Developing a juvenile stock-recruitment relationship for Yukon River Chinook salmon.

Yukon Restoration and Enhancement Fund Project CRE-160-18N

Final Report

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Abstract

A suite of seven small streams in the Dawson City area has been periodically monitored for mid-summer juvenile chinook salmon abundance since 1999. These streams are small non-natal streams that are colonized by juvenile salmon in the summer months. This report documents sampling conducted in the summer of 2018. Juvenile density was estimated in each stream, body size measurements and physical parameters were recorded, and DNA samples from juvenile salmon were collected for analysis. High flows resulting from heavy rain were encountered during sampling. Densities were somewhat lower than in other years, and some estimates were less precise due to lower capture efficiencies associated with high flows. Data collected in 2018 will be merged with previous results to evaluate the relation between juvenile abundance in these small steams, and parent spawner abundance to increase our understanding of how habitat limitation may affect population productivity.

Introduction

Chinook salmon harvest management in the Yukon River relies on escapement goals, and in particular the "border" escapement that sets the management goal for the Canadian portion of the stock aggregate. Escapement goals can be based on stock-recruit analyses that seek to identify the spawning escapement that maximizes long-term yield. However, stock-recruit datasets are often highly variable and the analyses are prone to bias due to uncertain stock and recruit estimates as well as other factors. Ancillary information such as habitat characteristics can play an important role by reducing uncertainty in stock-recruit analysis because limits to salmon production are usually related to the quantity and quality of freshwater habitat.

For Chinook salmon the use of ancillary information is challenging because there is considerable variation in life history both among and within populations, particularly in the juvenile phase. Large rivers are often important habitats but are difficult to sample for both habitat and juveniles. For some Canadian-origin populations previous research has shown that juveniles undergo significant downstream migrations during June and colonize small non-natal streams as rearing environments during the summer (Bradford et al. 2009). These small streams are amenable to quantitative sampling during summer low flow periods. Previous work has shown that juvenile salmon can reach high densities in preferred habitats, and densities are limited by habitat quality (Mossop and Bradford 2006).

The relationship between spawner abundance and juvenile density in non-natal streams can provide information about the number of spawners that may be sufficient to fully "seed" these habitats, and thus provide some evidence of limits to production, colloquially known as "bottlenecks". Such relationships have been found in small streams in the headwaters of the Snake River basin in Idaho and maximum densities of about 0.5 fish m^{-2} were observed in these high altitude streams (Thorson et al. 2014).

Further, quantitative information on the relationships between juvenile salmon density and habitat characteristics can provide valuable information for the management of fish habitat, including guidance for compensation and restoration activities.

The objective of this project is to add to an existing database of juvenile densities for small non-natal streams in the Canadian Yukon basin. With sufficient data it will be possible to identify if a relation between parent spawner abundance and juvenile densities exists, and if that relation has potential to predict salmon returns, or can be used to make inferences about habitat productivity.

Methods

In the late 1990s methods were developed for estimating the abundance of juvenile chinook salmon in small non-natal streams that were adaptations of standard methods for sampling juvenile salmon (Bradford et al. 2001). Those methods ranged from depletion electrofishing, usually employed in smaller shallow streams, to mark-recapture estimates, based on a combination of minnow trap and electrofishing for larger and deeper streams.

Between 1999 and 2002 a suite of small streams in the Dawson and Minto regions were sampled (Mossop and Bradford 2006), and in 2003 and 2016 seven of those streams located in the Dawson City area were again sampled. Sampling usually occurred in early August during the normal low-flow period.

As part of this project those same seven streams were resampled in 2018. The streams are Garner, Meachem, Ensley, Baker, Caribou, Quebec and Deadman Creeks. To ensure consistency with existing data the same methods were be applied in 2018 as were used in the past.

Sampling was conducted between August 7 and 10, 2018. A 5 m river boat, based in Dawson City, was used to travel to the sampling sites. At each site, a single survey reach was established that extended from just upstream from the confluence of the Yukon River for 70 to 200 m; the upper extent of sampling was usually at a significant riffle or barrier. The length and average wetted width of the stream was determined with a hip-chain and tape measure. Detailed surveys of the habitats have been conducted in the past; those studies found that stream gradient was a reliable predictor of juvenile density and that stream characteristic is not expected to change over time (Mossop and Bradford 2006). Stream temperature, conductivity, pH, oxygen and turbidity measurements were taken with portable meters.

