Evaluation and improvement of the Survey Method used to estimate Chinook escapement along the West Coast of Vancouver Island (WCVI)

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ABSTRACT

This project collected additional information from spawning populations of Chinook on the WCVI in order to test assumptions of the current area-under-the curve (AUC) escapement estimation model and improve the overall assessment framework building on the work conducted in 2010. In 2011, three study populations were tagged with radio and external spaghetti tags, a reduction from the four study populations in 2010. In 2012 we were back to four populations with the assistance of the Sentinel Stock Program (SSP). Tagging allowed direct estimation of survey life and observer efficiency, two parameters assigned qualitative values in the current AUC model used to estimate Chinook escapement. River discharge and visibility data were collected to examine the relationship between survey conditions and observer efficiency. Tag information was used to generate independent estimates of escapement through mark-resight models. In addition, a maximum likelihood method was used to estimate escapement as an alternative model to AUC estimation.

With a few exceptions, results indicate that survey life estimates are generally about levels that have been assumed and similar to those measured in previous studies. Observer efficiency is typically lower than the qualitative estimates reported by crews that have been used in AUC estimates. Much of the variation in observation efficiency was explained by river conditions (horizontal visibility and rate of discharge). When the AUC models were corrected for measured observer efficiency and survey life, escapement estimates were similar to those generated through either mark-resight or maximum likelihood models. The qualitative uncorrected AUC estimates were roughly 20% lower than the quantitative AUC estimate, but comparable to the both the likelihood and mark-resight models. Still, after adjusting escapement estimates and accounting for uncertainty, populations of wild WCVI Chinook systems are below provisional escapement targets based on S_{MSY} levels. This observation is consistent with the current status of assessment of WCVI wild Chinook.

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1.0 INTRODUCTION

WCVI Chinook stocks are important relative to the coast-wide Chinook resource. They contribute a significant amount of production to Aggregate Abundance Based Management (AABM) fisheries in Alaska south to Vancouver Island. The total known number of WCVI Chinook populations is about 101, based on various records.

WCVI Chinook populations remain at low levels. Populations originating from Clayoquot or Kyuquot Sound are of particular concern. Although the spawning habitat is relatively pristine in these areas, the populations have not responded to management actions (in fisheries) and remain at poor status. For a more detailed description of how WCVI Chinook and this project fit into the Southern Endowment Fund mandate, please refer to the 2010 Final Report for this project.

Currently, escapements to approximately 18 systems throughout the WCVI are surveyed and sampled annually by DFO-contracted and First Nation crews. The time series of escapement estimates are shown in Table 1. Together, these systems account for about 70% of the WCVI Chinook production outside major enhancement facilities, based on the historical record. With the exception of the populations in Area 24 (Bedwell, Moyeha and Megin) and Area 26 (Artlish, Tahsish and Kaouk), most have been enhanced, either through fry out-plants from the major facilities or through smaller-scale community enhancement facilities.

Escapement to these systems is estimated using the area-under-the-curve (AUC) method (English et al. 1992). Crews count spawners on the systems several times over the duration of the run (i.e. typically through 5 to 8 surveys, although less in recent years with budgetary restrictions). Chinook are usually counted during swims, but other methods may be used, such as aerial surveys or bank walks. Spawners are sampled for age at return (scales) and origin (through otolith mark rates) if enhancement has occurred. Surveys are scheduled for every 7-10 days during September, October and November, for a minimum of 4 surveys per system not including surveys for zero counts. Weather, water conditions, and water flows may impact this schedule. Generally 1 to 3 observers per team start surveys from upstream migration barriers, or the observed upstream limit, and snorkel downstream to the tidal limit.

Although survey methods have been consistently applied since 1995, the AUC method that has been applied does not allow for the description of statistical uncertainty in the population estimates. Two key parameters in the estimation, observer efficiency and survey life vary among surveys, years and populations. Because these have not been measured for every year and system (i.e. they have, for the most part, been assumed constant within and among systems), the AUC estimates potentially represent an index of escapement as opposed to an estimate of total escapement. Moreover, there is some concern that the methodology produces biased results (i.e. biased low). These issues have resulted in contention around the accuracy of spawner counts for WCVI Chinook, which in turn has presented challenges for evaluating the performance harvest management strategies developed under the Pacific Salmon Treaty (PST). Doubt regarding their accuracy, also presents challenges for using these data for developing escapement targets that may, in turn, be used to trigger further fisheries reductions under the PST. Therefore, there is a need to quantify the uncertainty of WCVI escapement estimates and better understand the potential bias of the estimates.

There are two components of this project. This first component is a field study with the objective to further work completed by Trouton et al. (2007) and previous unpublished studies that examined survey life and observer efficiency for WCVI Chinook populations. For the field study, a further objective was to apply Korman et al.’s (2007) methodology to examine the use of environmental correlates to estimate observer efficiency (i.e. in lieu of implementing costly field studies every year). The second component of the project is to conduct modeling work to inform developing a robust statistical framework that can be used to quantify the uncertainty of WCVI escapement estimates, standardize the methodology used for escapement estimation and inform the survey design and allocation of resources. The modeling component was completed in 2010 (Labelle). The work of comparing historical abundance estimates to the estimates generated by the new model has been completed for some systems, but based on the results of the Escapement Workshop in June of 2013, further work is needed to confirm the “best” parameters and procedures to use in applying the new model.

The specific objectives of the field study are to:

- Estimate total escapement of adult Chinook through a mark-resight study on selected systems;
- Quantify Chinook survey life and observer efficiency for selected systems;
- Determine potential environmental correlates with observer efficiency;

- Compare the mark-resight, maximum likelihood (constructed by Labelle in 2010), qualitative AUC (assumed survey life and observer efficiencies) and quantitative AUC (measured survey life and observer efficiencies) escapement estimates.

The specific objectives of the maximum likelihood model development were to:

- Identify and use scientifically defensible procedures to provide AUC escapement estimates and associate levels of uncertainty for selected WCVI systems surveyed recently.
- Based on the results obtained, assess the relative merits of alternative survey procedures that can be used to estimate total escapement to selected WCVI conservation units (CUs).
- Determine the relative benefits of complementary surveys to be initiated shortly in terms of gains in accuracy and precision of future AUC escapement estimates for selected CUs.

