Development of indicators of stream condition, function, and capacity for juvenile salmon

Executive Summary
BC Forest Science Program
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FP Number: Y062113

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YO62113 - Development of indicators of stream condition, function, and capacity for juvenile salmon

Project purpose and management implications

Minimizing impacts of forestry on stream ecosystems requires cost-effective methods to assess stream health. The monitoring and assessment of stream condition, function, and carrying capacity for fish requires application or development of appropriate assessment indices and protocols. Indicators of condition are fundamental to establishing resource objectives for streams, and evaluating whether objectives are being met. Most commonly used indicators of stream condition relate to channel structure and instream habitat features (Bain and Stevenson 1999). While physical habitat factors are critical components of stream condition and function, the role and use of biological components in standard assessment of condition and function have been neglected, which may be a significant factor contributing to inaccurate assessment of habitat condition and juvenile salmon rearing capacity. Goals of this project are to determine which combinations of physical or biological variables are the best indicators of stream condition (in terms of capacity to support juvenile salmon), as well as the costs and benefits of data acquisition involving varying levels of effort, providing a formal basis for optimizing information gained for effort expended. Management implications are the development of better protocols for assessing stream condition and carrying capacity, and a more explicit understanding of the costs and benefits of different indicator variables.

Project start date

This project started in Jan. 2005 as YO51113. It will continue for a total of 2 years and 3 months, and has one year left (the 2006-7 fiscal).

Methodology Overview

Project goals can be summarized as:

1) To develop and test indicators of stream condition and function in British Columbia.

2) To develop a rapid assessment protocol for assessing stream capacity for rearing juvenile salmon based on a hierarchy of variables of increasing sampling effort. Our approach will differ from more traditional ones in that we will integrate indices of both physical habitat structure and biological criteria (organic matter storage, invertebrate abundance, etc.), and develop a better understanding of how

biological variables drive juvenile salmon production, as well as their predictive correlates in different regions of B.C. (e.g. coast vs. interior).

3) To place protocols within an optimization framework that identifies indicators and protocols that give the maximum information per unit effort, so that managers can optimize effort in monitoring, and quantify the explicit trade-off between confidence in assessment and effort.

4) To communicate this information to managers and fisheries habitat inventory biologists, so that the results can be used to develop regional inventory and monitoring protocols.

Methods to collect and analyze data in support of these objectives in 2005/6 were:

Site selection. Study sites were selected to include a range of geographic locations and productivities, excluding high gradient streams. Forested fish-bearing streams in southwestern British Columbia from the west coast of Vancouver Island to the western Interior region were selected. Streams with existing salmonid capacity data were chosen when possible over streams where sampling was required. Access and site safety (e.g. water level) were considered for all sites. Study reaches were 20-30 bankfull widths long (80-250 m), and did not include major tributaries or changes in valley form, vegetation, or land use. Twenty six sites were surveyed in 2005, and an additional 20 will be surveyed in 2006.

Site surveys. Stream surveys were conducted similarly to the method described in (Moore et al., 1997). The length and width of each channel unit were measured, including units in secondary and backwater channels. These measurements were used to calculate the percent of the reach that is made up of each channel unit type, as well as mean bankfull width. The area of cover available to fish from each of four sources (LWD, small woody debris, banks, and boulders) and the organic matter coverage (% CPOM and FPOM) of each channel unit were estimated visually. Thalweg depth was measured at 3-5 locations, at the downstream end of pools when possible (Hogan, 1996). The intermediate dimension of the five largest water-moved pieces of sediment, the canopy cover, and the canopy composition were also measured at these sections.

Salmonid density estimates. Data on salmonid capacity (fish per square meter) was either collected from existing data sets or from the field. Triple-pass depletion electrofishing was done on a subset of surveyed channel units for each stream lacking existing density data. Depletion data were used to calculate the salmonid capacity of the study reach (Schnute, 1983; Zippin, 1958). Other groups used double- or triple-pass electrofishing to collect the salmonid abundance data that I borrowed, so their data are comparable with my measurements.

