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Pacific Region

Canadian Science Advisory Secretariat
Science Advisory Report 2016/006

EXPLORATION OF DATA AND METHODS FOR DEVELOPING ESTIMATES OF A BIOLOGICALLY-BASED SPAWNING GOAL AND BIOLOGICAL BENCHMARKS FOR LITTLE TAHLTAN CHINOOK (STIKINE RIVER DRAINAGE)

Chinook Salmon adult spawning phase. (Photo credit: Fisheries and Oceans Canada.)

Figure 1. Map of western North America showing Stikine drainage. (Map provided by Alaska Department of Fish and Game.)

Context:

The Little Tahltan River flows into the Tahltan River, a major tributary of the Stikine River. Little Tahltan River Chinook Salmon (Oncorhynchus tshawytscha) contribute to fisheries in the United States and Canada. The Pacific Salmon Treaty obliges the Parties to use a bilaterally agreed-to, maximum sustainable yield-based escapement goal for use in managing Stikine River Chinook Salmon. A drainage-wide Chinook spawning goal exists; however, there are concerns over a recent decline in the number of Little Tahltan Chinook. This has generated an interest to establish an escapement goal specific to Little Tahltan Chinook. In Alaska, for an escapement goal to be formally recognized, it needs to be biologically based to provide sustained yield and approved by the directors of Commercial Fisheries and Sport Fish divisions. In Canada, advice is sought through a Canadian Science Advisory Secretariat (CSAS) process. As part of implementing the Wild Salmon Policy (WSP), Fisheries and Oceans Canada is required to identify biological benchmarks to assess the status of WSP Conservation Units (CU) for Pacific salmon. There are two Chinook CUs identified for the Stikine River: early-run and late-run. Little Tahltan Chinook are considered part of the early-run CU and have served as an abundance index since 1975. Benchmarks for evaluating the relative abundance metric under WSP have not yet been identified for Stikine River CUs.

This Science Advisory Report is from the November 12-13, 2015 regional peer review on Estimates of a Biologically-Based Spawning Goal and Biological Benchmarks for Little Tahltan Chinook (Stikine River Drainage). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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Canada

SUMMARY

- The Little Tahltan River flows into the Tahltan River, a major tributary of the Stikine River. The Stikine River originates in the province of British Columbia and flows to the sea through the state of Alaska. Little Tahltan River Chinook Salmon have historically been major contributors to the total Stikine Chinook production, but have declined in recent years, both in abundance and relative contribution to the total Stikine Chinook run.
- Under the Pacific Salmon Treaty, a number of bilaterally agreed-to spawning goals have been established for transboundary river salmon. A drainage-wide spawning goal for Stikine River Chinook Salmon was established 15 years ago. Due to concern over the recent decline in abundance of Little Tahltan Chinook, the Canadian caucus of the Transboundary River Panel of the Pacific Salmon Commission expressed interest in a project to develop reference points that could be used as the basis for a biological spawning goal.
- The analytical process began with a review of size-specific spawner abundance estimates for Little Tahltan Chinook for the brood years 1985 to 2007. This was necessary as Transboundary management focuses on adult or “large” Chinook. To address variability in the estimates, three different spawner datasets were compiled. Similarly, due to variability in recruitment estimates, two different recruit datasets were developed. The three spawner abundance datasets and two recruit datasets were combined to provide four datasets for stock-recruitment analysis.
- The primary approach taken for the development of biological benchmarks was that of stock-recruitment modeling. Three model forms were explored: Ricker, Ricker AR1, and Beverton-Holt. As a consistency check on the results, a data-poor analysis technique known as the percentile method for biological reference ranges was also conducted.
- Little Tahltan weir counts and total Stikine mark-recapture abundance estimates follow a similar trend from 1996 (first year of mark-recapture data) through 2007. Following the 2007 return year, the weir counts show a decreasing trend while the mark-recapture estimates show an increasing trend.
- Beginning in the 2001 brood year (corresponding to the 2007 return year), and continuing until the 2006 brood year, the Little Tahltan Chinook exhibited a period of productivity below replacement. This pattern was consistent across the four datasets used for stock-recruitment analysis. The datasets seem to fit a classic Ricker-type relationship. However, separating the data into two time periods reveals two clusters of points, both of which lack any clear pattern. Prior to brood year 2001, estimates are for highly variable recruitment across a narrow range of spawner abundances, but for brood year 2001 and later there was a wide range of spawner abundances all with very poor recruitment.
- Data quality concerns confound the results of the stock-recruitment analyses. The potential productivity changes for Little Tahltan Chinook violate one of the assumptions for stock-recruitment analyses. It is also possible that the fish counting weir may have influenced the apparent spawner abundance used in the datasets. Therefore, science advice for the establishment of an escapement goal cannot be provided based on the results of this assessment.
- In order to estimate an escapement goal, the appropriate stock unit for analysis must first be determined; this may require additional field work. A review of the two Wild Salmon Policy Conservation Unit delineations for Stikine Chinook is recommended. In addition, alternative assessment approaches to the fish counting weir should be considered.

