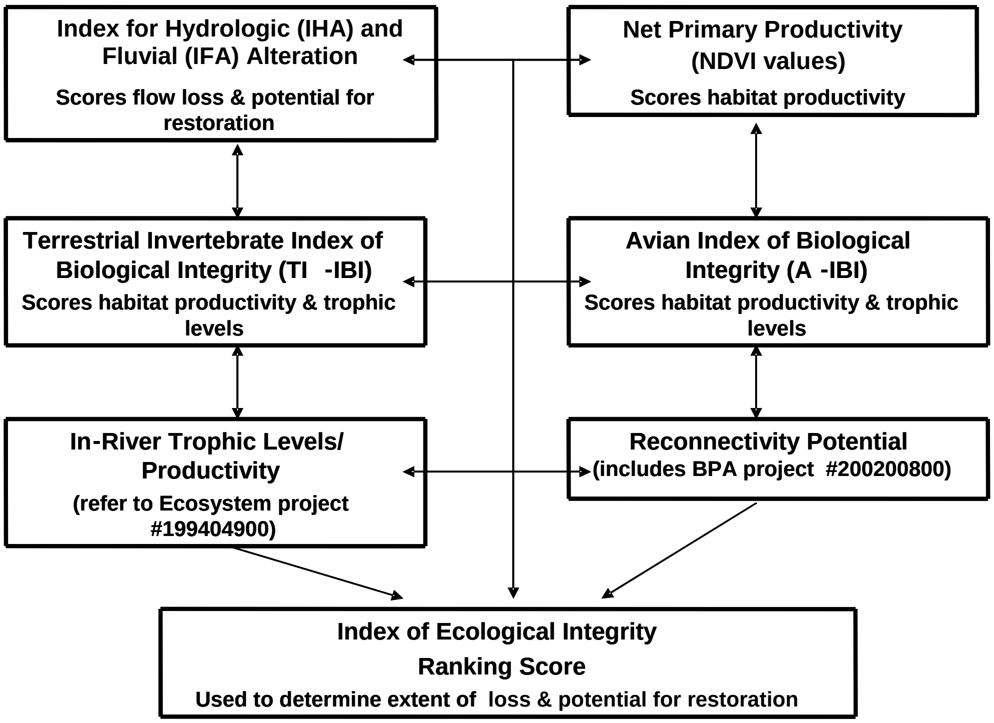


**Figure E-1. Diagram of proposed Index of Ecological Integrity (IEI) framework for the assessment of operations based ecological losses.**

As outlined in Figure E-1, the OLA project personnel and subcontractors accomplished or are progressing on the tasks outlined in the 2007-2009 proposal. Considerable progress has been made towards the development of these IEI components, with work to refine and finalize these components between FY2009 though FY2011. Major progress has occurred on the following tasks proposed within the 2007-2009 timeline:

- Development and refinement of an index of hydrologic (IHA) and fluvial alteration (IFA),
- Completed calibrations of hydraulic models to assess wetland and floodplain alteration timeframes,
- Development of a dynamic vegetation model based on hydraulic parameters,
- Documented changes in riparian woody vegetation establishment and survival,
- Development of a high-resolution remote sensed land cover classification,
- Completed a draft of 1 meter NDVI values to approximate net primary production,
- Sampling of avian and invertebrate communities basin-wide,
- Assessed sample size and power of avian and invertebrate sampling protocol,
- Assessed indicator values of avian and invertebrate species by land cover classification,
- Initiated development of indices of Biotic Integrity (IBI)

- Continued to update and enhance Web-based relational database, and
- Initiated regional review for operational loss assessment framework

## Development and refinement of an index of hydrologic and fluvial alteration

### *IHA: First-order impacts – Index of Hydrologic Alteration*

The IHA measures the hydrologic changes in the Kootenai River by comparing parameters collected at stream gages before and after the operation of Libby Dam. For this study, a 15 parameter subset of the IHA output was selected to simplify the analysis. The selected parameters represent the 5 core parameter groups reported by the IHA method and eliminate redundant parameters while representing the primary characteristics of the pre- and post-Libby Dam hydrology. The winter mean daily flow (increased minimum flows during the winter low-flow period) and the high pulse count (number of flows exceeding the 75$^{th}$ percentile of the pre-disturbance flow distribution) showed the largest change, indicating increased irregularity of the annual hydrograph. Each parameter was compared and the ensemble score was termed 'Index of Hydrologic Alteration'.

### *IFA: Second-order impacts – Index of Hydraulic/Fluvial Alteration*

This index was originally named the index of hydraulic alteration. To avoid confusion with the 'Index of Hydrologic' (IHA), the RDRT supported changing the name of this index to the 'Index of Fluvial Alteration' (IFA). This index aggregated second-order impacts using pie charts that respectively describe the total alteration of the study reach (Figure E-2a; historic vs. post-Libby Dam periods) that relate solely to Libby Dam (Figure E-2b; pre- vs.. post-Libby Dam periods). The results are nearly identical for the two cases, suggesting that the effects of Libby Dam dominate this section of the river (91% of the total change can be attributed to Libby Dam). For both cases, changes in the spatial and temporal patterns of stage fluctuation and stream power were the two greatest changes (Figure E-2, alterations in excess of 100%). Distributions of depth and wetted width have been altered the least of the seven parameters evaluated. These alterations are consistent with the dual facility objectives of flood control and hydropower generation. The ensemble score was termed 'Index of Hydraulic Alteration' in Burke 2006.

Burke (2006) developed a preliminary method for compositing first- and second-order impacts for integration into the IEI process using indices, as described above. At the time that these concepts were developed, use of the IEI concepts for the operational loss assessment was a relatively young concept. The major tasks for FY2009 period are to refine and confirm the approach for preparation of the indices, and to prepare/calculate the final indices of hydrologic and fluvial alteration.

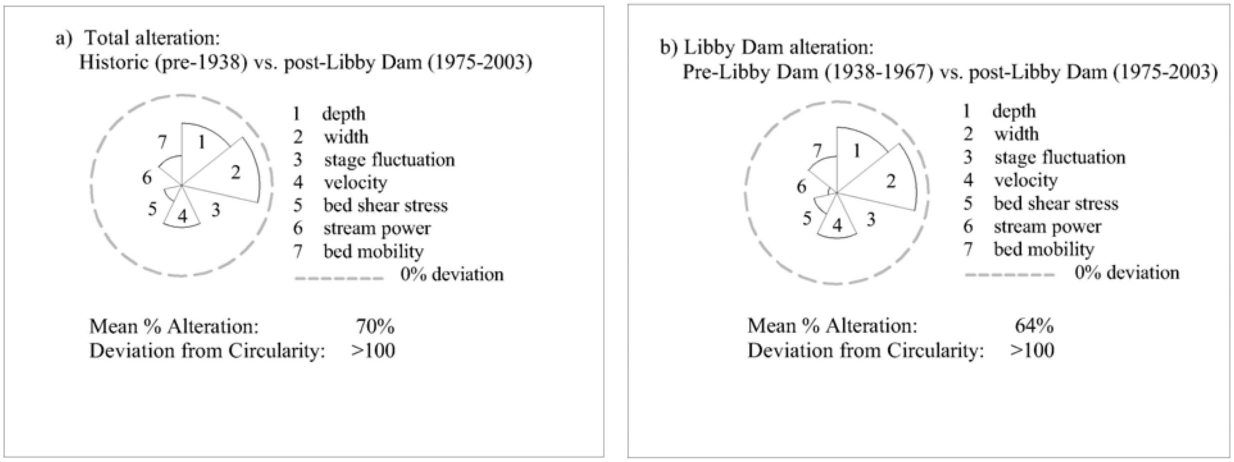


**Figure E-2. Pie charts of second-order impacts (altered channel hydraulics and bed mobility) resulting from a) all historic water management activities since 1938 (historic vs. post-Libby Dam periods) and b) operation of Libby Dam (pre- vs. post-Libby Dam periods), determined from the mean percent alteration values. Distance from the gray line indicates alteration, while the ratio of the largest piece to the smallest piece (deviation from circularity) gives an indication of uniformity of alteration.**

## Completed calibrations of hydraulic models to assess wetland and floodplain alteration timeframes

In an effort to assess ecologically significant floodplain processes, determine floodplain losses attributable to operations of dams and areas available for potential future restoration and river-floodplain reconnection potentials, we developed an abiotic hydrologic modeling process. The modeling process allows partitioning of anthropogenic alterations and predictive capabilities based on variation of input parameters.

Using the model, we can partition changes that are caused by hydrology (dam operation) and topography (levee construction, floodplain leveling). A differential evaluation of the physical processes and the ecological functions linked to them via habitat models allows quantification of losses and to attribute certain portions of the losses to either floodplain alterations, channel alterations, changes of the hydrological regime, levee construction, Kootenay Lake water levels or any other of the variables that influence the system.

In addition, the model allows us to predict the outcomes of various restoration events. In a case like the operational loss assessment in the Kootenai Floodplain, the one-dimensional (1-D) and two-dimensional (2-D) modeling are extremely relevant, since neither high flows over the entire floodplain, nor a situation where the dam operation is dramatically changed can be observed. Only physical process-based models integrated into this effort can provide this needed information. These models allow us to simulate what a combination of efforts and actions could do to water movement and location across the floodplain and subsequent habitat availability.