Normally stream discharge measurements are taken, however, an equipment malfunction prevented them from being recorded. We did observe that stream flows were high as a result of rainfall that occurred before and during the sampling campaign (Figure 1). Some modification of sampling methods were required as in many cases minnow traps could not easily be deployed and their efficiency was low.

Figure 1. Baker Creek in August 2018 showing high flows resulting from local rainstorms

Densities of juvenile Chinook salmon were estimated for each sample reach. Although the sample reaches cannot be enclosed during the sampling, the upstream limit of the sample reaches are usually set at a significant riffle, rapid or drop, that likely restrict upstream movement. Previous work in the Yukon and elsewhere has shown movements of juvenile fish are often limited and will have only a minor impact on population estimates.

For those streams where a mark-recapture estimator was used, minnow traps were deployed overnight to capture fish for marking. Due to low catches (caused by high flows), additional fish were recovered by electrofishing. Fish from this first sample were marked with elastomer tags and released. The following day the study reach was sampled with a single electrofishing pass and the number of previously tagged fish in the sample was recorded.

In smaller, shallower, streams an electrofishing-based two pass depletion estimate was used, consistent with past surveys. Electrofishing was conducted in an upstream direction, and there was an interval of at least one hour between passes. Densities were estimated using standard formulae (Carl and Strub 1978, Ricker 1975) as implemented in the FSA package in R statistical software (http://derekogle.com/FSA/).

All captured salmon were measured for fork length to the nearest mm and caudal finclips were taken from a subsample for DNA to determine the populations of origin.

Data resulting from this project are currently housed by DFO and will be compiled with the historical sampling data when the final analysis is completed.

Results

As noted above flows were not estimated this year, but they were significantly higher than normal low-flow summer conditions observed in previous years. Correspondingly, stream temperatures were lower than observed in the past (Table 1).

Table 1: Summary of physical measurements for the 7 study streams and the Yukon River near Dawson.

Stream	Width (m)	Turbidity (NTU)	Conductivity	pH	Temperature (°C	DO (mg/L)	DO (%)
Baker	4.3	28	131	8.2	4	13.0	103.5
Caribou	2.5	3	240	8.5	2.7	13.6	105.1
Deadwood	3.5	3	265	8.5	2.7	13.6	104.6
Ensley	3.9	89	505	8.3	4.6	12.7	103
Garner	3.9	58	277	8.1	5.7	12.0	100.2
Mechem	3.8	173	314	8.4	4	12.9	102.7
Quebec	4.4	2	139	8.5	2.3	13.7	104
Yukon River		940	242	8.5	13.6	10.2	102.8

Despite high flows we were able to capture sufficient numbers of fish to generate population estimates for each streams. However, the uncertainty in those estimates (as indicated by the standard errors (SE)) is relatively high for the mark-recapture estimates due to the lower than usual catches. The 95% confidence interval for each estimate can be approximated as ±2SE.

Table 2. Study reach size, fish captures and population and density estimates based on 2-pass depletion methodology employed on the four smaller streams. N is the estimated number of salmon in the study reach, SE is the standard error.

	Study Reach		Fish captures		Estimates			
Stream	Area (m^2)	Length (m)	Pass 1	Pass 2	N	SE	Density /m^2	SE
Baker	337.9	79	31	15	56	9.04	0.17	0.03
Caribou	176.5	67	7	0	7	0	0.04	0.00
Deadwood	240.6	69	18	7	27	3.13	0.11	0.01
Quebec	384.7	87	15	5	21	2.09	0.05	0.01

Table 3. Study reach size, fish captures, abundance and density estimates based on mark recapture methods employed on the three larger study streams. For the fish captures, M is the number of marks applied, n is the number of fish captured in the second sample, and m is the number of marks in the second sample. N is the estimated number of salmon in the study reach, SE is the standard error.

	Study Reach		Fish captures			Estimates			
Stream	Area (m^2)	Length (m)	M	n	m	N	SE	Density /m^2	SE
Ensley	821.1	208	57	49	8	321	85	0.39	0.10
Garner	451	117	25	39	11	86	15	0.19	0.03
Meachem	691.6	182	21	42	3	236	91	0.34	0.13

Size data

Table 4 summarizes length data for fish captured during the sampling program. These data will be compared to the other years of sampling in the final data summary and review.