Using results of this study, our intent is to establish a robust statistical framework, tools and tested field methodology to continue to describe the statistical uncertainty of WCVI escapement estimates after this project is terminated. It is also our intent, to gather the requisite information to establish escapement goals for WCVI Chinook populations.

2.0 METHODS

This report generally describes methods and results from the Field Study component of the project. A more thorough description is available in the 2010 Final Report of this project (Dobson, 2011). These methods focus on changes to the methods between 2011 and 2012.

2.1 STUDY SYSTEMS

There were four study systems including the Marble, Tahsis, Leiner, and Tranquil Rivers. The Tahsis River was added due to additional funding becoming available from the Sentinel Stocks Program (SSP). The SSP also provided funds to install fixed receivers at the top and bottom of the Marble, Tahsis, and Leiner survey sections as well as for applying tags in approach areas rather than exclusively in-river. All of the study systems are part of the extended PSC indicators for WCVI Chinook. The study systems are typical of most WCVI Chinook bearing rivers; topography is steep and spawning is generally constrained to the mainstem. Similar to the WCVI area as a whole, these rivers are located in areas subject to high levels of precipitation during spawning periods.

The Marble River is located in Quatsino Sound and flows into Holberg Inlet (DFO Statistical Area 27). The spawning length is 4.9 km from upstream migration barrier to the mid tide area. Total watershed area is relatively large at 194 km^2. Survey conditions in the Marble are challenging; frequent flood events reduce visibility and recovery time after flood events can be prolonged due to two relatively large lakes above the spawning barrier. The system has limited road access, requiring travel by trail to reach the main spawning areas of the river. Since 1995, escapement estimates for Chinook have averaged about 2900 (Table 1). The estimated habitat based escapement target is about 1200 (Table 2). There has been some modest and periodic stock enhancement by a local stewardship group.

The Leiner River is located in Nootka Sound flowing into the head of Tahsis Inlet (DFO Statistical Area 25). The spawning length is 1.9 km from the upstream migration barrier to the mid tide area. Total watershed area is moderate at only 104 km^2. Survey conditions in the Leiner are usually favorable with clear visibility and quick recovery times after flood events. The system has relatively good road access. Since 1995, escapement estimates for Chinook have averaged about 460 (Table 1). The estimated habitat based escapement target is about 680 (Table 2). There has been some modest stock enhancement by a local stewardship group.

The Tahsis River is also located in Nootka Sound and is near the Leiner River. The accessible length is 14.4 km, but Chinook spawning is primarily in the lower 5 km. The total watershed area is 77 km^2. Water clarity is exceptional and typically clears within 48 hours of a major weather event. The system has limited road access. The first 3.3 km are accessible by road. An old logging grade provides foot access to the beginning of the survey section at Marker 10 (river km 5), though in recent years, erosion has forced surveyors to walk in the river to reach Marker 10. Since 1995, the escapement estimates for Chinook have averaged about 545 (Table 1). The estimated habitat based escapement target is about 510. There has been some modest and periodic stock enhancement by a local stewardship group.

Tranquil creek is located in the south end of Clayoquot sound flowing into the head of Tranquil Inlet (DFO Statistical Area 24). The spawning length is 3.5 km from the impassable falls to the mid tide area. Total watershed area is relatively small at only 60 km^2. Survey conditions in the Tranquil are usually favorable with clear visibility and quick recovery times after flood events. The system has relatively good road access.

Since 1995, escapement estimates for Chinook have averaged about 750, but have not exceeded 250 in the last five years (Table 1). The estimated habitat based escapement target is about 420 (Table 2). There has been some modest and periodic stock enhancement by a local stewardship group.

2.2 FIELD STUDY

For all systems, crews were instructed to conduct up to five tagging events through beach seining or angling. Due to problems seeing the “Kurl-loc” tags in 2010, only spaghetti tags plus a secondary mark, operculum punch, were applied, for mark-resight estimation and development of tag depletion curves. In addition, they were instructed to apply up to 30 radio tags. The radio tags used for this project were coded motion tags (SR-M16-25) which emit a different signal when the fish stops moving for more than 24 hrs. Those fish with radio tags applied had a corresponding external tag applied.

For each system, crews conducted up to 12 snorkel surveys recording observations of marked and unmarked Chinook in each 500m section of each stream. Surveys were planned from late August to mid-November. Survey crews examined carcasses throughout the swim surveys to estimate visual tag loss and collect biological samples. Before each swim survey the following data were collected: horizontal distance of visibility under water (each swimmer), water temperature, water flow, gauge height and pool secchi depth.

2.2.1 Changes in 2011

To reduce tagging stress, data collected during tagging was reduced to tag number, color, and condition, so length and sex are only available from carcasses or individuals taken for broodstock.

A fixed, 2 antenna telemetry receiver was installed at Marble Lake (at hatchery), which is at the top end of the swim survey area (same as 2010). The purpose of this fixed station was to monitor radio tagged fish migrating past the swim survey area. One swim survey near peak spawn was conducted on 2 of the major Marble River tributary (Link and Benson) streams upstream of the typical swim survey area This was conducted to determine whether significant numbers of fish were spawning above the index section. Telemetry surveys were coordinated in conjunction snorkel surveys to locate radio tagged fish and estimate emigration tag loss (straying) as well as observer efficiency. In the Marble, telemetry surveys continued while high water precluded snorkel surveys to allow for an estimate of survey life based on observing how long individual tags remained alive in the index section.

2.2.2 Changes in 2012

External radio tags were applied in Quatsino Inlet and in Tahsis Inlet. Fixed telemetry receivers were installed at the top and bottom of the survey sections in Marble, Tahsis, and Leiner.

Discharge from the Marble, Tahsis, and Leiner was estimated using the methods described in the Discharge Survey Manual (Appendix 2).

2.3 ANALYSIS

2.3.1 Tag Loss

Tag loss is calculated by dividing the total number of carcasses with a secondary mark (operculum punch) by the total marked carcasses recovered for each system. Given the historical difficulty of recovering carcasses from the study system, a minimum tag loss estimate is the number of tags recovered by crews divided by the number of tags applied.

2.3.2 Survey Life Estimation

Survey life is defined as the mean duration of time (days) that individuals of one species were available for counting in the stream or the mean number of days fish were alive in the stream (Perrin and Irvine 1990).

The length of time each tag was active in the area provided an estimate of the survey life of individual Chinook. The radio tags used for this project were coded motion tags (MCFT2_3A) which emit a different signal when the fish stops moving for more than 24 hrs.