We calibrated and tested two hydrodynamic models (MIKE 11, MIKEFLOOD) to predict the flow conditions in the lower Kootenai River and floodplain. MIKEFLOOD is a professional hydrodynamic model that uses a finite-difference scheme to calculate 1-D flow in the Kootenai River and 2-D flow on the floodplain. We chose a 2-D model because they provide accurate simulations of floodplain flow processes in complex terrain (Horritt, 2000; Horritt & Bates, 2002; MacWilliams et al., 2004), unlike 1-D or quasi 2-D models (Gillam et al., 2005). The flow properties are calculated in a rectangular grid based on measured topography, bed resistance, and hydraulic boundary conditions. We have three time periods of interest: 1) **historic** (pre-1938) when the study area was minimally disturbed, 2) **pre-dam** (1939-1967) when levees, drainage, and land leveling occurred, and 3) **contemporary** (1974-present) which includes all previous human modification and Libby Dam operation.

The mean daily discharge at the Leonia gage station and mean water levels at the WSC (08NH07) Kootenay Lake gage were used as the upstream and downstream boundary conditions, respectively, for all time periods. These locations were chosen to minimize the impacts of the boundaries on the modeled results. Calibration of Manning's roughness coefficient (calculates the frictional losses caused by bed, bank, and vegetation resistance) was necessary to properly predict the flow in all modeled scenarios. We did not calibrate the Manning roughness coefficient on the floodplain because no quantitative data (e.g. flood extent map, measured velocities, and water depths) were available. We divided the floodplain into eight different Manning coefficient values based on the observed vegetation (recent and historic air photos, and wetland maps) the Normalized Difference Vegetation Index (NDVI) calculated using 30m Landsat imagery, and reported literature values (e.g. Acrement and Schneider, 1989; Alkema and Middelkoop, 2005; Ayres Associates, 2002; Chow, 1959; Hesselink et al., 2003). We conducted detailed sensitivity analyses to understand the impact of Manning's roughness, grid size, and simulation duration on model results.

We assessed the operational losses from levee construction and Libby Dam operation by predicting the flow hydraulics (spatial variation in water depth, velocity and shear stress) and flood inundation extent during the three time periods (see above). To simplify calculations, the annual hydrographs for all three time periods were divided into eight different hydrologic classes (e.g. high, average and low discharge). Typical wet (W_1, W_2, W_3), average (A_1, A_2, A_3) and dry (D_1, D_2) years are identified based on similar annual peak discharges, average discharges and hydrograph shapes. During a 100-year flow event, much of the floodplain was historically inundated and this inundated area was significantly limited after levee construction (Figure E-3). A summary of the floodplain inundation calculations for each time period and flow event is given in Table E-1. All these simulations assume that the levee system is completely effective. Prior to Libby Dam construction, levee failures were report approximately 1 in every 4 years.

**Table E-1. Summary of inundation extent.**

| Climatic condition | ~RI (year) | | Total flooded area | | | Operational losses in term of flooded area | | | | | | Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | C | P | H | Total loss (H-C) | | River modification (H-P) | | Dam operation (P-C) | | |
| | Max | Av | ha | ha | ha | ha | % | ha | % | ha | % | R* |
| D_1 | 1 | 1 | 103 | 82 | 97 | -5 | -5 | 16 | 16 | -21 | -26 | -1 |
| D_2 | 1.25 | 1.3 | 63 | 413 | 996 | 932 | 94 | 583 | 59 | 349 | 85 | 2 |
| A_1 | 2 | 2 | 68 | 1244 | 8847 | 8779 | 99 | 7603 | 86 | 1176 | 95 | 6 |
| A_2 | 3.5 | 5 | 133 | 2279 | 15334 | 15202 | 99 | 13055 | 85 | 2146 | 94 | 6 |
| A_3 | 2 | 25 | 103 | 1244 | 3035 | 2932 | 97 | 1791 | 59 | 1141 | 92 | 2 |
| W_1 | 5 | 3.5 | 149 | 2893 | 15858 | 15709 | 99 | 12964 | 82 | 2745 | 95 | 5 |
| W_2 | 10 | 3.5 | 239 | 7313 | 13427 | 13188 | 98 | 6113 | 46 | 7075 | 97 | 1 |
| W_3 | 100 | 25 | 278 | 11655 | 16955 | 16677 | 98 | 5301 | 31 | 11376 | 98 | 0 |

**R***= Ratio of losses due to River modification and Dam operation — **C=** Contemporary — **D=** Dry year
**~RI**= Approximate Recuernce Interval — **P=** Pre-dam — **A=** Average year
**Max**= RI based on maximum peak flood in historic condition — **H=** Historic — **W=** Wet year
**Av**= RI based on yearly average flood in historic condition

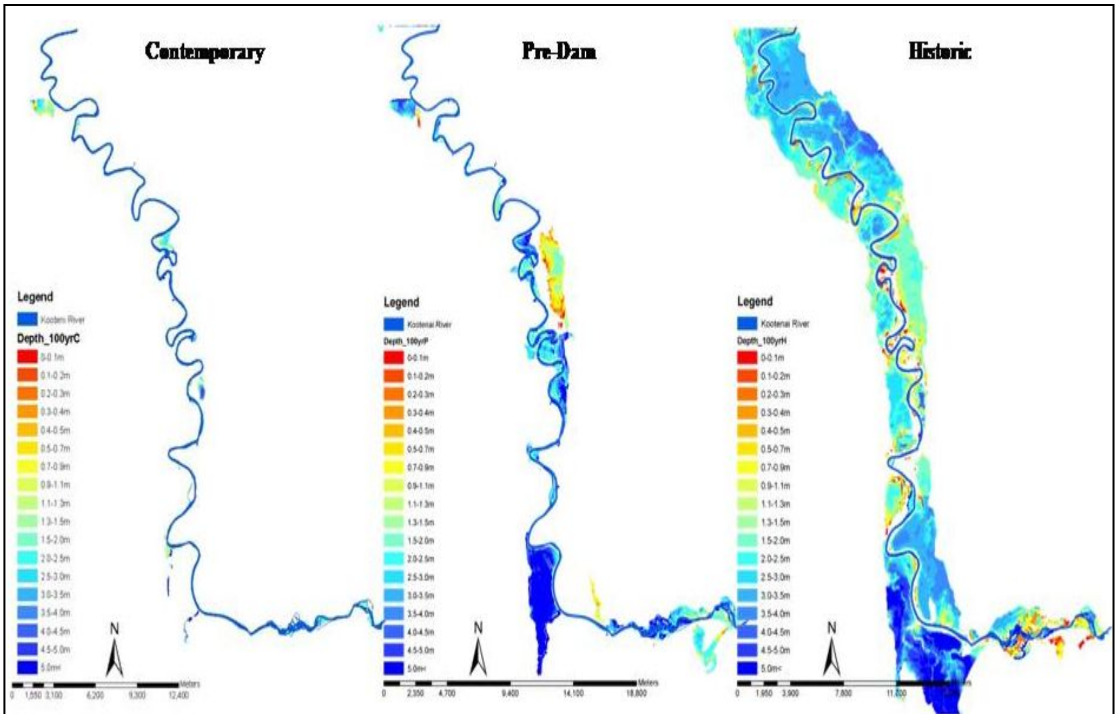


**Figure E-3. Spatial distribution of inundation area (colors are flow depths, blue is low) for contemporary, pre-dam and historic scenarios during a 100-year flood event. Areas with no color were not inundated.**

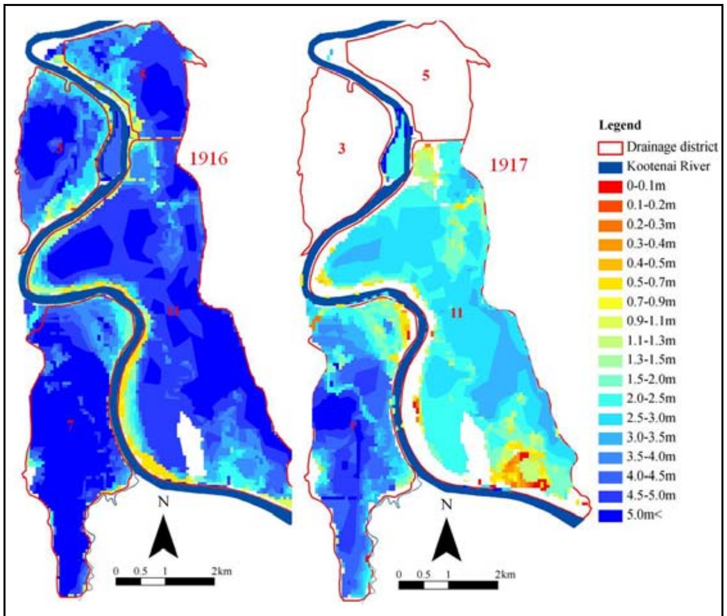


**Figure E-4. Inundated flow depths in a former wetland during the historic time period for relatively average (1917) and large discharges (1916), see Table 2 for values.**

Large amounts of wetlands were converted to agricultural cropland over the past 100 years (KTOI 2006). We therefore calculated the amount of wetland habitat (important for many aquatic and waterfowl species) that could have existed in the Kootenai basin under historic conditions using our hydrologic model to determine the inundation area, flow depth, flood duration (number of days an area is flooded), and water volume (product of area and depth) in wetlands for a range of flow conditions (Figure E-4). An area known to contain historic wetlands was divided into eleven distinct regions (regions 3, 5, 7, and 11 are shown in Figure E-4) to determine the primary historic wetland locations. For all modeled flow events, region 7 had the greatest flood duration (43 days in 1934) compared to other wetlands. Some locations (regions 3 and 5) were only flooded for a minimum of 1 day (in 1921 and 1913) and a maximum of five days (in 1916). Currently none of these wetlands exist except region 7, which is managed by artificial flooding (pumping water from the river and feeding water from tributaries). Such results could be used to quantify wetland losses and identify primary areas (highest inundation frequency etc.) for wetland restoration in the future.