Food availability. Invertebrate drift samples were collected at the upstream end of pools below riffles, using a 1 m long, 250 μm mesh net with an 0.2 m opening, for 180-300 minutes depending on water velocity. Three samples were collected from each site. The depth and velocity of water being filtered at the net opening were measured in order to calculate the volume of water sampled, and thereby the density of drift invertebrates. The samples were collected at least two hours after sunrise and two hours before sunset, to reduce daily variability in light intensity. Samples were preserved using 5% formalin and returned to the lab for sorting. Not all samples from 2005 have been processed at this point, but for those that have been sorted invertebrates were removed from the samples at 10X magnification, then identified to order or family. The length of each invertebrate was measured, and length-weight curves will be used to calculate the biomass of each taxon present.

Data analysis. The habitat capacity model will be built using a generalized linear model with the statistics software R, and the best model selected using the Akaike Information Criterion (or other appropriate model selection procedure). Preliminary regressions will be used to select candidate variables to enter into the model selection procedure, and interactions between variables will be allowed. Correlation between candidate variables will be avoided.

The costs of these habitat variables will be assessed by determining the field time and laboratory time required to measure each variable. The total time for each variable will be determined by adding the field and laboratory times. The benefits will be determined according to the predictive ability (r^2) of each variable.

Project scope and regional applicability

Results from this project should have broad application for assessing habitat condition in streams throughout B.C. The methods of assessment, the protocols for optimizing variable selection, and the conclusions with respect to the power of individual variables (as well as physical versus biological classes) should have general application for stream assessments in north temperate climates.

Interim results from 2005 field sampling

<u>Summary of 2005 field season</u>

26 sites were surveyed in 2005 (Table 1). The sites covered a wide geographic range and a variety of productivities, ranging from 0.36-4.37 fish/m². Fish density data existed for 17 of those sites, and six of the remaining sites were triple-pass electrofished. High flows or the presence of spawning adults prevented us from electrofishing the other three sites. Sites were selected to cover a wide geographic range as well as a wide range of productivities.

Table 1: Sites surveyed in 2005, with region, source of salmonid population data, and salmonid population estimate.

Site name	***Region***	***Density data source***	***Estimated salmonid density(fish/m²)***
Chapman	Sunshine Coast (SC)	Allen Hanson, BCCF	0.55
Coho S Trib	SC	Jordan Rosenfeld	1.87
Cook	SC	Jordan Rosenfeld	0.99
Crazy	Interior	2005 electrofishing	0.64
Finish Early	Vancouver Island (VI)	Jordan Rosenfeld	0.56
High Falls	Lower Mainland (LM)	Allen Hanson, BCCF	0.41
Husdon	SC	Jordan Rosenfeld	0.73
Kootowis A	VI	Jordan Rosenfeld	2.47
Kootowis B	VI	Jordan Rosenfeld	0.78
Kootowis C	VI	Jordan Rosenfeld	2.24
Lemieux	Interior	2005 electrofishing	1.98
Linquist	Interior	2005 electrofishing	4.37
Lost Shoe	VI	Jordan Rosenfeld	0.56
Sandhill	VI	Jordan Rosenfeld	0.26
Senn	Interior	2005 electrofishing	3.77
Shovelnose	LM	Allen Hanson, BCCF	1.61

Site name	*Region*	*Density data source*	*Estimated salmonid density(fish/m²)*
Silverhope	LM	Allen Hanson, BCCF	0.6
Slesse	LM	Allen Hanson, BCCF	1.4
Wakefield	SC	Jordan Rosenfeld	0.95
Yard	Interior	2005 electrofishing	0.16
Yola	LM	Allen Hanson, BCCF	0.66
Colvin	SC	poor data quality – will re-shock in 2006	
Vermelin	Interior	poor data quality	
Depot	LM	spawners present on shocking date	
Fennel	Interior	water level too high to shock	
South Pass	Interior	water level too high to shock	