BACKGROUND

The Little Tahltan River drains an area of approximately 314 km^2 and flows into the Tahltan River, a major tributary of the Stikine River. The river is 40 km in length and it drains a significant section of the southwest quadrant of Level Mountain. The confluence of the Little Tahltan and Tahltan Rivers is approximately 32 km northwest of the community of Telegraph Creek, British Columbia (BC). The Stikine River originates in British Columbia, Canada, and enters the sea approximately 32 km south of Petersburg, Alaska, United States (Figure 1). The Stikine drainage covers about 52,000 km^2, of which about 90% is inaccessible to anadromous fish due to natural barriers and velocity blocks. The Stikine River's principal tributaries include the Tahltan, Chutine, Scud, Iskut, and Tuya rivers. The lower river and most tributaries including the Chutine, Scud, and Iskut rivers are glacially occluded.

Because of natural barriers to migration, Chinook Salmon (*Oncorhynchus tshawytscha*) spawning is limited to the lower mainstem and tributaries of the Stikine River including the Tahltan and Little Tahltan rivers, the Chutine, Katete, Craig, Barrington and Tuya rivers as well as Beatty, Christina, Verret, Shakes, Sixmile, Andrew and Tashoots creeks (Bernard et al. 2000). Little Tahltan River Chinook have historically been major contributors to the total Stikine production, but this has changed in recent years as a result of a marked decline in abundance. Due to concerns over this decline, the Canadian caucus of the Transboundary River Panel (TRP) of the Pacific Salmon Commission (PSC) requested that a project be undertaken to explore the population dynamics of Little Tahltan Chinook and develop quantitative estimates of reference points, as the basis for establishing a biologically-based spawning goal.

Chinook Salmon returning to the Stikine River are caught incidentally in the United States marine gillnet and Canadian in-river gillnet Sockeye Salmon fisheries, as the timing overlaps with the latter part of the Chinook run. Stikine River Chinook Salmon are also caught in marine recreational fisheries and the commercial troll fishery in Southeast Alaska, and in Aboriginal, recreational, and commercial fisheries in Canada (Pahlke et al. 2010).

Under the Pacific Salmon Treaty (PST), a number of bilaterally agreed-upon spawning goals have been established for transboundary river salmon. A drainage-wide escapement goal for managing large Stikine River Chinook Salmon (i.e. Chinook Salmon greater than 659 mm mid-eye to fork length, generally 3-5 ocean age), based on the objective of maximizing sustainable yield was developed and adopted 15 years ago. This drainage-wide goal range corresponded to a range of 2,700 to 5,300 through the Little Tahltan weir based on historical contribution rates (Bernard et al. 2000). However, these were intended as indicator values in the event that drainage-wide escapement estimates could not be generated, not as a spawning goal specific to the Little Tahltan River.

As part of implementing Strategy 1 of the Wild Salmon Policy (WSP), Fisheries and Oceans Canada (DFO) is required to identify biological benchmarks to assess the status of WSP Conservation Units (CU) for Pacific salmon (DFO 2005). There are two Chinook CUs identified for the Stikine River: early-run and late-run. Little Tahltan Chinook are considered part of the early-run CU and have served as an abundance index since 1975. WSP benchmarks for the relative abundance metric have not yet been identified for Stikine River CUs.