## Development of a dynamic vegetation model based on hydraulic parameters

A riparian habitat and vegetation model was developed for this project by Rohan Benjankar under the guidance of Dr. Klaus Jorde and the University of Idaho’s Center for Ecohydraulics Team in Boise, Idaho (Benjankar 2009; Benjankar in prep.). Riparian vegetation is one of the main indicators of long-term environmental change due to anthropogenic disturbances altering river and floodplain systems. Age structure of vegetation communities can also be used to reconstruct historic river and hydrological conditions. Therefore, a dynamic vegetation model was developed for estimating and simulating the change in vegetation habitats and communities due to river regulation by Libby Dam.

The main objectives were:

- simulate vegetation dynamics based on the physical processes of the floodplain for current, pre-dam and historic scenarios,
- simulate loss in vegetation habitats and communities due to dam operation and river regulation,
- perform an analysis of the age structure of vegetation communities,
- simulate vegetation structure and type for terrestrial ecosystems (bank and floodplain zones) for use in an index of biotic integrity (IBI) for estimating different anthropogenic disturbance types, and
- analyze spatial distribution of suitable habitats of indicator vegetation and animal species.

We considered physical processes to be the main driving forces of vegetation dynamics. Thus, these processes are simulated by a combined one-dimensional (1D, river) and two-dimensional (2D, floodplain) hydrodynamic model using river hydrology, cross sections and a Digital Elevation Model (DEM) of the floodplain as inputs. A dynamic link between the hydraulic and vegetation models has not yet been installed, but will be developed in the future.

A dynamic rule-based vegetation model was developed based on the simulation of physical parameters, observed data, and expert knowledge. The vegetation model is created in an

ArcGIS environment using the Model Builder module (Politti 2008). It is a grid-based (raster) type of approach and simulates the vegetation succession or retrogression in annual time steps within 10x10 m grid cells. The model outputs the *Potential Natural Vegetation* (PNV) communities at the end of each computed year.

The model area is classified into three zones, i.e. aquatic zone (AZ), bank zone (BZ) and floodplain zone (FZ). Zone definition underlies the concept that magnitude and frequency of flooding governs the presence, absence and structure of riparian vegetation communities. AZ is part of the river, BZ is approximately the area being flooded by bankful discharges. FZ corresponds to the floodplain defined as the area being flooded by a 100-year flood event.

Model outputs include temporal and spatial community Potential Natural Vegetation types (PNV) distributions in the study area. Output communities are defined regardless of land use changes.   An example of a vegetation map for 2006 that was calculated by the model is shown in Figure E-5. Currently, the model is in the verification and calibration phase.

The final goal of the vegetation model is to use different community types as calculated by the model for the development of indices of biotic integrity (IBI) and to estimate the impact of different anthropogenic disturbances within the floodplain, including hydrologic modifications, on riparian vegetation and habitats in the Kootenai River floodplain.

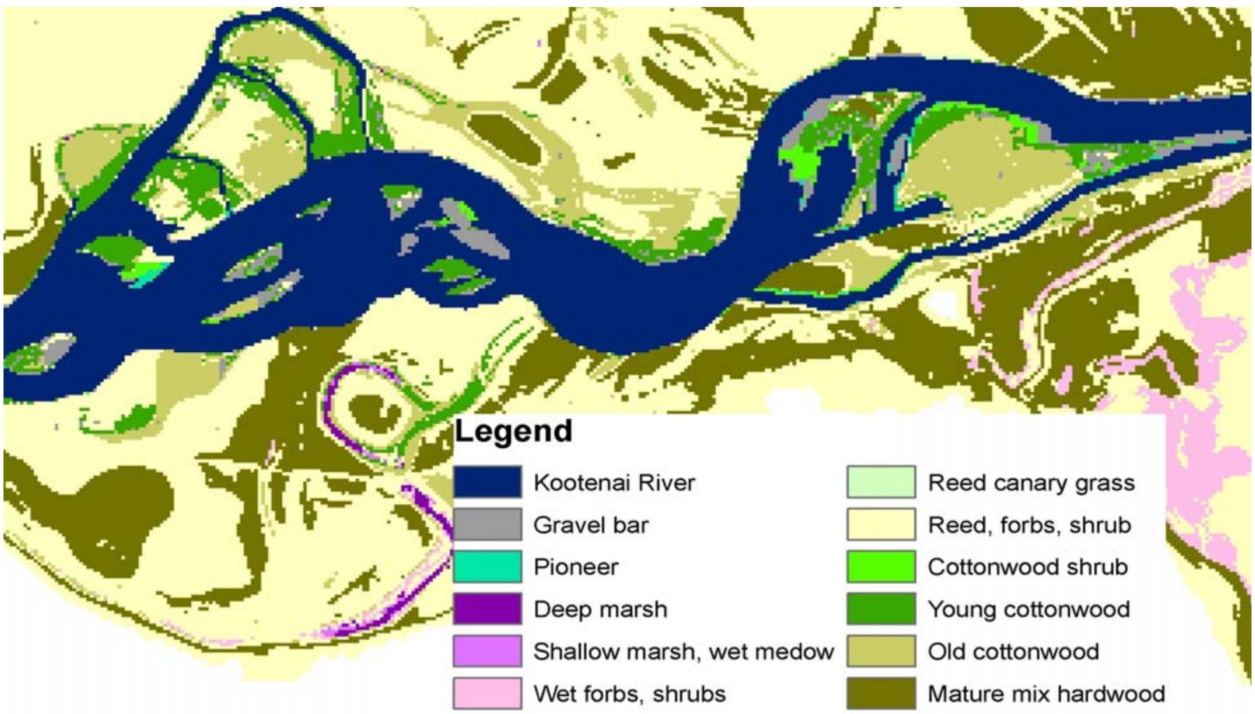


**Figure E-5: A model of Potential Natural Vegetation types at the Kootenai River in 2006.**

## Changes in Riparian Woody Vegetation Establishment and Survival

In addition to using model approaches, we are assessing woody riparian vegetation, mainly black cottonwood and sandbar willow, establishment post “sturgeon flows”.  Like all populations, healthy cottonwood populations are self-sustaining with periodic recruitment of new individuals into the population.  However, as with many rivers that have been dammed or hydrologically altered, cottonwood recruitment along the Kootenai River has been disrupted

(Polzin and Rood 2000; Jamieson and Braatne 2001). Many locations along the river support mature trees that established prior to damming, but are lacking juvenile trees (Polzin and Rood 2000). Many other studies have also shown a lack of recruitment associated with change in the timing and magnitude of stream flows on which cottonwood life history processes depend (Braatne et al. 1998; Johnson 1992; Rood et al. 1995; Cooper et al. 1999; Scott et al. 1996).

To assess riparian woody vegetation establishment and recruitment, previous sampled and new belt transects were relocated or established from the waters edge to the back of the floodplain. In each quadrat (2m x 4m) along the transect, the leaf area cover of each woody species was noted. On occasional, herbaceous plants cover within the quadrat was noted, also. The percent cover of bare ground was also noted. Heights of the tallest and the shortest saplings were noted to provide the range of sizes. The sizes of individual saplings were not measured, because the range estimate provided sufficient detail for characterizing overall size structure diversity and individuals of the same age can often vary in height. Two to three saplings near the transect were selected and cut at ground level for aging, and a few of the larger trees were aged by taking a core with an increment borer. Some of the smaller cottonwoods were excavated to determine if they are of seedling or clonal origin. We anticipate that there was an initial expansion of the riparian woodlands in the lower elevation riparian zones that would have been periodically scoured and more dynamic prior to the flood attenuation imposed by Libby Dam.

In the coming year, data from the prior studies (Polzin and Rood 2000; Jamieson and Braatne 2001) and new field data from the summer of 2008 will be analyzed. The transects established in the prior studies in the braided and meandering reaches will be re-surveyed. Field data from sites along free-flowing river reaches such as the upper Kootenay, the Elk and Fisher Rivers will be retrieved from prior studies and used to provide information on reference sites, which are needed for the IBI approach. Indicators will be further developed and the data collected will be applied to them. Preliminary field visits in the braided reach indicate continued recruitment and patches of healthy-looking riparian woodlands.

## Continued development of a fine-scaled land classification cover

An accurate, high-resolution land cover map of the project area is the foundation for several of the OLA Project initiatives. Only high-resolution imagery is suitable for mapping the complex habitat mosaic of land cover types occurring along riparian corridors such as the Kootenai River Valley. To accomplish these goals, we acquired 1-meter resolution multispectral imagery from the USDA National Aerial Imagery Program (NAIP). True color NAIP imagery is available nationwide at no cost, while color infrared imagery coverage and cost is variable. NAIP imagery carries with it the primary benefits of high resolution, excellent positional accuracy, and low or no cost.

Although the high resolution imagery captures the complexities of the landscape, it also captures shadows of trees. Shadows cannot be considered a cover type and so must be associated with a cover type to classify them appropriately. Spectral similarities with water exacerbate this problem. Accordingly, a variety of methods were used to classify the imagery into land cover classes. These include supervised and unsupervised image classification routines, masking, stratification by elevation or topographic position, and direct image interpretation combined with heads-up vector digitizing using ArcGIS.

We adopted the hierarchical cover classification scheme developed for the Gap Analysis Program (Scott et al. 1993) for Montana and Northern Idaho. Because the scheme was developed in the context of Landsat satellite image classification at 30-meters, some changes were made to the scheme to accommodate the high resolution and the ecological cover classes occurring in the project area. Classification accuracy will be determined by using 1117 polygons that were digitized around avian survey points. A portion of the land cover classification, located in the Kootenai National Wildlife Refuge, near Bonners Ferry, Idaho is show in Figure E-6.