Plans for 2006 field season

We plan to survey at least 20 more sites this summer, to bring the total number of usable sites to at least 40. We are discussing possible sites with staff from DFO, Provincial Fisheries, and non-governmental organizations such as the Salmon River Community Roundtable. All field methods will be the same as in 2005, with the exception that invertebrate drift samples will be collected for a maximum of 180 minutes, unless invertebrate drift is extremely low. The reason for this change is that many of the samples collected in 2005 are very large and require too much time to sort. We are confident that this change will not reduce the quality of the data.

Preliminary results

We performed some preliminary regressions on transformed and untransformed data (percentage data were arcsine-squareroot transformed to improve normality). At this time we have not found an individual variable that significantly predicts fish population; most of the univariate regressions have very low r^2 values. Several of the regressions show a wedge-shaped data pattern (eg Bankfull width). This pattern indicates that quantile regression may be the best way to analyse the data. We are currently researching this method.

The wedge-shaped data pattern indicates that the variable in question limits fish density when no other variables are limiting. That is, fish density is limited by several variables, so different variables are limiting at different sites (Terrell et al., 1996). Several variables showed these wedge-shaped patterns: bankfull width, conductivity, average largest particle, pieces of large woody debris, pool area, and total canopy cover.

The slopes of the 90^{th} quantiles (estimated visually) indicate that juvenile salmonids do best in small streams with low canopy cover, smaller average particle size, little wood, few pools, and few pieces of large woody debris. These visually estimated results contradict much of the research on juvenile salmonid habitat, but support the idea the food availability may limit salmonid abundance more than habitat. Streams with low canopy cover have more primary production, and therefore higher production of invertebrates. Streams with high canopy cover, and the associated high amount of large woody debris, could have fewer fish because of low food availability. These results support the idea that small streams with low maximum flows and gradients (and therefore smaller particle size) have higher densities of juvenile salmonids. The patterns will be more clear after a generalized linear model has been constructed, and 90^{th} quantile regressions have been performed. This preliminary interpretation has to be tempered by the observation that canopy cover and the abundance of Large Woody Debris, pools, and invertebrates are confounded. Coastal streams in the data set have abundant Large Woody Debris, pools, and high canopy cover that likely results in lower prey abundance. Interior streams have low LWD and pool abundance, and low canopy cover that results in higher *in situ* prey production and densities of fish. Thus it may appear that pools are associated with lower fish density when in fact this is a spurious correlation driven by higher prey abundance in interior streams with lower pool frequencies. In other words, habitat and prey abundance may jointly limit fish production, i.e. an increase in pools in interior streams could result in an increase in fish biomass, as would and increase in prey in coastal streams.

Because these results are preliminary, and are based on a superficial univariate analysis that does not include any actual estimates of prey abundance, they should be viewed as speculative until a valid analysis is completed with all available data.