A second survey life estimate was estimated through the depletion curve based on re-sighting the external tags. The area-under-the-tag-curve (AUC_{tag}) survey life was determined by tagging salmon in the lower portion of the stream, prior to the onset of spawning and resighting the tags during swim surveys. Raw swim counts were used to generate the trapezoidal approximation of the AUC_{tag} and the total tag days were divided by the original number of tags applied to estimate survey life in days as described by Irvine et al (1992) and Hetrick and Nemeth (2003). Because we did not expand the number of tags based on either the qualitative (self-reported) or quantitative (calculated based on the number of “alive” radio tags present vs. observed) observer efficiency, this “SL” estimate includes the effect of SL and OE into one factor which can be used to expand the observed fish to the total, assuming the tagged fish are representative of the population.

A third survey life for the study systems was estimated through a tag depletion curve of the radio tags on the Marble, Leiner, and Tranquil rivers. This is a modification of the visual tag-based method of estimating survey life (English et al. 1992). The area-under-the-tag-curve ($AUC_{tag\text{-}tel}$) was divided by the number of tags detected in the system at least once to estimate SL. Using the radio tag detection rather than observation, assuming detection rate is 100%, should provide an estimate of SL independent of OE.

2.3.3 Observer Efficiency Estimation

Observer efficiency was calculated from the proportion of the visually and radio tagged fish seen by the swimmers versus the total number available as determined by telemetry surveys conducted prior to or during spawner surveys.

2.3.4 Observer Efficiency Correlates

The relationship between observer efficiency and the ratio of horizontal visibility and discharge was explored through the method described by Korman et al. (2002). Data collected directly from the Marble, Tahsis, Leiner, and Tranquil rivers were analyzed as well as discharge and stage from nearby Environment Canada monitoring stations.

2.3.5 Escapement Estimation

Comparisons of escapement estimates generated through the following methods were made (when data for the system were sufficient to support the particular analysis):

- The trapezoidal AUC method with qualitative assessment of observer efficiency and survey life (i.e. the method normally used to generate WCVI escapement estimates);
- The trapezoidal AUC method with quantitative assessment of observer efficiency and survey life based on 2012 study results;
- The mark-resight method using the joint hypergeometric maximum-likelihood estimator (JHE) described by White (1996);
- The mark-recapture method using the Chapman modification of the Petersen estimator (Ricker, 1975 and Cousens et al., 1982)
- The unimodal maximum likelihood escapement estimation model developed by Labelle (2011) as part of this project;

- the biomodal maximum likelihood escapement estimation model developed by Labelle (2011) as part of this project.

For context, the results were compared to the provisional habitat based escapement targets that are estimated for the study systems using the Parken et al. (2006) methodology.

2.3.5.1 Trapezoidal Approximation

Total live Chinook salmon counts were plotted for each date to form the fish curve, and the areas of the trapezoids were summed to estimate total fish-day component of the AUC. The total fish-days or the AUC ($\hat{A}_i$) for year i was (Irvine et al. 1992):

$$\hat{A}_i = 0.5 \bullet \sum_{j=2}^{n} \left(t_j - t_{j-1}\right) \bullet \left(\hat{p}_j + \hat{p}_{j-1}\right),$$

where t_j was the number of days since the first fish commenced spawning, n – 2 was the number of swim surveys, and $\hat{p}_j$ was the number of salmon counted on day j (sum of the fish counts by strata). For the qualitative AUC, the observer efficiency used was the self-reported value from the survey crew. The quantitative AUC used the proportion of radio tags present that were observed as the observer efficiency if available or 100% if radio tags were not available. Surveys were temporally bounded by the day the first fish commenced spawning (j = 1, $\hat{p}_j$ = 0) and the first day when there were no longer any live spawners (tn, $\hat{p}_n$ = 0). The first and last dates of spawning were estimated from spawning observations made during swim surveys. Note that t_j = 1 and p_j = 0 for the day when the first fish commenced spawning and t_n was the number of days that live spawners were present; thus p_n = 0.

The AUC method for calculating the annual escapement ($\hat{N}_{i,AUC}$) was

$$\hat{N}_{i,AUC} = \frac{\hat{A}_i}{\hat{S}_i},$$

where $\hat{S}_i$ was the survey life in year i defined as the mean length of time (d) live fish were available for counting. Both the area-under-the-tag-curve and index survey life were used to determine escapement estimates using the AUC method.

2.3.5.2 Carcass Mark-Recapture

The adult Chinook salmon population ($\hat{N}$) using carcass recoveries was estimated using the Chapman modification of the Petersen estimator (Ricker, 1975 and Cousens et al., 1982):

$$\hat{N}_{i,MR} = \frac{(M+1)(C+1)}{(R+1)}$$

where N is the estimate of adult salmon, M is the number of adult salmon marked, C is the total number of adult carcasses examined for marks and R is the number of marked adult carcasses recovered (Ricker, 1975). This adjusted Petersen estimate is the most commonly used mark-recapture formula and provides a nearly unbiased estimate of N (Cousens et al., 1982).

2.3.5.3 Mark-Resight

The visual swim survey re-sight procedure involved counting the number of marked and unmarked Chinook salmon; whereas, the AUC estimates utilized total live counts. Total escapement was calculated using the joint hypergeometric maximum-likelihood estimator (JHE) described by White (1996):

$$L(N \mid M, c_k, r_k) = \prod_{i=1}^{k} \frac{\binom{M}{r_k}\binom{N-M}{c_i - r_k}}{\binom{N}{c_k}},$$

where $L(N \mid M, c_k, r_k)$ = Likelihood of N conditional on the observed values of M, c_k, and r_k, and N is the population size, M is the number of tagged fish in the study area (tags applied), c_k is the number of fish inspected for tags on the kth survey, and r_k is the number of tagged fish counted on the kth survey. The likelihood of different escapements and confidence bounds around the estimates were calculated using the likelihood profile.

Tag loss, which was assumed to occur during competitive interactions among fish actively spawning, was not used to adjust mark-resight observations as sample sizes were too low to detect tag loss over time or to provide a precise estimate of tag loss.