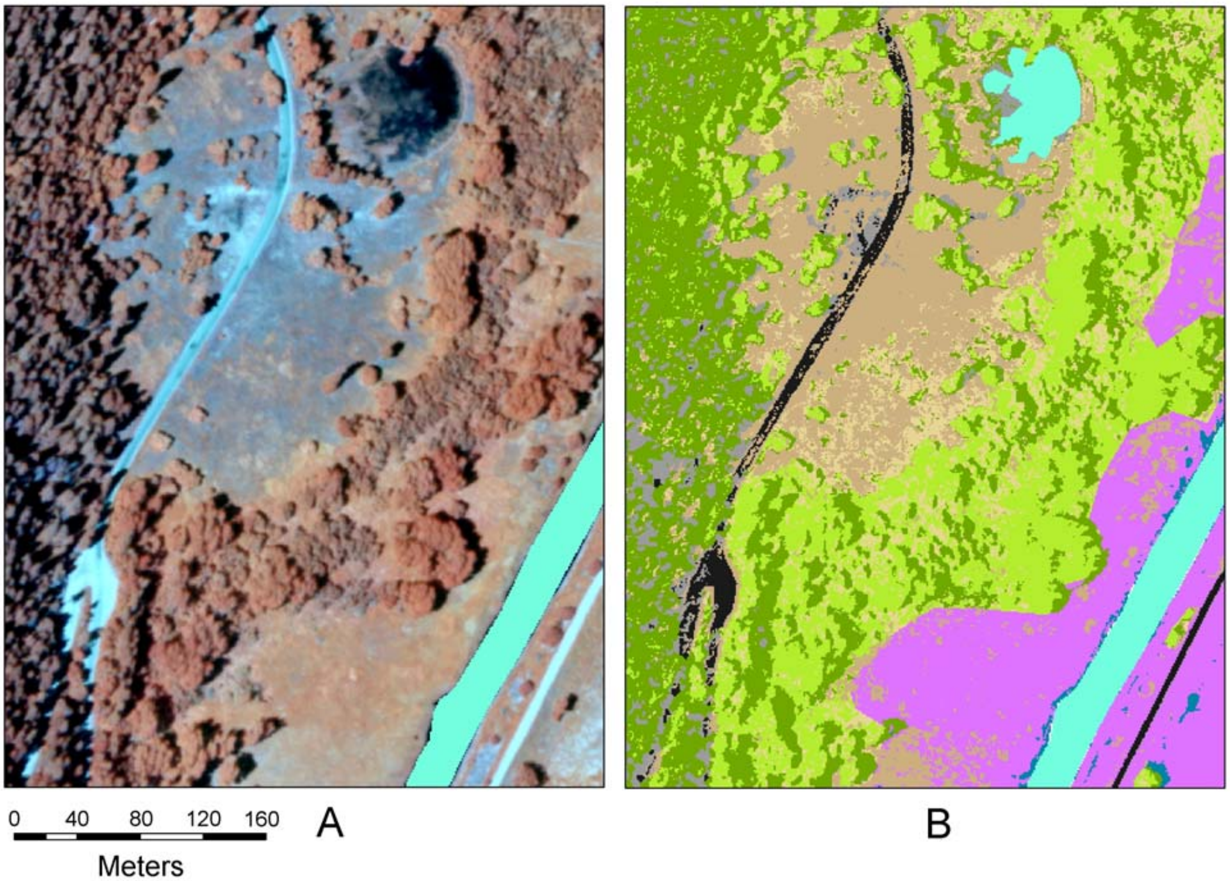


**Figure E-6. (A). A portion of the 1-meter NAIP color infrared image composite from the Kootenai National Wildlife Refuge, and (B), a corresponding, classified image.**

## Assessing primary production using NDVI

The normalized difference vegetation index (NDVI) is an image processing product derived as a ratio of red to infrared pixel values. NDVI is particularly sensitive to chlorophyll concentration and therefore bright NDVI pixels indicate areas where photosynthesis is occurring at a higher rate then duller pixels. Photosynthesis varies naturally across vegetation cover types and age classes. We used bands 2 and 3 from the color infrared NAIP composites to create an NDVI theme for the study area with the intent of deriving NDVI values for various cover types, preferred avian habitats, and insect transect areas. These correlates will permit us to enhance our characterization of riparian wildlife habitat and to contrast different portions of the riparian zone.

A preliminary NDVI product has been produced and its values were stretched to take advantage of 8-bit integer image depth. However, because separate NDVI scenes were merged, these subsets need to be readjusted separately to ensure the continuity of NDVI values across the entire study area. A portion of the NDVI image is shown in Figure E-7.


**Figure E-7. A portion of the NDVI image derived from 1 meter NAIP imagery. The image area corresponds to that shown in Figure E-6.**

## Assess sample size and power of avian and invertebrate sampling protocol

This analysis encompasses a critical evaluation of the current sampling scheme employed by the OLA project. The statistical analyses include determination of required sample sizes for various taxonomic assemblages at different precision levels, along with statistical power analyses accounting for potential spatial and/or temporal variability and monitoring.

### *Sample Size Estimation*

The formulation for calculating sample size can be derived from a confidence interval constructed for the population mean and is given by (Cochran, 1977):

$$n = (z*s/d)^2 \quad (1)$$

where n is the estimated sample size, s is the sample standard deviation, d is the desired precision, and z is a tabulated critical value related to the level of confidence and is specified as a quantile of the standard Normal distribution.

The resulting sample size values are preliminary, as the calculations are based on available data.

### *Avian Richness*

The OLA Project avian data encompasses 27,488 observations collected between 2002 and 2008 at 153 sites. All observations were identified to species. In the sample size calculations below, results are shown for avian species richness at the 95% level of confidence within predefined river reaches. The desired precision level in equation (1), *d*, was set to the absolute level of 1, 2, 3, or 4 species (i.e. the mean richness of the avian data is estimated to within one to four species). Estimates of variability, *s*, were obtained from the available data. Sample size, in this case, refers to the number of sites necessary to obtain the desired level of precision within a given river reach.

Figures E-8a and E-8b show the sample size estimates relative to the actual sampling densities for the years 2003 through 2008. Annual estimates (colored dots) falling below the actual sampling densities (red squares) indicate an adequate sampling density for achieving the desired precision and confidence levels. While the estimates computed for the highest precision level of one species appear inadequate, those at precisions of 2 or more species meet or exceed the desired expectations. Given these results, the current level of site sampling is adequate to estimate the mean richness of each reach to within at least 2 species. Other scenarios estimating the combined number of sites and dates or, alternatively, the number of dates within a specified site at the same precision level, are provided in supporting information and further indicate that the avian sampling protocol is adequate.

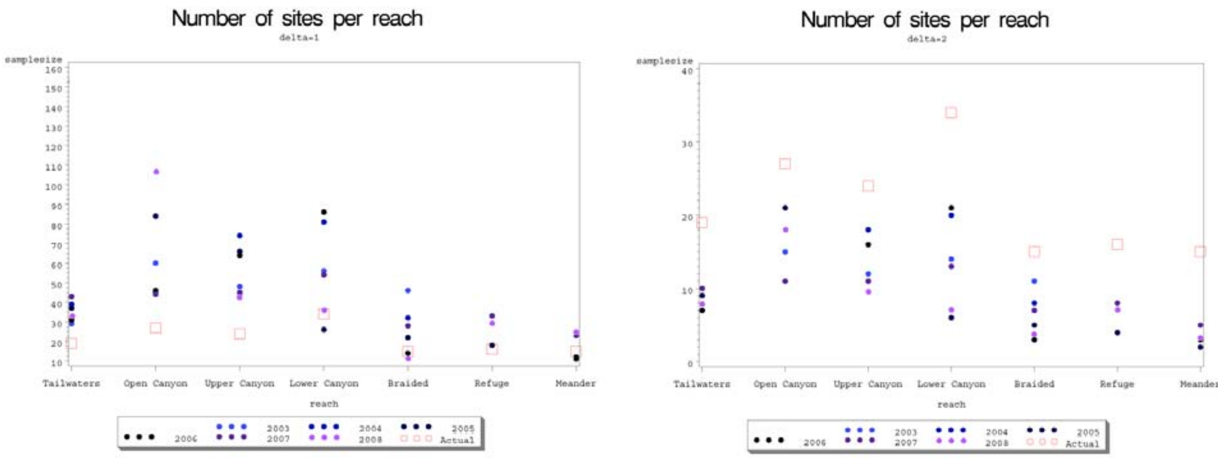


**Figure E-8a. Estimated avian sample sizes (number of sites) for seven river reaches in the years 2003 to 2008. Separate plots are provided for each of the four precision levels ranging from delta = 1 species to 2 species. Dots represent individual year estimates, while red squares represent the actual sampling densities.**

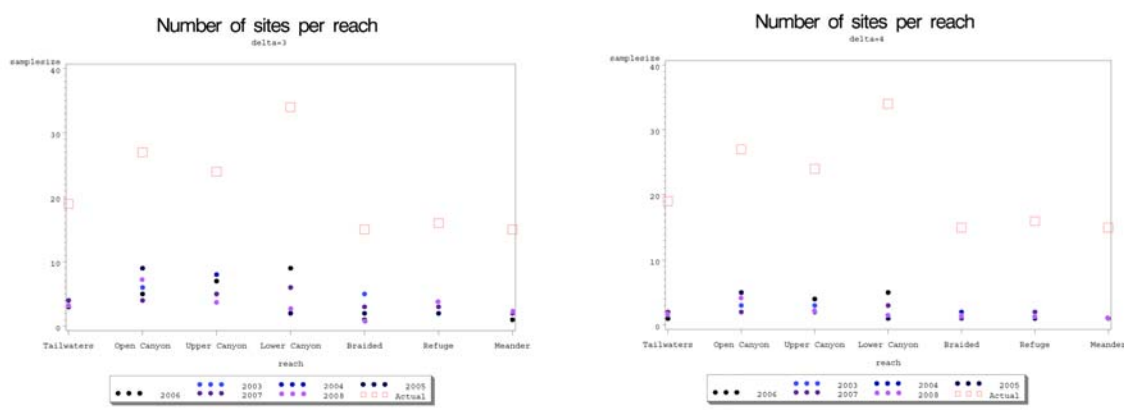


**Figure E-8b. Estimated avian sample sizes (number of sites) for seven river reaches in the years 2003 to 2008. Separate plots are provided for each of the four precision levels ranging from delta = 3 species to 4 species. Dots represent individual year estimates, while red squares represent the actual sampling densities.**