This analysis complements earlier estimates of optimal Chinook production (Bernard et al. 2000) for the entire Stikine River. The Canadian caucus of the TRP identified the need for a review of the population dynamics and resulting management goals due to the following observations:

- Productivity of Little Tahltan Chinook spiked in the 1999 and 2000 brood years, resulting in large returns and large catches. However, productivity dropped immediately afterwards to well below the long-term average and has not rebounded.
- The contribution of Little Tahltan to the total Stikine run has declined steadily over the last 15 years.

Other sources of concern regarding Little Tahltan Chinook include the following:

- Age and size composition has changed over the last 30 years, shifting towards younger age-at-maturity (i.e. fewer age 6, more age 4 and 5) and smaller size (i.e. higher proportion of fish with less than 660mm fork length).
- A rockslide occurred in late May 2014 at a site located approximately 800 metres upstream from the mouth of the Tahltan River. The rockslide introduced a seasonal migration barrier to Chinook Salmon ascending the Tahltan River including Little Tahltan Chinook; moreover, the slide may have altered the age and size composition of the spawning escapement. Preliminary observations for 2015 indicate this may be an on-going effect.

These observations have implications for the assumptions made about population dynamics (i.e. capacity, productivity, density dependence). In turn this affects the choice of analysis methods, thereby influencing the estimates of biological benchmarks, and ultimately the considerations that shape management goals.

To provide scientific advice to establish a biologically-based spawning goal for the Little Tahltan Chinook, the specific objectives of this Canadian Science Advisory Secretariat review were to:

- Review Chinook production and escapement data for the Little Tahltan River.
- Develop biological benchmarks, including the number of spawning adults that would produce a maximum sustainable yield of Chinook Salmon using various models.
- Examine and identify uncertainties in the data and methods.
- Examine the models presented in the working paper and provide recommendations on applicability.

ANALYSIS

The analytical process began with the development of three datasets of spawner abundance for Little Tahltan large Chinook for brood years 1985 to 2007. These were developed using different age composition assumptions. The result was three alternative sets of abundance of large Chinook (i.e. jacks removed) passing the fish counting weir on the Little Tahltan River. Following this, two recruit datasets were developed. The recruit datasets sum spawner abundance with fishery harvests to determine total run size and then apply annual estimates of age composition to assign returns to brood years. Similar to the approach taken with the spawner abundance datasets, two recruit datasets were calculated based on different age composition assumptions. The three spawner abundance datasets and two recruit datasets were combined to provide four datasets for stock-recruitment analysis.

The primary approach taken for the development of biological benchmarks for Little Tahltan large Chinook was that of stock-recruitment modeling. This is suitable for situations when adult recruitment data are available, such is the case with this review. The analyses used stock-recruitment model methods to estimate biological benchmarks of spawner abundance. Three stock-recruitment model forms were explored:

- Ricker: characterized by a density-dependent drop in recruitment at larger spawner abundances;
- Ricker AR1: Ricker with a 1-year autoregression term to correct for patterns over time (i.e. good years tend to follow good years, so that residuals are not independent); and,
- Beverton-Holt: characterized by approaching a fixed production limit at larger spawner abundances (i.e. a maximum number of recruits), rather than a density-dependent decline in production.

Each model form was fitted to the four spawner-recruit datasets. Sensitivity analyses were performed to examine the impact of different resampling approaches and different estimation approaches for the derived biological benchmarks.

As a consistency check on the results the datasets were analyzed using the percentile method for biological reference ranges. This method is used in data-poor situations when recruitment data are not available and to reflect the lower level of confidence, the resulting range can be used as a Sustainable Escapement Goal (SEG) rather than a biological escapement goal.

Results

The Little Tahltan weir counts and total Stikine mark-recapture abundance estimates follow a similar trend from 1996 (first year of mark-recapture data) through 2007 return years (Figure 2). Since then the weir counts show a decreasing trend while the mark-recapture estimates show an increasing trend.