2.3.5.4 Maximum Likelihood Model

This method assumes an underlying statistical distribution model of fish arrival and death from which the number of fish alive in the stream can be predicted on a given day, and the pattern of arrival and death is assumed normally- or beta-distributed (Hilborn et al.1999). Observer counts of fish and index survey life are used to estimate the number of fish in the stream. For this project, Hilborn's (1999) likelihood model was modified to allow for uncertainty in the survey life and observer efficiency and also for bimodal migration patterns (Labelle 2011, see 2010 companion report).

3.0 RESULTS AND ANALYSIS

3.1 FIELD STUDY

Survey conditions in 2012 were mixed. Extremely low water levels into mid-October made the application of almost 400 radio tags prior to river entry possible, but also delayed entry. Once the rain started in mid-Oct, flooding caused accessibility issues both in terms of road access and river safety until Late-October.

3.1.1 Tag Application

Chinook in the study populations were captured through angling, trolling, hot-picked gillnet, and beach seine. Fish were tagged starting in Late August prior to Chinook entering the river. 128 external radio tags were applied on Marble River fish, 114 in Quatsino Inlet and 14 in river, 269 external radio tags were applied in Tahsis Inlet, and 25 internal radio tags were applied in the Tranquil River. In addition, 29 spaghetti tags alone were applied to a portion of the Tranquil population (Table 3).

3.1.2 Spawner Survey Results

A total of 11, 6, 12 and 15 spawner surveys were conducted on the Marble, Tahsis, Leiner and Tranquil Rivers, respectively, during snorkel swims on the accessible length of the river. The maximum number of Chinook observed was 1092, 109, 347 and 181 on the Marble, Tahsis, Leiner and Tranquil Rivers, respectively (Table 4). Crews in the Tahsis, Leiner and Tranquil systems were unable to conduct spawner surveys for a period of 12 to 18 days in Mid to Late October due to high flows, that coincided with the probable peak in migration.

Insufficient carcasses were recovered to estimate tag loss based on carcasses retrieved with secondary marks and no tags, but eight tags were recovered from the Marble independent of a carcass of the 32 tags detected in the river (~25% tag loss). Of the tags lost and recovered by swim crews in the Marble, the average time from tag application to tag recovery was 32 days (CV of 15%). Also, two live fish were seen in the Leiner after losing their radio tags, one of which also lost both of the Petersen tags of the 67 tags that entered (~3% radio tag loss, ~1.5% Petersen tag loss). In the Tranquil, two radio tags and seven spaghetti tags were recovered from fish likely still alive eight days after tag application (~9% radio tags loss, ~32% spaghetti tag loss).

3.1.3 Telemetry Surveys

After radio tag application and corresponding external (Petersen or spaghetti tag) mark application and before spawner surveys, telemetry surveys were conducted. Telemetry results were used to estimate survey life based on the difference between radio application and time of death. An additional survey life estimate based on telemetry was a trapezoidal approximation of the area under the tag curve based on live tag detection divided by the number of tags applied and detected at least once. A total of 11 telemetry surveys were conducted on the Leiner River, 9 on the Tahsis, 8 on the Tranquil River, and 17 on the Marble (Table 5). After tag application, it was discovered that the mortality sensors in the tags were faulty, resulting in false readings of “death”. Post-season we determined fish status per survey based on location over time, movement, and in some cases direct observation. The OE and survey life based on our post-season determination of status may have unanticipated bias.

3.2 DATA AND ANALYSIS

3.2.1 Age and Length Composition

Length measurements and biosamples were taken from some of the fish tagged, but to reduce tagging stress in Tahsis Inlet and Tranquil, lengths were only collected from carcasses (Tranquil) or when broodstock were collected (Leiner) (Table 6).

Average standard length for the Marble population was 884 and 889 mm for females and males, respectively. The average age composition for the Marble River tagged females was 2%, 19%, 47% and 33% age 2_1, 3_1, 4_1, and 5_1 fish, respectively. The average age composition for the Marble River tagged males was 7%, 30%, 39% and 25% age 2_1, 3_1, 4_1, and 5_1 fish, respectively.

Average post-orbital fork length for the Leiner population was 706 and 677mm for females and males, respectively. The average age composition for the Leiner River females was 65% and 35% age 4_1 and 5_1 fish, respectively. The average age composition for the Leiner River males was 4%, 13%, 79% and 4% age 2_1, 3_1, 4_1, and 5_1

fish, respectively. The average age composition for the females tagged in Tahsis Inlet was 52% and 48% age 4_1 and 5_1 fish, respectively. The average age composition for the males tagged in Tahsis Inlet was 5%, 83% and 12% age 3_1, 4_1 and 5_1 fish, respectively.

Average post-orbital fork length for the Tranquil population was 679 and 594 mm for females and males, respectively. The average age composition for the Tranquil River females was 27%, 36% and 36% age 31, 41 and 51 fish, respectively. The average age composition for the Tranquil River males was 4%, 50%, 42% and 4% age 21, 31, 41 and 51 fish, respectively.

3.2.2 Survey Life Estimates

From 2010 to 2012, survey life (SL) was estimated for five systems. Most of the estimates ranged roughly between 15 and 30 days, except for Marble which was consistently longer, roughly 25 to 40 days. Also, fish tagged later in the season had a shorter survey life. When SL was estimated based on the tags observed by swimmers, estimates were shorter. Due to the faulty mortality tags, the 2012 Marble, Leiner, and Tahsis observed SLs are estimated. A confidence level is associated with each estimate. High confidence estimates are based on detecting the fish entering and leaving the survey area. Medium confidence estimates are based on tag movement patterns, the exact date of death is uncertain. Low confidence estimates are based on the last time a tag was observed and should be considered minimum estimates as tags that were likely shed prior to death are included (Table 7). In 2012, the estimated survey life was 44.1, 26.1, 23.4 and 17.9 days for the Marble, Leiner, Tahsis and Tranquil populations, respectively based on the unimodal maximum likelihood model. The average estimated survey life was 33.2, 20.1, 16.3 and 9.7 days for the Marble, Leiner, Tahsis and Tranquil populations, respectively based on the bimodal maximum likelihood model.

3.2.3 Observer Efficiency Estimates

Observer efficiency of the spawner survey crews was estimated for the Marble, Leiner, Tahsis and Tranquil systems. Observer efficiency varied across surveys. Across surveys within a study population, the weighted average estimated observer efficiency was 52%, 54%, 46% and 46% for the Marble, Leiner, Tahsis and Tranquil populations, respectively (Table 8). (Averages were weighted by total number of Chinook observed in the survey. However, in practice, each survey is expanded by an individual estimate of observer efficiency.)