**Species accumulation curves:** In addition to the sample size determination, species accumulation curves were calculated to determine whether the sampling effort was sufficient to record the majority of avian species occurring in the floodplain region of the watershed. This analysis was performed by bootstrapping species richness data for samples with sequentially larger sample sizes (Southwood & Henderson, 2000). For the purposes of this specific analysis we defined a "sample" as the number of species occurring at a bird sampling plot (site) on a single day ("site/day"). The idea behind species accumulation curves is that fewer and fewer new species are recorded with each sequential sampling event; hence when plotted, accumulation curves are asymptotic reaching an asymptote when sufficient sampling effort has been expended to record all species in the environment. The shape of the species accumulation curves for each year indicates that during each sampling season we recorded most bird species occurring in the floodplain region of the watershed. Figure E-9 shows a combined species accumulation curve combined across years.

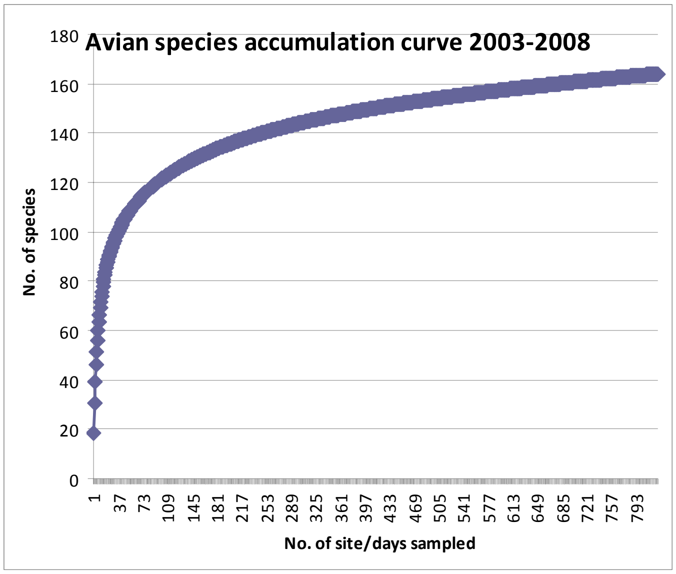


**Figure E-9. Aggregated avian species accumulation curve for 2003-2008**

### *Invertebrate Richness*

The OLA Project invertebrate data encompasses 8,315 observations collected in 2005 and 2007 at 81 sites. All observations were identified to the family level of taxonomic classification. Figures E-10a and E-10b show estimated sample sizes for 2005 and 2007 invertebrate family richness. In this case, adequate sampling levels were not achieved until a precision level of d = 4 families. Therefore, it cannot be expected that invertebrate richness means will estimate the true richness values to within less than four families.

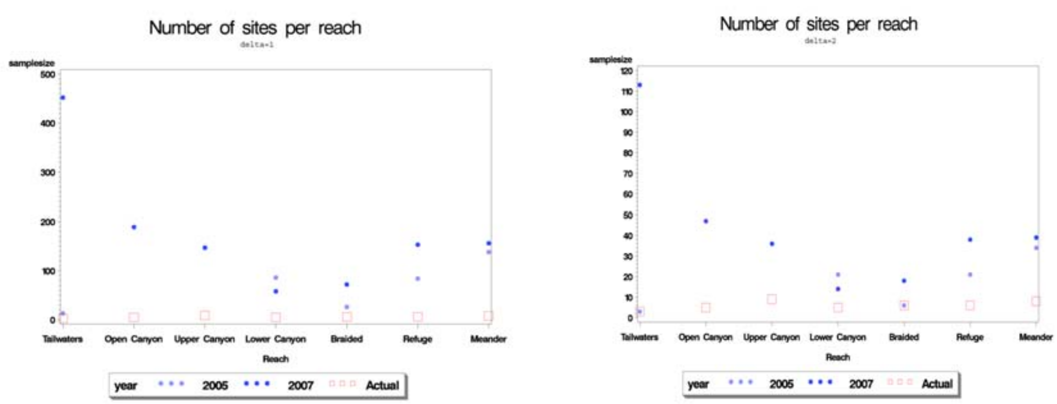


**Figure E-10a. Estimated invertebrate sample sizes (number of sites) for seven river reaches in the years 2005 and 2007. Separate plots are provided for each of the four precision levels ranging from 1 family to 2 families. Dots represent individual year estimates, while red squares represent the actual sampling densities.**

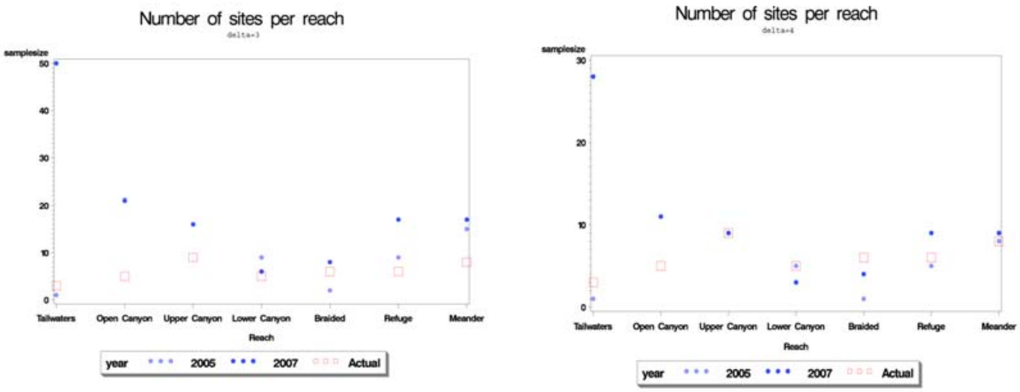


**Figure E-10b. Estimated invertebrate sample sizes (number of sites) for seven river reaches in the years 2005 and 2007. Separate plots are provided for each of the four precision levels ranging from 3 families to 4 families. Dots represent individual year estimates, while red squares represent the actual sampling densities.**

**Family accumulation curves:** Family accumulation curves were also calculated to determine whether the sampling effort was sufficient to collect the majority of invertebrate families occurring in each geomorphic reach or in the watershed. This analysis was performed by bootstrapping Family richness data for samples with sequentially larger sample sizes (Southwood & Henderson 2000). The Family accumulation curves shown in Figure E-11 indicate that during the 2007 season we did not capture all invertebrate families within each sampled geomorphic reach, and that a larger sample size would be required to accomplish this. These results are complementary to those reported above that indicated sampling precision of invertebrates was lower than avian species due to the lower sample size of invertebrates.

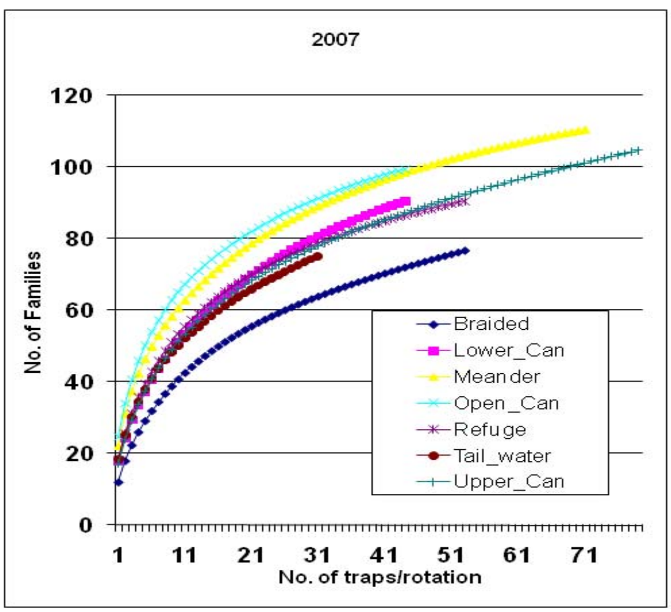


**Figure E-11. Family accumulation curves for the invertebrate fauna found by hydro-geomorphic reaches within the watershed.**

***Power Analysis***

***Avian Richness***

Power analyses for the avian data are based on a one-way classification Analysis of Variance (ANOVA) comparing mean species richness across river reaches. For the purpose of demonstration, the ANOVA results for the most recent year (2008) were used. The effect of reach was highly significant, i.e. at least one reach mean richness differed from the others. To fully assess the effect of reach on species richness, mean contrasts were also tested. All contrasts indicated significant results, with the exception of the Refuge versus Meander contrast. The Canyons versus Meander contrast was marginally significant with a p-value of 0.09.

Power curves for these contrasts are provided in Figure E-12. As is expected from the results above, the Canyon vs. Meander and Refuge vs. Meander contrasts have the lowest power, never reaching above 60% while the Refuge vs. Canyon contrast has very high power, rapidly rising to more than 80% power at moderate sample sizes. Hence, it is easier to detect differences in richness for these reaches than differences between other sets of reaches. Estimated power curves pertaining to similar contrasts for the years 2003-2007 are given in supporting documents.