Table 4. Mean fork length of juvenile chinook salmon sampled in 7 non-natal streams. N is the sample size.

Creek	N	Length (mm)	SE
Baker	31	61	1.1
Caribou	7	63	1.4
Deadwood	25	69	1.1
Ensley	49	63	0.8
Garner	40	65	0.6
Meacham	42	65	0.9
Quebec	20	67	1.6

DNA

Approximately 420 DNA samples were sent to the Pacific Biological Station genetics lab for the determination of population of origin. In addition to samples taken from this year's program some archival samples from similar sampling conducted by DFO in 2016 were also submitted. Results are not available at the time of writing.

Juvenile density analysis.

The major goal of this project is to accumulate sufficient data to be able to develop a relation between parent spawning escapement and subsequent juvenile density. Such a relation will help inform the potential limits to production for Yukon River chinook salmon. An example of this relation is shown in Figure 2. This is a preliminary figure based on juvenile densities for two streams and the corresponding Canadian border escapement. Ultimately data from all streams will be included in this analysis and a more comprehensive method of analysis will be used that accounts for the uncertainty in the estimates and missing data. It is expected that DNA results will allow for some fine-tuning of the escapements to correspond to the populations that contribute most of the juveniles to the study streams.

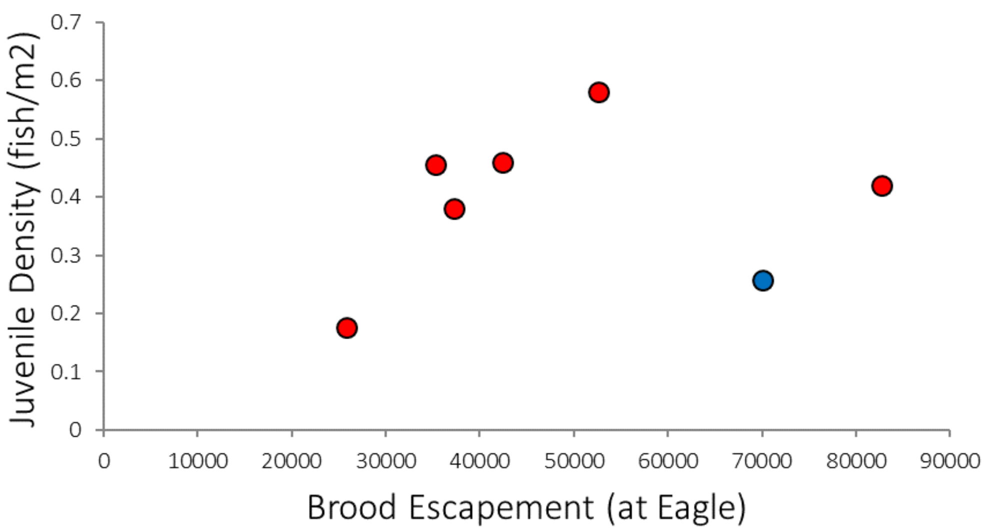

Figure 2. Average density in Ensley and Baker Creeks in relation to the abundance of potential parent spawners (one year earlier than the year of juvenile sampling), 1999-2018. Blue symbol are results from 2018.

Discussion

The 2018 sampling program was successful in obtaining sufficient data for population estimates for the study streams. Sampling conditions were not ideal and as a result confidence intervals for some estimates of density are large due to small numbers of fish captured. From this preliminary review of the data we do not anticipate that the estimates would be biased by low capture efficiencies. In the final analysis of all data collected on these streams the precision of individual estimates will be used to weight data when modelling the relation between spawner abundance and juvenile density. Consequently the 2018 estimates will have less influence than other data collected under better sampling conditions.

It is unclear whether high flows also influenced the actual densities of fish. Juveniles could move freely between the Yukon River and tributary creeks, and fish may chose to leave streams when hydraulic conditions are less favorable for successful foraging. Juveniles have been found to occur at high densities in mixing zones at the mouths of creeks (Bradford et al. 2009).

Additional years of data will be beneficial to establish the relation suggested by the data in Figure 1. Additional data will also be of value to determine if the densities in these creeks have any value in predicting future returns of adult chinook salmon, or if densities in freshwater can be related to density estimates made in the Bering Sea that are taken about 12 months after our creek surveys.

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