3.2.4 Environmental Correlates of Observer Efficiency

Prior to each spawner survey, snorkel crews collected environmental data, including horizontal distance of visibility under water (for each swimmer), water temperature, water flow, gauge height, and pool Secchi depth (Table 9).

The relationships between survey life and environmental correlates for the Marble, Leiner and Tranquil Rivers are displayed in Figure 2, Figure 3, and Figure 4, respectively. For all systems there was a positive relationship between observer efficiency and the horizontal visibility/discharge (HV/Q) index.

For the Tranquil River, the Tofino River discharge estimate from Environment Canada is informative, but the measurements taken directly from the Tranquil appear to have a tighter relationship with the measured observer efficiency (Figure 5).

3.2.5 Escapement Estimates

Escapement was estimated for the study populations using data generated from the study and a number of alternative estimation models (Table 10, Table 11). These estimates were compared within and across the study populations.

For the Marble River, the trapezoidal AUC method with qualitative assessment of observer efficiency and survey life (i.e. the method normally used to generate WCVI escapement estimates) yielded an escapement estimate of 2,363. The trapezoidal AUC method with quantitative assessment of observer efficiency and survey life based on 2012 measurements yielded an escapement estimate of 2,509. The mark-resight method yielded an estimate of 1,340 (95% CI 1,090-3,470). The unimodal and bimodal maximum likelihood escapement estimation models yielded estimates of 1,092 and 2,157 respectively.

For the Leiner River, the trapezoidal AUC method with qualitative assessment of observer efficiency and survey life yielded an escapement estimate of 566. The trapezoidal AUC method with quantitative assessment of observer efficiency and survey life based on 2012 measurements yielded an escapement estimate of 772. The mark-resight method yielded an estimate of 563 (95% CI 490-665). The unimodal and bimodal maximum likelihood escapement estimation models yielded estimates of 347 and 523 respectively.

For the Tahsis River, the trapezoidal AUC method with qualitative assessment of observer efficiency and survey life yielded an escapement estimate of 163. The trapezoidal AUC method with quantitative assessment of observer efficiency and survey life based on 2012 measurements yielded an escapement estimate of 227. The mark-resight method yielded an estimate of 249 (95% CI 165-500). The unimodal and bimodal maximum likelihood escapement estimation models yielded estimates of 109 and 187 respectively.

For the Tranquil River, the trapezoidal AUC method with qualitative assessment of observer efficiency and survey life yielded an escapement estimate of 262. The trapezoidal AUC method with quantitative assessment of observer efficiency and survey life based on 2012 measurements yielded an escapement estimate of 268. The mark-resight yielded an estimate of 200 (95% CI 180-230). The Chapman modification of the Petersen mark-recapture estimator based on the recapture of four tagged fish on the second tagging event is 161. The unimodal and bimodal maximum likelihood escapement estimation models yielded estimates of 219 and 365 respectively.

3.2.6 Comparison of Escapement Estimates with Provisional Habitat Based Escapement Targets

The maximum estimated escapement estimates for 2012 were compared with provisional habitat-based escapement targets that are defined for WCVI Chinook populations using the model of Parken et al. (2006). The escapement estimates were also compared with the Chinook rebuilding goals defined under the 1985 PST (Table 14). With the exception of the Marble River (located in the far north of WCVI, DFO Statistical Area 27), those populations, that do not receive any form of stock enhancement are well below both provisional targets. On the other hand, populations that receive some level of enhancement, including Leiner and Tranquil Chinook, are near the provisional escapement targets. However, the Tranquil population has declined over the last several years after the enhancement program there was terminated. This observation is consistent with the current stock assessment of WCVI Chinook.

4.0 CONCLUSION / RECOMMENDATIONS

The objective of this study was to collect additional survey data to improve the estimation of escapement of WCVI Chinook populations. Other than the Robertson Creek CWT Indicator stock, escapement to WCVI Chinook systems is estimated using the Area-Under-the-Curve (AUC) method to expand counts gathered through stream surveys (usually gathered during snorkel surveys conducted about once per week for 4 to 6 weeks).

The results are informative and will help inform the improvement of the overall WCVI escapement survey design. For those systems where the study design was successfully implemented, it was possible to directly measure survey life and observer efficiency, two key parameters that are subjectively estimated in the current WCVI AUC surveys.

Although survey life is not directly measured each year during WCVI escapement surveys, the range of survey life estimates that are applied are based on previous studies (e.g. Trouton et al. 2007 and earlier unpublished work). Generally speaking, for larger WCVI systems and for Chinook, measured survey lives are longer than for other systems and species on Vancouver Island. Survey life was estimated at about 8 to 12 days for coho systems on the east coast of Vancouver Island (Irvine and Perrin, 1990) whereas for WCVI Chinook systems survey life is typically estimated at between 15 to 30 days (Trouton et al. 2007 and unpublished studies). From year to year when no empirical data are available, whether the lower or higher range is applied depends on a qualitative assessment of survey conditions. For example, prolonged summer drought through September leading to delayed migration on the first freshet would result in application of a lower survey life. A higher survey life would be applied with the observation of periodic migration to the river over the prolonged period.

For this study, it was possible to estimate survey life for all three of the study systems. Telemetry results indicate the survey life estimates where within the range that is typically applied for WCVI systems (i.e. 20 to 25 days).

Crews assess their observer efficiency based on a qualitative assessment of survey conditions. Consistent with the findings in 2010, crews tend to over-estimate their observer efficiency, particularly when survey conditions deteriorated later on during the migration period. It was interesting that surveyors did not generally report major increases or decreases in their observer efficiency despite significant changes in river conditions. However, the changes in river conditions were described by measuring parameters such as Secchi depth, horizontal visibility and discharge. Following Korman et al. (2007), observer efficiency was well-correlated with an index of river conditions described by horizontal visibility/discharge. Further work to develop this relationship (i.e. through more direct measurement of observer efficiency, river conditions) will greatly improve the quality of AUC estimates of Chinook for WCVI populations. Survey conditions can be indexed by measuring horizontal visibility and discharge for each survey at much lower cost than directly estimating observer efficiency through telemetry studies.