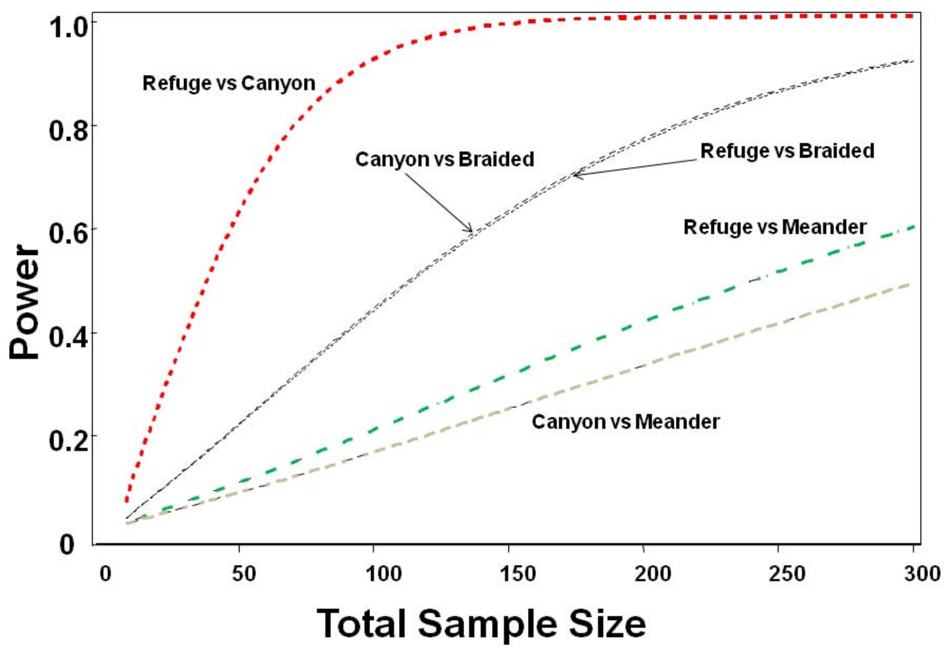


**Figure E-12. Power curves for the 2008 avian river reach contrasts.**

### *Invertebrate Richness*

As with avian data, power analyses for the invertebrate data are based on a one-way analysis of variance, however the response in this case is family richness. The ANOVA results for the most recent year available (2007) were computed. The effect of reach was highly significant. Mean contrasts for each comparison were also tested. Only the Canyon vs. Braided contrast was highly significant, although the Refuge vs. Meander and Canyon vs. Meander contrasts were marginally significant.

The corresponding power curves are shown in Figure E-13. The Canyon vs. Braided contrast shows the highest power (steepest power curve) while the Refuge vs. Canyon contrast has the lowest.  The power curves pertaining to the same contrasts for the year 2005 are given in supporting documents.

Sampling intensity for the avian and invertebrate data of the OLA Project, based on the geomorphic designation of reaches, appears to be sufficient with adequate power in testing the majority of specified hypotheses.  In 2008, increased invertebrate sampling occurred in the tailwater and open canyon reach to increase precision levels within these reaches.  The river reach definitions are somewhat arbitrary, however, more accurate and biologically meaningful analyses will involve reassessing the analyses presented here using additional information on habitats (GapCode designations), site relevant information (KEC Data), or biological guild specific information. Such analyses will be carried out for the Operational Loss project as these data become available.

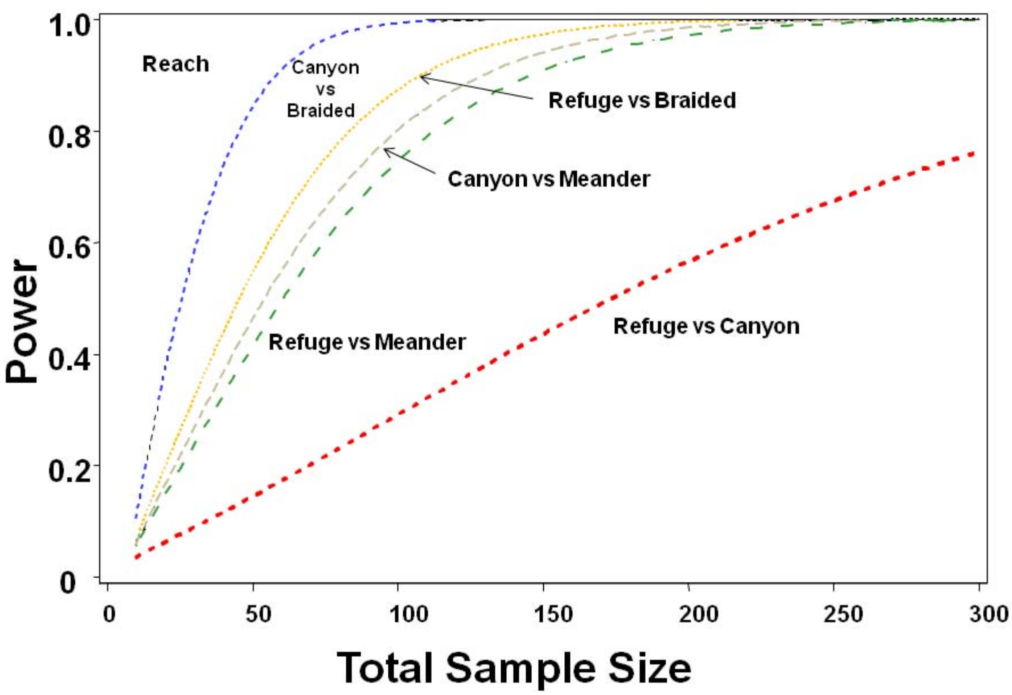


**Figure E-13.  Power curves for the 2007 invertebrate river reach contrasts.**

## Continued Sampling of Biotic Communities Basin-Wide

We plan to continue collecting avian and invertebrate community data from 153 sampling sites distributed throughout the 500-year floodplain, annually.  In 2008, we added 2 sampling locations in agricultural fields and 1 sampling location near the Canadian border to provide better sampling distribution and representation in the meander reach.  We plan to sample these same sites in 2009, but may reduce the total number of sites to allow for sampling outside the basin.

To standardize habitat classification across years, distance and direction data collected during avian point counts were plotted spatially using ArcMap.  For invertebrate collections, we marked each invertebrate pit trap using Garmin E-trex GPS units.  These coordinates were downloaded into ArcMap and corrected using NAIP true color aerial photography.  We used these locations, habitat description recorded by the observer, and land classification maps to assign standardized habitat assignments for each avian detection and invertebrate pitfall trap location across years. These efforts standardized habitat descriptions of numerous observers over several years with the high resolution land cover classification to facilitate analysis and comparison among and between land cover classes.

**Avian**

The avian community was sampled at each of the selected points using a ten-minute point count (Hutto, Pletschet, and Hendricks, 1986, Ralph 1992). All birds heard or seen were recorded. The distance to each bird was estimated as well as the direction from the point to each observation. Abundance was also recorded for those instances when multiple birds were detected in one location. Each observation was assigned a habitat designation. In addition, a framework for the guild analysis has been created. We chose to look at functional guilds as well as additional categories. Eleven categories were created (see Appendix C). The initial guild assignments have been completed. Modifications to the proposed guild structure are being examined.

**Invertebrate**

The invertebrate fauna was sampled by pitfall trapping within a subset of avian sampling sites. Pitfall trapping is a common method of sampling invertebrates in epigeal and terrestrial habitats. The method is economically efficient and yields high rates of capture (Luff 1975; Spence & Niemela, 1994; Sunderland et al. 1995). Invertebrate specimens were identified at different levels of taxonomic resolution depending on the fauna under investigation. Insects and spiders were identified to the Family level, while all other invertebrates were identified to the Class or Order level. In addition, we identified the following four families of insects to the species level: Carabidae (ground beetles), Curculionidae (weevils), Scarabaeidae (scarab beetles) and Silphidae (carrion and burying beetles). All taxonomic groups were classified into guilds for future analysis. In 2007, we adjusted the invertebrate sampling design to optimize sampling effort and allow for analyses by habitat. In 2008, we increased sample size by adding samples primarily in the tailwater reach in response to the sample size analysis. By the end of 2008, all specimens collected were identified and the data were entered into databases for validation prior to incorporation into the Web-based relational database.

## Assess indicator values of avian and invertebrate species by land cover classification

The indicator value analyses given here are based on the work outlined in Dufrene and Legendre (1997). Similar analyses may also be found in subsequent work such as McGeoch et al. (2002). Specifically, a statistic known as the indicator value is computed for individual taxonomic groups within specified site classifications, such as habitat. This index combines the relative abundance of the taxonomic groups with their relative frequency of occurrence in various habitats. It is argued that the indicator value, a measure of ecological bioindication, can help in explaining the hierarchical structure of taxa distributions and that it is stable over temporal changes. It has also been suggested that the indicator value, denoted by "$I$", of a certain taxonomic group for a typology of sites is the maximum value observed over all groups of that typology. While maximum values of *I* represent indicator "characteristic" species for a particular habitat, it has been suggested that moderate values imply indicator "detector" species for that habitat. Although other cutoffs are suggested in the literature, it is noted that they are subjective benchmarks, and thus, indicator values should only be interpreted in a relative manner based on the data at hand and the research objectives.

Individual value analysis provides a linkage between habitat and biological indicators. The analyses identify potential taxonomic groups, which may be useful for discerning environmental changes. The analyses below have been shown to be temporally stable across multiple years, thereby providing a useful environmental measure for the OLA project. The initial analyses (below) began the process of identifying appropriate taxonomic groups for assessing avian and invertebrate organisms. Continued monitoring of the indicator and detector species or families in conjunction with other environmental correlates will aid the assessment of the project goals and targeting monitoring plans toward appropriate species, guilds, trophic levels, or functional groups.