Complete recruitment estimates are not yet available for brood years following 2007. A time-series of reconstructed recruits per spawner for Little Tahltan, from 1985 to 2007, shows a break point in productivity in the 2001 brood year (Figure 3), which corresponds to the 2007 return year for the dominant age class. Beginning in the 2001 brood year and continuing until 2006, the datasets show a period of productivity below replacement (i.e. on average one spawner produced less than one recruit). This pattern was consistent across the four datasets used for stock-recruitment analysis.

The stock-recruitment analysis datasets were examined using a spawner-recruit scatterplot (Figure 4). At first glance, the stock-recruitment dataset seems to fit a classic Ricker-type relationship, with increasing production as spawner abundance increases, then a peak and decline in production as capacity is reached and exceed. However, when separating the data into the two time periods previously discussed, there are actually two clusters of points, both of which lack any clear pattern. Prior to brood year 2001, estimates are for highly variable recruitment across a narrow range of spawner abundances, but for brood year 2001 and later there was a wide range of spawner abundances all with very poor estimated recruitment (below replacement in most years).

Among the stock-recruitment model and dataset variations tested, the biggest difference in estimates is between the Ricker and Beverton-Holt models. However, regardless of model form and dataset, the resulting estimates are somewhat similar to each other. It is important to note that some of the models predict a spawner-recruit point that is not representative of the distribution of points seen in their stock-recruitment analysis dataset. All three variations of the percentile methods used give reasonable SEG ranges for Little Tahltan Chinook, and produce estimates that are consistent with one of the biological benchmark estimates from the stock-recruitment analyses.

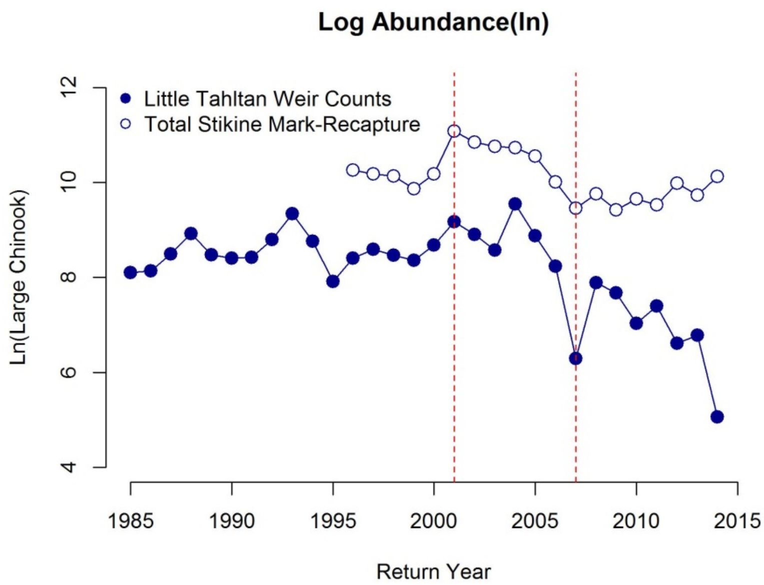

Figure 2. Relative spawner abundance time-series for Little Tahltan weir counts and total Stikine mark-recapture estimates by return year. Weir counts are available beginning in 1985 while mark-recapture estimates are available beginning in 1996. The leftmost vertical dashed line indicates the peak Stikine abundance year of 2001 that was followed by a period of declining abundance until 2007. The rightmost vertical dashed line indicates the return to increasing Stikine abundance beginning in 2007, but Little Tahltan weir counts continued to decline. Note that the obstruction created by the 2014 slide on the Tahltan River likely restricted fish passage to the Little Tahltan River. Note that the vertical axis is log-transformed.