When the ‘qualitative’ (i.e. standard approach with assumed OE and SL) AUC estimate of escapement for the study populations was compared with estimates generated through either i) using directly measured OE and SL; ii) maximum likelihood estimate; iii) mark-resight or iv) mark-recapture, all the methods produced estimates within the similar range, including the ‘quantitative’ AUC estimate using directly measured OE and SL. In 2010 the qualitative AUC estimates were roughly 50% less than the estimates using alternative means, probably due to difficult survey conditions. In 2011 and 2012, survey conditions were also challenging, but not quite as extreme as 2010, so the results of the multiple estimation methods were generally comparable.

For management purposes, it is important to understand the magnitude and consistency of bias in escapement estimates when determining the status of a population relative to biological benchmarks (e.g. S_{MSY} or PSC rebuilding goals). While conditions are often challenging on the WCVI for spawner surveys, 2010 was particularly difficult and the effects of underestimating observer efficiency or overestimating survey life may have been greater than average. The results of the 2011 and 2012 study, during which conditions were more typical, show that the qualitative AUC estimate is a reasonable number on which to base management decisions.

Although the flooding was particularly extreme in 2010, high rainfall during the peak river migration is typical of the study area and, along with isolation, one of the logistical challenges along of working on WCVI river systems. These challenges result in safety, access and expense issues in addition to survey design challenges. Some alternative escapement estimation methods (e.g. mark-recapture or counting weirs) are more vulnerable to these challenges than the snorkel-survey method currently employed. On the WCVI high discharge rates generally lead to unsuccessful dead-pitch surveys.

Therefore, it is often difficult to retrieve sufficient carcasses for tag loss estimation to support mark-resight (or recapture) estimation methods. Also, in addition to the significant expense associated with mark-recapture or counting weir programs, the behaviour of fish that are handled extensively may be altered sufficiently to bias the estimate.

We suggest that while the short-term intensive studies such as the mark-recapture and mark-resight programs currently being conducted on WCVI systems will help validate current escapement estimates, they are not sustainable in the long-term. The magnitude of bias in the AUC estimates is mostly determined by the estimation of annual survey life. Our objective is to improve our understanding of annual variation in survey life and conditions related to increased/decreased survey life from year to year. If for many systems the assumption of 20 to 30 day survey life is valid, then the magnitude of bias in the AUC estimate is largely dependent on whether a good peak count was achieved since survey life is not much shorter than duration of the migration period. On the other hand if there are systems for which survey life has been grossly over-estimated then these studies may help us classify the conditions or characteristics of the systems that result in lower survey life. The initial work conducted in 2010, 2011 and 2012 suggests that we will be able to develop a good relationship in between OE and survey conditions. If the relationship is well established, then measuring environmental correlates to inform observer efficiency assumptions is a relatively simple and inexpensive improvement to the current AUC program.

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6.0 ACKNOWLEDGEMENTS

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7.0 TABLES AND FIGURES

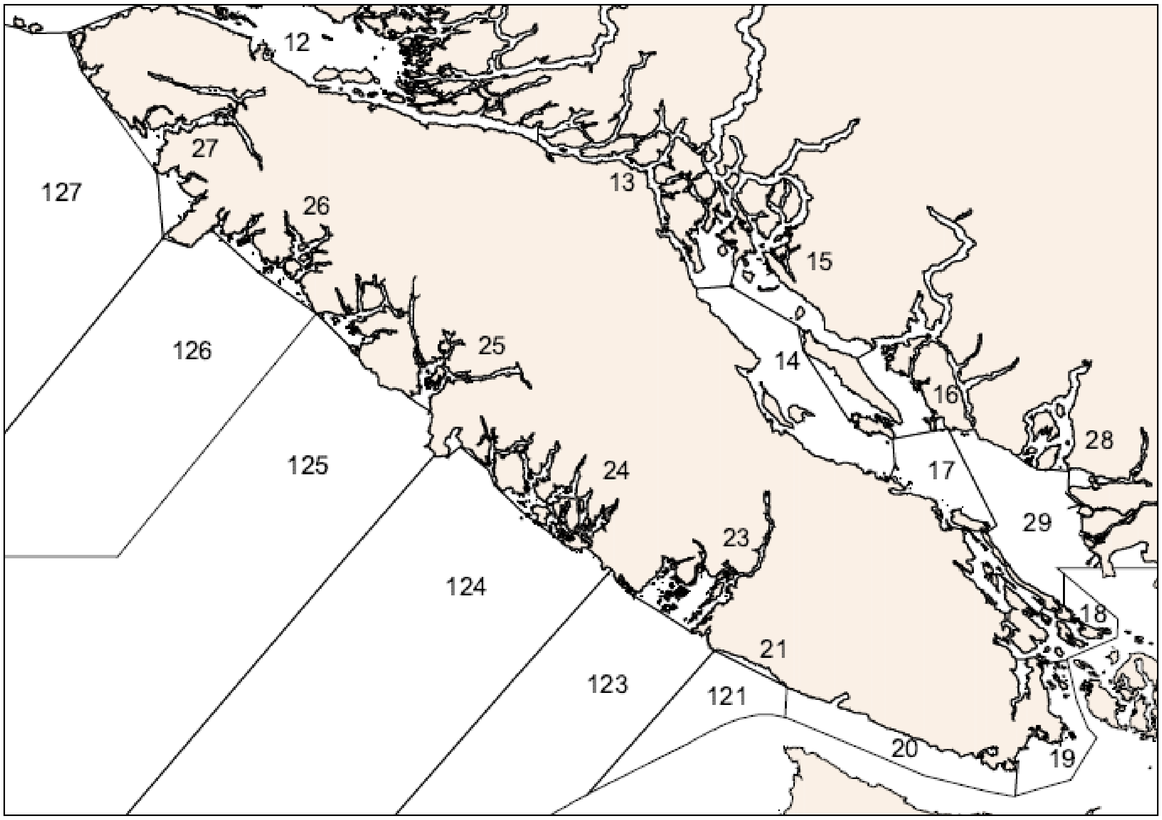


Figure 1. Vancouver Island and DFO Statistical Areas.

Table 1. Escapement estimates to WCVI Chinook indicators (1995 to 2012).