In addition to the indicator value analyses, we have used ordination analysis to look for compositional gradients in the invertebrate community due to habitat type and composition. Results of the ordination agree quite well with the individual values analysis, largely identifying the same taxa as indicators or detectors of the five habitats of interest.

The indicator value for the $i^{th}$ taxonomic group in the $j^{th}$ habitat, $I_{ij}$, is calculated as:

$$I_{ij} = a_{ij} \times b_{ij} \tag{1}$$

where, $a_{ij}$ and $b_{ij}$ are referred to as the specificity and fidelity, respectively. Specificity is a measure of abundance given by:

$$a_{ij} = \frac{N_{ij}}{N_{i.}} = \frac{N_{ij}}{\sum_j N_{ij}} . \tag{2}$$

The $N_{ij}$ represents the average number of individuals of taxonomic group i in the $j^{th}$ habitat while $N_{i.}$ is a sum of all mean abundances for taxonomic group i. The average number of individuals is used here as a method for mitigating the effect of different numbers of sites within each of the j habitats. Specificity will be maximized at 1.0 when the $i^{th}$ taxonomic group is only present in habitat j, that is, the taxa group is specific to a particular habitat.

Fidelity, $b_{ij}$, is defined as:

$$b_{ij} = \frac{Ns_{ij}}{Ns_{.j}} \tag{3}$$

where $Ns_{ij}$ is the number of sites in habitat j containing taxa group i and $Ns_{.j}$ is the total number of sites in habitat j. In other words, fidelity is the proportion of sites in habitat j containing the $i^{th}$ taxonomic group. Fidelity is maximized at 1.0 when a taxonomic group, i, is observed at all sites in habitat j.

***Avian Data***

The OLA Project avian data encompasses 25,431 observations collected over the years 2003 to 2008 in 153 sites. Due to anomalies in the dataset, 2002 avian data were not used in these analyses. All observations are identified to the species level of taxonomic classification. Sites were initially classified into 25 Gap Code habitat classifications. Because in some cases the number of sites available in each year - habitat combination were sparse, the habitat classifications were condensed into 11 habitat types.

The following discussion only highlights a couple of examples for the reader. Morning doves (MODO) showed the largest indicator value for Transportation Surfaces (habitat 1200). The value, however, is moderate in magnitude, 0.19, suggesting that this species may be a good detector species for that habitat. In addition, the next three species, Brewer's blackbird (BRBL), American crow (AMCR), and rock dove (RODO) show indicator values lower than MODO. That is, any of these species would be poor choices for indicator detector species in habitat 1200. In contrast, the next habitat, Disturbed Grassland (habitat 3102), shows the species vesper sparrow (VESP), chipping sparrow (CHSP), tree swallow (TRSW), eastern kingbird (EAKI), and violet-green swallow (VGSW) with a relatively higher indicator values. These may be good indicator characteristic species for habitat 3102. In fact, sparrow and swallow species make up 4 of the top 5 indicator values for this habitat, suggesting a commonality between them may exist. A few species, such as spotted sandpiper (SPSA) in the habitat 5100 (River and Stream), show high indicator values (.43) as well as the component values for specificity and fidelity, and may be considered indicator species for those habitats.

The literature suggests that species with low specificity values, e.g. AMCR in the habitat 1200 are generalists. That is, they occur in multiple habitats other than 1200. On the other hand, higher specificity values, such as species VESP in habitat 3102, indicate that these species are fairly specialized and are found almost exclusively in that habitat type.

Fidelity is a measure of a species distribution within a habitat. Low fidelity, such as American kestrel (AMKE) in habitat 1200, suggests that this species is only found in a few sites related to habitat 1200 and is, therefore, sparsely dispersed, while the species CHSP in habitat 3102, with a high fidelity, was observed in the majority of the 3102 sites and, hence, is more uniformly dispersed across that habitat. Finally, species showing both moderate specificity and fidelity (the detector species) can be important in evaluating changes in habitat conditions and integrity as they will more easily shift across habitats when necessary. An example here might be species BRBL in habitat 1200. This species is found in the 1200 habitat, but is not exclusive to that habitat. Likewise, within this habitat, it does not occupy all sites and could potentially move from site to site within the habitat. Monitoring such species may prove valuable for assessing the impacts of past or future environmental changes.

***Invertebrate Data***

The OLA Project invertebrate data encompasses 8,315 observations collected over the years 2005 and 2007 in 81 sites. The sampling protocol for 2005 differed from that of 2007 and Gap Code designations for 2005 data were not yet verified and available. Hence, the invertebrate individual value analyses below will concentrate on the 2007 data. There are 42 sites recorded for the year 2007, with 6955 observations. All observations were identified to the family level of taxonomic classification. Twenty-six Gap Code habitat classifications were initially used to classify sites. To avoid situations where the numbers of sites within each habitat were sparse, the habitat classifications were condensed into 9 habitat types

The following discussion only highlights a couple of examples for the reader. The family Slender-Springtail shows the largest indicator value for all families detected in habitat 3101 (upland grassland) at 0.35. This high indicator values was due largely to a high Fidelity value of 0.84, but only a moderate Specificity of 0.42. The indicator value, however, is moderate in magnitude, 0.35, suggesting that this species may be a good detector species for that habitat. Two other springtail families (Isotomidae and Sminthuridae) also appear in the top indicator rankings for this habitat, indicating that springtail families may be good detector families, in general, for habitat 3101. For habitat 6202 (shrub-dominated riparian), two true bug families (Leafhopper and Big-eyed bugs) show relatively high indicator values of 0.41 and 0.33, respectively. These may be good indicator families for habitat 6202, while other families, such as Miridae (Plant-bugs) are not.

The literature suggests that families with low specificity values are generalists and correspondingly, families with higher values may be considered as specialists. Additionally, families showing both moderate specificity and fidelity can be important in evaluating changes in habitat conditions as they will more easily shift across habitats when necessary.

## Initial development of an index of Biotic Integrity (IBI)

To develop an IBI, data collected on biotic communities need to span the range of the anthropogenic disturbance of concern. Several methods are being considered to define “biological integrity”. First, we are investigating the use of only sites in the Kootenai River Basin. These sites cover a range of varying conditions found in the Kootenai River Floodplain. In addition, reference sites in free flowing rivers or analogue sites might need to be selected to cover the range of variation and/or to test the IBI metrics developed using the current sampling location. Second, we intend to use the dynamic rules-based vegetation model to simulate the response of biotic communities to vegetation alteration caused by hydrologic alterations.

The OLA project is presently developing a terrestrial IBI using avian and terrestrial invertebrate data collected within the Kootenai River floodplain between 2003 and 2008. It is still undetermined if these will be separate IBI’s or combined into one terrestrial IBI. Data collected in 2009 and beyond could be used to improve IBI calibration and/or evaluate the IBI. These IBI’s will be an integral component of the overall Index of Ecological Integrity (IEI) assessing operational losses at the reach or basin level, and will be used at a finer scale (site, project, parcel, etc.) as a monitoring and evaluation tool. Site specific vegetation components (Key Ecological Correlates - KEC) will be used to scale the effects of human impact at each site.

The first step in developing an Index of Biological Integrity (IBI) is to rate sampling sites based on their integrity (Karr 1981). Since the sampling sites for the operational loss assessment contain numerous land cover types, a method that could rate and aggregate all land cover components of the site needed to be developed. To accomplish this task, a rating system based on land classification cover and site-specific KEC (The Northwest Habitat Institute 2006) was developed. The mapped land cover classes (P. Tanimoto, Conservation Imaging Inc., Moscow ID; 12/04/07) were aggregated into generalized land cover classes (GLCC) (Table E-2). For each GLCC, a habitat rating was derived using information from KEC data. Each GLCC was given a score of 1 to 5 based on its natural ability to sustain itself over time. A score of 5 indicated the highest ability for the cover type to be retained over time or in other words, the highest integrity. The criteria and justification for each GLCC rating is displayed in table E-2. Each rating was then weighted by the proportion of area of the GLCC in question within the 50 m radius of the plot center. All weighted ratings found in the polygon were summed to obtain an overall site rating and rounded to the nearest integer.

Since development of this rating system in December 2008, field visits resulted in additional criteria for consideration and incorporation into the rating system (the influence of natural succession, river migration, and landscape context). We will investigate these and other issues by analyzing free-flowing rivers and sites within the Kootenai floodplain that have minimal anthropogenic impacts, along with interpretation of historical aerial photographs. In addition, the vegetation model may provide information to assess these and other variables related to site rating. These tasks are planned for FY2009, but likely will continue into FY2010. Validation and calibration of the IBI will need to be completed in FY2010 and FY2011 using sites held back from the initial analysis, current data not currently used in development of the model, and/or sites from other river floodplains.

Once the site rating system is finalized, metrics for terrestrial communities will be regressed against site rating to identify significant metrics to use in IBI development. The metrics chosen should be sensitive to hydrological changes and related to ecological functions. These metrics will be placed in a pie chart similar to the IHA for easy identification of the contribution of each metric to the overall IBI and IEI.