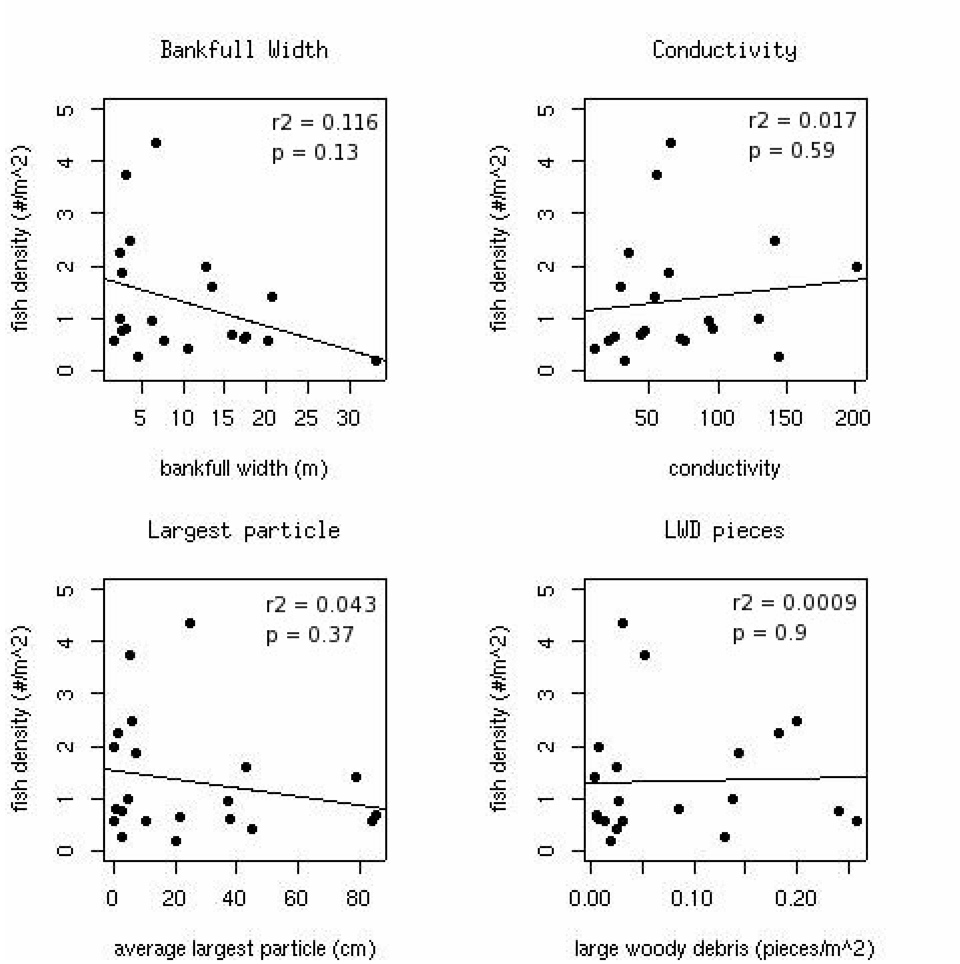

Figure 1. Univariate relationships between fish density and bankfull channel width, conductivitiy, the average largest particle size in a stream, and the abundance of LWD.