Statistical Area	System	Year																		Average
		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
20	**San Juan**	710	950	1,080	4,570	1,560	370	810	1,457	1,930	540	1,200	4,520	1,890	1,700	2,870	1,300	560	860	1,600
23	**Nahmint**	210	260	240	1,010	930	70	230	520	660	1,220	160	490	170	150	100	470	640	180	430
	Sarita	140	490	1,870	2,420	770	300	1,530	3,300	3,710	3,450	1,220	3,300	1,630	1,000	730	900	1,300	1,480	1,640
	Toquart	100	270	510	310	160	100	170	200	590	700	-	860	-	-	-	320	-	-	240
24	**Bedwell/Ursus**	290	530	280	310	160	140	260	130	140	140	70	100	40	70	40	50	90	200	170
	Megin	320	160	270	370	230	160	-	20	30	70	40	120	10	20	20	10	50	80	110
	Moyeha	90	240	80	160	240	90	120	50	160	360	120	90	110	150	60	190	70	-	130
	Tranquil	450	650	940	850	750	1,780	2,080	190	1,780	1,130	640	410	250	220	210	230	210	260	720
	Cypre	10	10	20	20	10	-	640	30	500	490	500	420	870	450	250	440	1,100	660	360
25	**Burman**	590	720	2,350	3,210	2,400	210	110	440	770	2,640	640	520	350	520	1,800	3,030	2,020	1,020	1,300
	Leiner	410	720	520	380	820	130	390	940	400	630	330	180	180	270	730	430	390	570	470
	Sucwoa	440	340	50	20	70	220	110	40	-	330	40	-	150	80	-	10	230	-	120
	Tahsis	530	770	720	590	1,730	1,220	390	760	760	910	180	140	130	280	780	380	220	160	590
	Tlupana	140	40	70	70	50	90	360	1,160	330	470	1,040	1,050	320	180	10	40	30	-	300
	Zeballos	160	350	860	670	690	60	100	150	70	390	90	450	440	470	120	120	110	-	290
26	**Artlish**	100	50	400	300	540	80	140	40	380	450	200	230	160	200	210	110	100	140	210
	Kaouk	270	220	560	820	450	110	410	250	360	300	490	540	190	260	550	190	300	220	360
	Tahsish	600	290	520	1,430	880	390	240	310	440	500	120	80	230	380	80	360	260	190	410
27	**Marble**	1,630	3,970	2,640	5,300	4,190	2,570	1,450	2,490	1,750	3,660	2,350	3,070	2,760	2,680	3,440	3,560	3,910	3,350	3,040
	Colonial/Cayeghle	80	70	40	170	880	530	570	380	600	1,370	-	320	170	160	630	520	410	90	390

Table 2. Provisional habitat-based escapement targets for WCVI Chinook indicators (based on Parken et al. 2002).

River System	Area	Survey Length	Barrier Distance	Effecttive Watershed Area (Km^2)	Optimal CK Escapements Smsy (80% confidence interval)	Replacement CK Escapements Srep (80% confidence interval)
Sarita River	23	6000	6000	99	643 (522 - 791)	2,028 (1,657-2,481)
Nahmint River	23	3500	3500	193	1,189 (988 - 1,430)	3,361 (3,064-4,375)
Bedwell R / Ursus C	24	17500	17500	98	638 (518 - 786)	2,015 (1,646-2,466)
Moyeha River	24	9000	11000	181	1,121 (930 - 1,352)	3,460 (2,890-4,143)
Megin River	24	10000	16000	135	857 (704 - 1,044)	2,674 (2,211-3,235)
Tranquil Creek	24	3500	8000	61	415 (331 - 521)	1,333 (1,069-1,662)
Cypre River	24	7000	9700	60	405 (323 - 509)	1,303 (1.044-1,626)
Burman River	25	7500	7500	242	1,459 (1,221 - 1,744)	4,458 (3,757-5,290)
Tahsis River	25	2000		77	512 (412 - 636)	1,629 (1,319-2,013)
Leiner River	25	1930	1930	105	681 (555 - 837)	2,145 (1,758-2,619)
Zeballos River	25	1500	1500	193	1,188 (987-1,429)	3,658 (3,061-4,371)
Kaouk River	26	9000	17000	115	741 (605 - 907)	2,325 (1,912-2,829)
Artlish River	26	10600		125	796 (652 - 972)	2,491 (2,054-3,022)
Tahsish River	26	6000	6280	106	690 (562 - 847)	2,171 (1,780-2,649)
Marble River	27	4915		194	1,191 (990 - 1,434)	3,669 (3,071-4,384)
Cayeghle/Colonial	27	19300		85	560 (452 - 694)	1,778 (1,445-2,188)

Srep is the maximum escapement in the absence of any harvest (human impacts).

Table 3. Number and date of tag application in study populations.

Population	Date	Radio Tags	Spaghetti Tags
Marble	8/27/2012	3	
	8/28/2012	1	
	8/29/2012	2	
	9/5/2012	24	
	9/6/2012	18	
	9/7/2012	12	
	9/8/2012	5	
	9/9/2012	7	
	9/10/2012	1	
	9/11/2012	5	
	9/12/2012	6	
	9/13/2012	8	
	9/14/2012	2	
	9/17/2012	7	
	9/18/2012	3	
	9/19/2012	1	
	9/20/2012	4	
	9/28/2012	1	
	10/1/2012	2	
	10/2/2012	1	
	10/3/2012	1	
	10/11/2012	14	
	Total	**128**	
Tahsis Inlet	8/29/2012	3	
	8/30/2012	3	
	9/3/2012	5	
	9/4/2012	22	
	9/5/2012	10	
	9/6/2012	8	
	9/10/2012	31	
	9/11/2012	29	
	9/12/2012	33	
	9/13/2012	32	
	9/17/2012	21	
	9/18/2012	21	
	9/19/2012	16	
	9/20/2012	16	
	9/24/2012	6	
	9/25/2012	13	
	Total	**269**	
Tranquil	10/17/2012	25	
	10/25/2012		29
	Total	**25**	**29**

Table 4. Spawner Survey Dates and Observations on Study Populations.