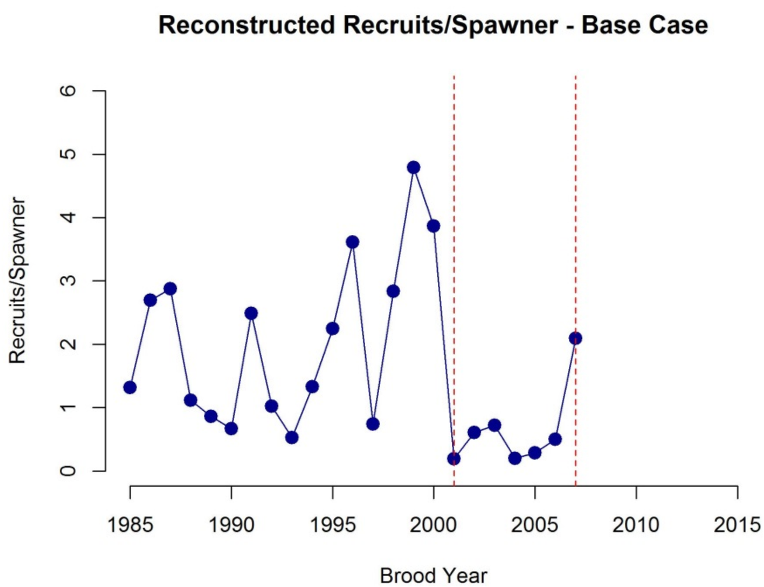

Figure 3. Recruits per spawner time-series by brood year for the four Little Tahltan stock-recruitment analysis datasets. Adult recruit estimates are available for brood years 1985 to 2007 and are derived from annual estimates of spawner abundance and catch based on age composition.

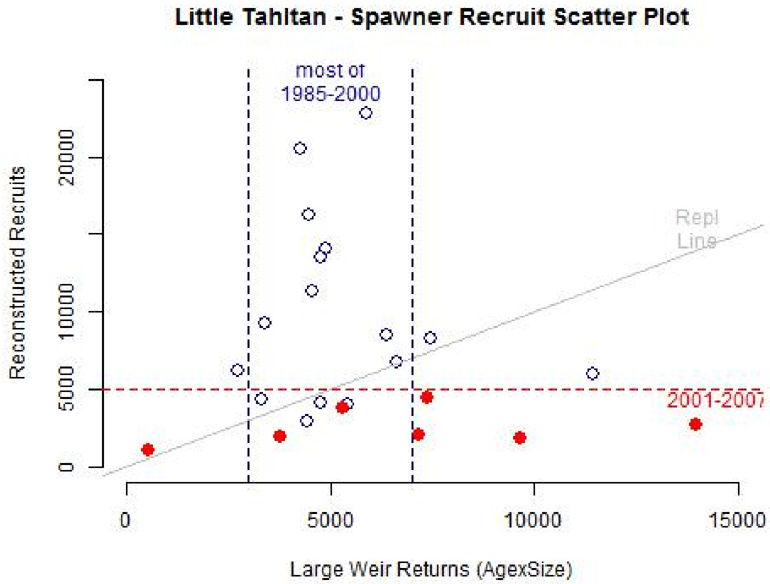

Figure 4. Spawner-recruit scatterplot by brood year for one of the Little Tahltan Chinook stock-recruitment analysis datasets showing the two time period clusters. The diagonal line shows replacement (i.e. the number of recruits equals the number of spawners).

Sources of Uncertainty

- It is possible that there has been an increase in bear predation as result of the weir installation. Over time bears have become habituated to the predation opportunity that the weir affords due to its restriction of fish passage and access to the middle of the river. The impact is potentially more significant at times of low spawner abundance and low water levels resulting in even lower observed spawned abundance. Furthermore, higher bear abundance has been observed at the weir in more recent years, again likely due to habituation. Bears are known to demonstrate sex selectivity when preying on salmon and will preferentially choose female fish. Such behaviour at the Little Tahltan weir could result in a decrease in productivity from the reduction in the number of females that spawn successfully relative to males. This is relevant since the stock-recruitment analyses use total fish rather than just females.
- Chinook that utilize the Little Tahltan River may have experienced changes in maturation rates over the analysis period that cannot be accounted for due to lack of data on this characteristic. Similarly these fish may have also seen changes in the size at age of individual fish; this would confound estimation of productivity of the stock due to the impact of female spawner size on egg fecundity.
- The data treatments required to support the stock-recruitment analysis assume that the scale age analyses were completely accurate. However, scale age determination for mature Chinook Salmon (particularly as they approach the spawning grounds) is reported to be challenging and subject to some degree of aging error.
- It is uncertain whether fish utilizing the Little Tahltan River upstream of the counting weir constitute a separate stock unit, as there are additional spawning areas just downstream of the Little Tahltan counting weir (e.g., the confluence with the Tahltan River) where fish could intermingle and shift in abundance between these spawning areas over time.