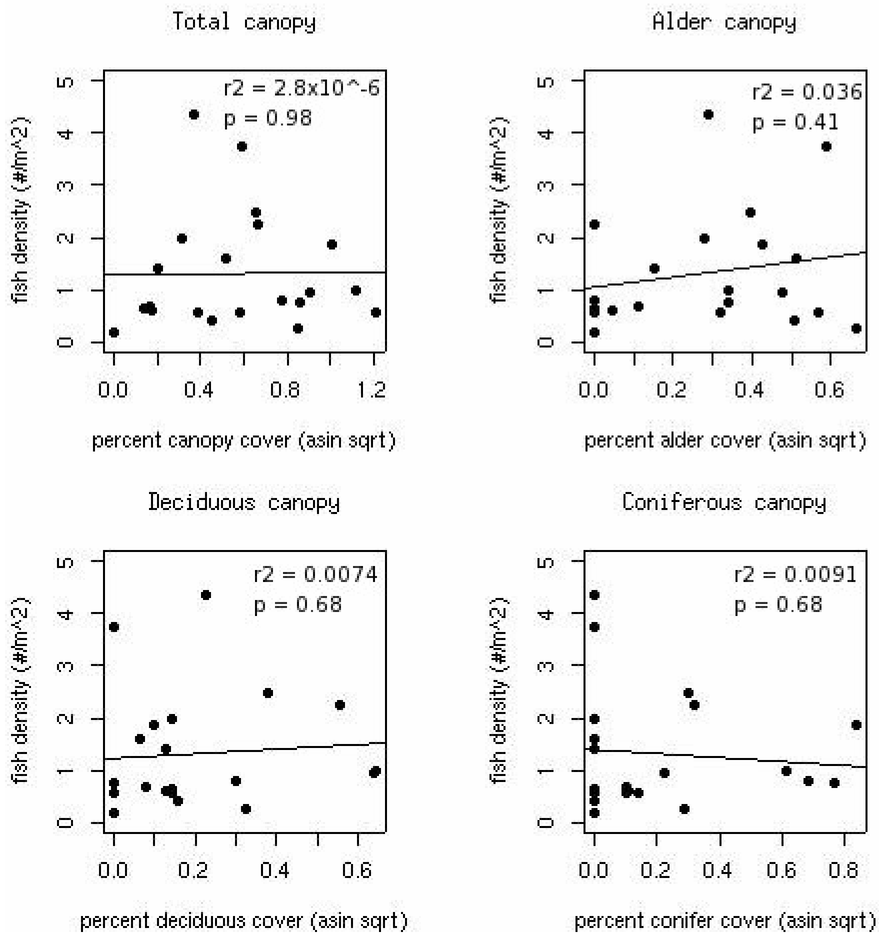

Figure 2. Univariate relationships between fish density and total canopy cover, alder canopy cover, deciduous canopy cover, and coniferous canopy cover.