As part of the OLA project, a series of variables and metrics were developed for Indices of Biological Integrity (IBIs) from project meetings, RDRT discussions and assignments, and various sources in the literature. IBI variables refer to independent or predictive variables, such as site rankings, GAP code, habitat composition, or distance to habitat edge (Table E-3), whereas IBI metrics can be thought of as biotic response variables or dependent variables, such as abundance, growth rate, or taxa richness (Table E-4). Because functional large river floodplain ecology involves interaction of species assemblages and energy pathways among adjacent aquatic, riparian, and terrestrial habitats, we chose to include and portray IBI variables and metrics in the following tables across assemblages among these habitats (Tables E-3 and E-4). These tables outline some independent variables and metrics that are currently being considered, however, these tables are not all inclusive and are subject to change as analyses continue. These metrics could be measured at varying spatial scales (site, parcel, subbasin) and would provide metrics for monitoring plans. Another monitoring metric could be associated

**Table E-2. Criteria and justification for rating each GLCC.**

| GLCC | Rankings | Justification |
|---|---|---|
| Urban | 1 | Urban and transportation surfaces are not natural habitats and represent areas with heavy anthropogenic effects. Without continued anthropogenic actions, these areas would convert to a natural GLCC. |
| Agriculture | 1 | Agriculture represents areas with heavy anthropogenic effects. Without continued |

| | | |
|---|---|---|
| | | anthropogenic actions, these areas would convert to a natural GLCC. |
| Grass/Forb | 1-5 | The rating of this GLCC is heavily influenced by the presence and dominance of invasive species. The more invasive species present, the more likely that this native GLCC will convert to a non-native GLCC.<br>5 - no invasive species present<br>4 - 0-10% canopy coverage of invasive species<br>3 – 11-35% canopy coverage of invasive species<br>2 – 36-65% canopy coverage of invasive species<br>1 – more than 65% canopy coverage of invasive species |
| Shrub | 1-5 | The rating of this GLCC is based on the number of canopy layers and the presence of invasive species. It is assumed that the more canopy layers, the more likely the GLCC will be retained over time, however, a high canopy cover of invasive species will reduce the likelihood of retaining the natural GLCC. The number of canopy layers provided the initial scoring (1 layer = 1, 2 layers = 3, 3 layers = 5) with the presence of heavy infestation of invasive species (>36% canopy cover) reducing the initial rating by 1. |
| Tree | 1-5 | The rating of this GLCC is based on size class distribution of trees. It is assumed that the more size classes of trees present, the longer the GLCC will be retained on the landscape. Therefore, the scoring is based on the presence of trees in each of 5 size classes; seedling, saplings, pole, mature, and large and giant. |
| Rock | ??? | Initially rated as a 1, but actually, this GLCC is likely to be unaffected by anthropogenic influences. We need to develop an adequate rating system for this GLCC. |
| Gravel | ??? | Initially rated as a 1. This GLCC might be positively affected by hydrologic changes by stabilization of substrates and allowing primary succession to start. We need to develop an adequate rating system for this GLCC. |
| Water | 3 | Initially, used a 3, but we need to give this some serious thought. Many sites have a water component. Do we just ignore the water component (subtract from the numerator and denominator), since this is a terrestrial IBI? Or is there a good way to score water? Should we score River/streams differently from ponds/wetlands? If so, how? |

with determining adequate detector species using the indicator value analyses (discussed above) across the range of site ratings. These tasks are planned for FY2009, but likely will spill over to FY2010. Validation and calibration of the IBI will need to be completed in FY2010 and FY2011 using sites held back from the initial analysis, current data collected, and/or sites from other river systems (North Fork Flathead, Fisher, Upper Kootenai Rivers are being considered).

We are exploring another method to develop an IBI based on the vegetation model (Benjankar et al., in progress). In this method, the vegetation model will be used to approximate landscape context and stand conditions throughout the basin. Multiple runs of the vegetation model given historic hydrologic parameters could be used to define a “”natural range of variation” of the landscape or site conditions. Metrics and associations developed using the current dataset will be used to populate the vegetation model outputs to estimate historic and pre-dam community conditions. This IBI would measure the difference between expected and observed communities at the reach or basin level, but would likely be inappropriate to use on a site basis or as a monitoring metric.

## Continued update and enhanced Web-based relational database

In December 2003, SCS was commissioned to create, customize, maintain, and operate a Web-based relational database for the KTOI. This included incorporation and operation related to all trophic level data and associated information for BPA Ecosystem, Operational Loss, and later for Kootenay Lake projects. Exploratory summary and graphical routines were subsequently implemented for each project component, as specified by database users. More sophisticated options, such as data censoring, multi-year-trophic level plotting displays, dynamic maps, etc, were then incorporated on needs/available funding basis. User profiles were also created, and security was implemented at a level requested and specified by the KTOI project leaders. The KTOI fish and wildlife database has been operational since March 2004.

The Ecosystem database is designed around separate trophic level data components including algae, macroinvertebrates, fish, and water quality parameters, currently encompassing years 2001 to 2007. The current Kootenay Lake database includes components for water chemistry, phytoplankton, zooplankton, and mysid shrimp data covering years 2003 to 2007. The Operational Loss Relational database currently includes avian, terrestrial invertebrate, and site components, encompassing years 2002-2007. This database is extensive and materials may be obtained by a formal request (database site: http://www.scsnetw.com). Website data updates and enhancements will continue to occur as data becomes available and enhancements are needed.

## Initiated regional review for operational loss assessment framework

In 2009 and 2010, we plan to initiate peer-review of project activities and results with the local and regional fish and wildlife managers. Peer review will be accomplished through open forum meetings (i.e., CBFWA assistance with facilitation), informational meetings, presentations of IBI's, IHA, the framework behind IEI assessment tool through presentation and publication of annual reports, methodologies, relational database data exchange. The exchange of project information as well as consultation with other fish, wildlife, and land managers will help to ensure that project implementation activities are efficient and maximizing resource benefits in the cost effective manner. The sharing of data, implementation techniques and assessment strategies with other managers will also promote a more consistent, cost effective, and coordinated strategy for watershed restoration efforts throughout other Subbasins, Provinces, internationally and Columbia River Basin as a whole.

We will emphasize a two-way flow of information (between the region and RDRT), where RDRT will incorporate ideas, comments, and recommendations into assessment framework and redistribute for a continuing feedback loop. We plan on utilizing our relational database, CBFWA website, and additional online opportunities similar to StreamNet in our dissemination of information and feedback loops wherever possible.

The Tribe has provided interaction with CBFWA, NWPCC, Tribes, states and agencies for project consistency with regional activities and operational loss assessment frameworks. In this way, we have assisted the region in understanding the potential in adopting an ecosystem-based operational loss framework, make protocols/methodologies consistent, and help to enable the transfer of critical information that project managers need to develop similar operations-based ecological assessment tool.

**Table E-3. Predictor variables under considered for IBI development.**

| Potential IBI Variables (Ind., predictive variables) | Aquatic Assemblages | | | Riparian and Terrestrial Assemblages | |
|---|---|---|---|---|---|
| | Algae/ Periphyton | Benthic Invertebrates | Fish | Invertebrates | Avian Community |
| Distance to Dam | X | X | X | X | X |
| Distance to floodplain terminus | | | | X | X |
| Distance to habitat edge | | X | X | X | X |
| Distance to nutrient addition site | X | X | X | X | X |
| Distance to water | | | | X | X |
| Elevation | | | | X | X |
| GAP code | | | | X | X |
| Geomorphic reach | X | X | X | X | X |
| Gradient (slope) | X | X | X | | |
| Habitat[a] composition | X | X | X | X | X |
| Habitat[a] diversity (H', J, D) | X | X | X | X | X |
| Habitat[a] evenness (E) | X | X | X | X | X |
| Habitat[a] richness (S) | | | | X | X |
| KECs (Key Environmental Correlates) | | | | X | X |
| Landscape context (e.g. surrounding habitat condition, % agr. lands, sampling plots at various distances) | | | | X | X |
| Landscape structure[b] (e.g. patch size, quality, and diversity, perimeter-area ratio, distance between patches) | | | | X | X |
| Litter depth | | | | X | X |
| NDVI | | | | X | |
| RKM | X | X | X | X | |
| Soil types | | | | X | X |
| Stream order | X | X | X | | |
| Stream substrate type | X | X | X | X | X |
| Varial zone influence | X | X | X | X | |
| Water quality variables (e.g. temp., D.O., nutrient availability, pollutants, minerals, metals, clarity, etc.) | X | X | X | | |

a: Use of the term "habitat" is synonymous with vegetation community or cover type b: Landscape structure data will be recorded and analyzed at various spatial scales (e.g. within plots, among plots, by reach)

**Table E-4. Response variables under considered for IBI development.**

| Potential IBI Metrics (Biotic response variables) | Aquatic Assemblages | | | Riparian and Terrestrial Assemblages | |
|---|---|---|---|---|---|
| | Algae/ Periphyton | Benthic Invertebrates | Fish | Invertebrate Community | Avian Community |
| Abundance | X | X | X | X | X |
| Age/year class structure | | X | X | | |
| Biomass | X | X | X | | |
| Density | X | X | | | |
| Diversity measures (H', J, D) | X | X | X | X | X |
| Dominant Seral stage | | | | | |
| Endemism | | X | | X | X |
| EPT richness, diversity, evenness | | X | | | |
| Fecundity | | | X | | |
| Fidelity | | X | | X | X |
| Fulton's K | | | X | X | X |
| Functional guilds | | X | | X | X |
| Functional redundancy | | | X | X | X |
| Growth rate | X | | X | | |
| Litter depth | | | | X | X |
| Mean length at age | | | X | | |
| Number eggs/clutch | | | | | X |
| Number of clutches/season | | | | | X |
| Percent exotic (non-native ) taxa | | X | X | X | X |
| Percent generalist taxa | | X | X | X | X |
| Percent intolerant taxa | X | X | | X | X |
| Percent specialist taxa | | X | | X | X |
| Percent tolerant taxa | X | X | | X | X |
| Resilience | X | X | | X | X |
| Taxa richness | X | X | X | X | X |
| Specificity | | X | | X | X |
| Taxonomic classification | X | X | X | X | X |
| Taxonomic redundancy | X | X | | X | X |