CONCLUSIONS AND ADVICE

- The Little Tahltan weir counts were initially a useful indicator of Stikine River spawner abundance as demonstrated by their correlation with the drainage-wide mark-recapture estimates from 1996 to 2007 return years. However, after the 2007 return year, the disconnect between the trends of weir counts and mark-recapture estimates (Figure 2) suggest this may no longer be the case.
- The obstruction created by the 2014 slide on the Tahltan River has the potential to restrict fish passage to the Tahltan mainstem and tributaries including the Little Tahltan. However, at some water levels fish can successfully pass the obstruction. This was confirmed with visual observations in 2014, and again in 2015 by using radio tag telemetry.
- Recent observations suggest that the marine survival for transboundary Chinook (such as Little Tahltan Chinook) has changed. This would have a negative impact on the validity of using a stock-recruitment analysis for benchmark determination.
- The Little Tahltan watershed has seen no significant human impacts to spawning habitat that could account for the changes in productivity suggested by a review of the stock-recruitment data.
- The results of the stock-recruitment analyses would lead to benchmarks similar to those developed by Bernard et al. (2000). This is likely due to the data having a wide range of recruit levels for a small range of spawner escapements over the period 1985 to 2000. Adding a few more years of data is unlikely to change the analysis outcome, since the analyses are driven by the earlier larger recruitment estimates.
- Data quality concerns confound the results of the stock-recruitment analyses. The data suggest potential productivity changes for the Little Tahltan Chinook, which violates one of the assumptions for stock-recruitment analyses. It is also possible that the fish counting weir may have influenced spawner abundance due to fish avoidance behaviour (Little Tahltan returns not passing the weir but instead spawning in the Tahltan River) and increased predation by bears. Therefore, science advice for the establishment of an escapement goal cannot be provided based on the results of this assessment. As a result, objective 2 for this review cannot be addressed with the information currently available.
- It is not clear whether Little Tahltan Chinook is the appropriate stock unit for a stand-alone escapement goal. The Tahltan River may be more representative of the CU. In order to estimate an escapement goal, the appropriate stock unit for analysis must first be determined. This may require additional field work including assessment activities in both the Little Tahltan and the Tahltan rivers. Alternative assessment approaches to the fish counting weir should be considered, for example, aerial surveys combined with passive techniques such as tower or SONAR-based counts. In order to better understand the Chinook distribution relationship between the Little Tahltan and Tahltan rivers, there is a need to expand assessments to Tahltan-wide.
- Given the need to determine the appropriate stock unit for analyses, it would be useful to perform a review of the Stikine Chinook WSP Conservation Unit delineations as has been done for other Chinook CUs. The two CU definitions have not been reviewed since their initial delineation (Holtby and Ciruna, 2007). Examination of delineation criteria, in addition to the run timing criterion of the current definitions, is recommended.
- Future analyses for benchmarks should consider alternate methods, in addition to stock-recruitment, such as a the “cohort analysis” approach used by the Chinook Technical

Committee of the PSC (use coded-wire tag release and recovery data to reconstruct the history of exploitation for individual stocks and then generate estimates for population parameters for assessment), and a habitat modeling approach that examines fish carrying capacity of the freshwater environment.

SOURCES OF INFORMATION

This Science Advisory Report is from the November 12-13, 2015 regional peer review on Estimates of a Biologically-Based Spawning Goal and Biological Benchmarks for Little Tahltan Chinook (Stikine River Drainage). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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