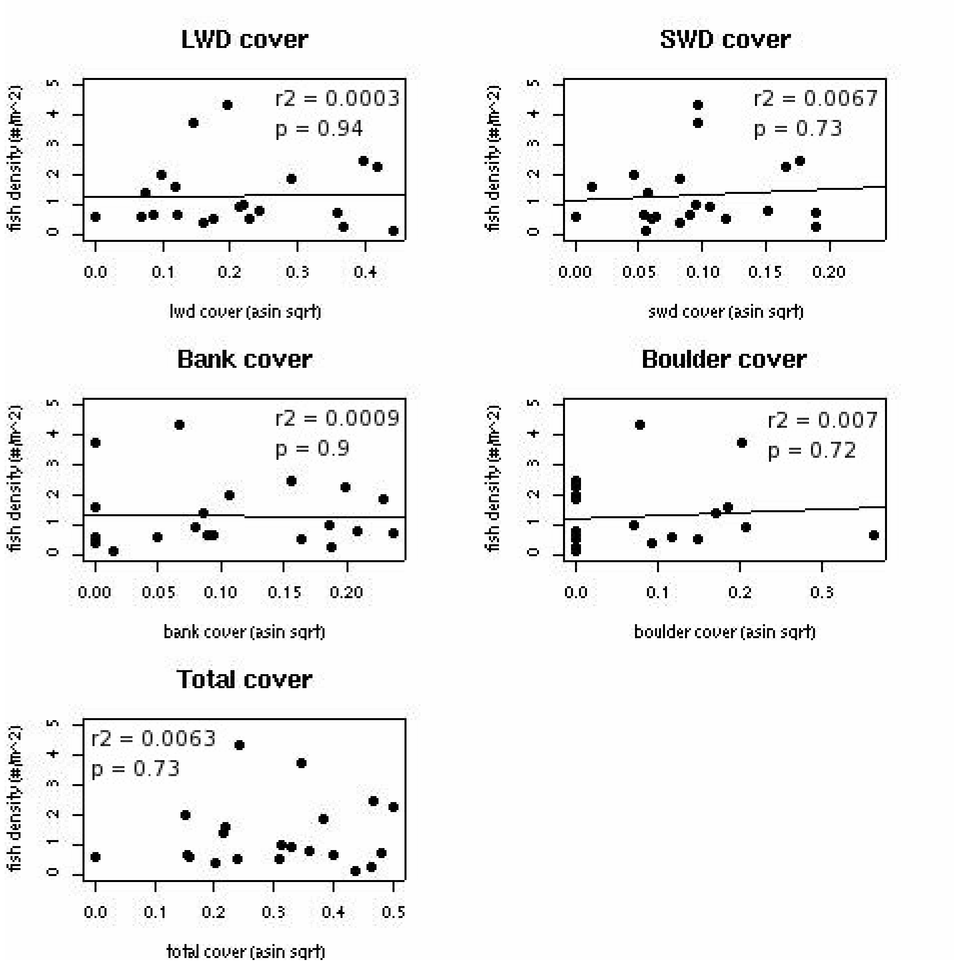

Figure 3. Univariate relationships between fish density and instream LWD cover, SWD cover, bank cover, boulder cover, and total cover.

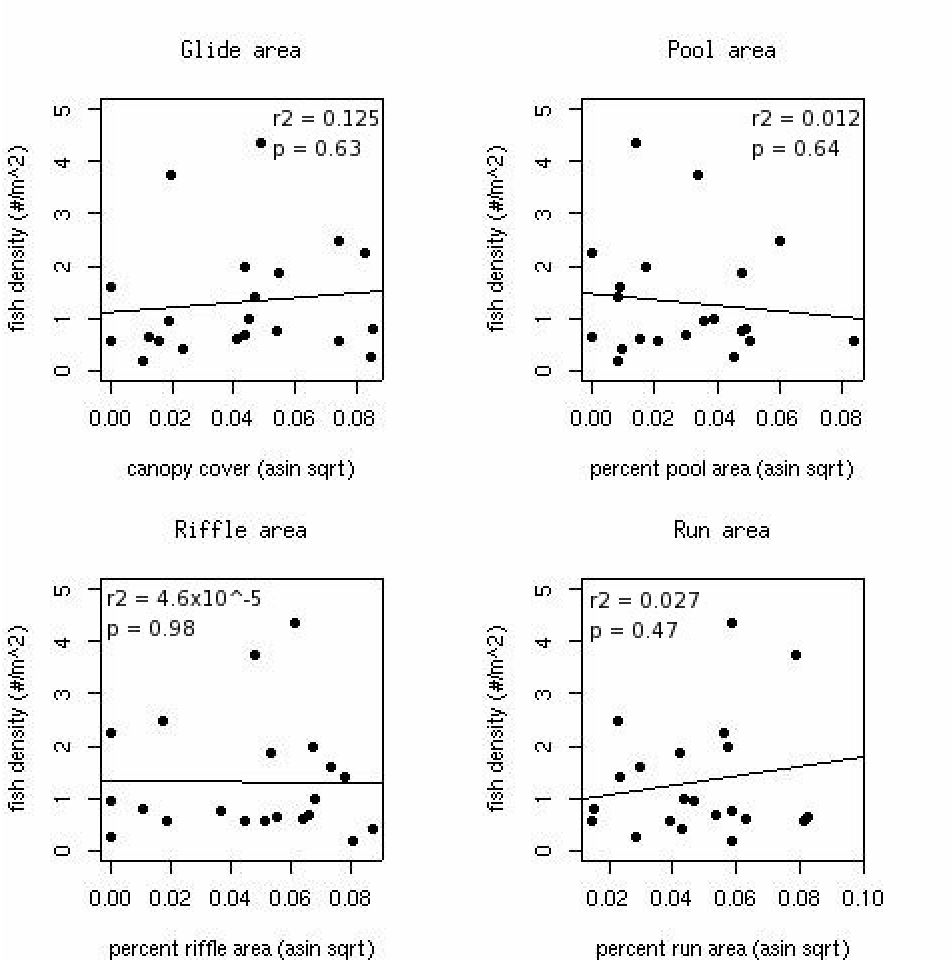

Figure 4. Univariate relationships between fish density percent of the sampled site as glide, pool, riffle, or run habitat.

References

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