System	Survey Date	Total Adult CN	Unmarked	Marked
Marble	8/29/2012	20	20	0
	9/4/2012	394	394	0
	9/10/2012	474	473	1
	9/14/2012	722	718	4
	9/19/2012	596	591	5
	9/24/2012	820	813	7
	9/28/2012	885	885	0
	10/4/2012	1092	1085	7
	10/9/2012	902	899	3
	10/15/2012	633	632	1
	10/31/2012	654	654	0
Total	11			
Leiner	4-Sep-12	30	30	0
	14-Sep-12	126	117	9
	16-Sep-12	143	133	10
	23-Sep-12	199	185	14
	26-Sep-12	192	183	9
	4-Oct-12	347	326	21
	7-Oct-12	247	233	14
	24-Oct-12	25	25	0
	26-Oct-12	14	14	0
	2-Nov-12			
	8-Nov-12			
	12-Nov-12	0		
Total	12			

System	Survey Date	Total Adult CN	Unmarked	Marked
Tahsis	6-Sep-12	0		
	15-Sep-12	15	13	2
	25-Sep-12	18	17	1
	5-Oct-12	10	10	0
	23-Oct-12	109	105	4
	9-Nov-12	0		
Total	6			
Tranquil	4-Sep-12	1	1	
	11-Sep-12	3	3	
	18-Sep-12	9	9	
	29-Sep-12	9	9	
	9-Oct-12	10	10	
	21-Oct-12	181	149	32
	25-Oct-12	168	145	23
	27-Oct-12	135	97	38
	2-Nov-12	67	52	15
	6-Nov-12	41	30	11
	10-Nov-12	22	19	3
	15-Nov-12	10	5	5
	22-Nov-12	3	2	1
	26-Nov-12	2	1	1
	6-Dec-12	0		0
Total	15			

Table 5. Telemetry survey dates Marble, Leiner, Tahsis, and Tranquil Rivers.

System	Survey Date
Marble	4-Sep-12
	11-Sep-12
	14-Sep-12
	19-Sep-12
	24-Sep-12
	28-Sep-12
	4-Oct-12
	10-Oct-12
	12-Oct-12
	15-Oct-12
	18-Oct-12
	24-Oct-12
	30-Oct-12
	7-Nov-12
	13-Nov-12
	22-Nov-12
	30-Nov-12
Marble Total	17
Tranquil	21-Oct-12
	25-Oct-12
	27-Oct-12
	2-Nov-12
	6-Nov-12
	10-Nov-12
	15-Nov-12
	22-Nov-12
Tranquil Total	8

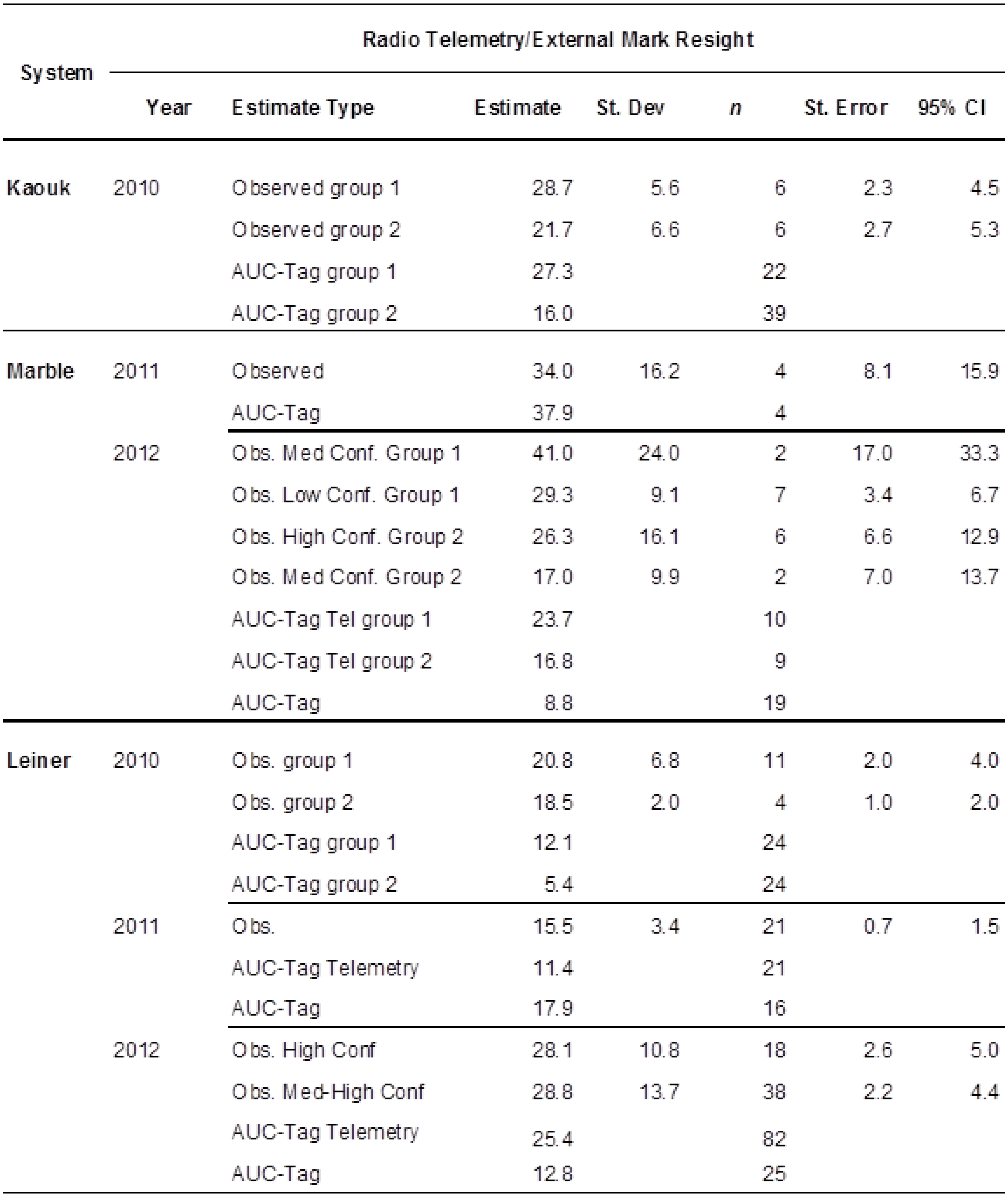
System	Survey Date
Tahsis	6-Sep-12
	17-Sep-12
	25-Sep-12
	4-Oct-12
	12-Oct-12
	19-Oct-12
	23-Oct-12
	1-Nov-12
	9-Nov-12
Tahsis Total	9
Leiner	7-Sep-12
	14-Sep-12
	18-Sep-12
	24-Sep-12
	26-Sep-12
	3-Oct-12
	11-Oct-12
	18-Oct-12
	24-Oct-12
	2-Nov-12
	8-Nov-12
Leiner Total	11

Table 6 Length and age data collected from study populations. *Kaouk samples were not separated by sex.

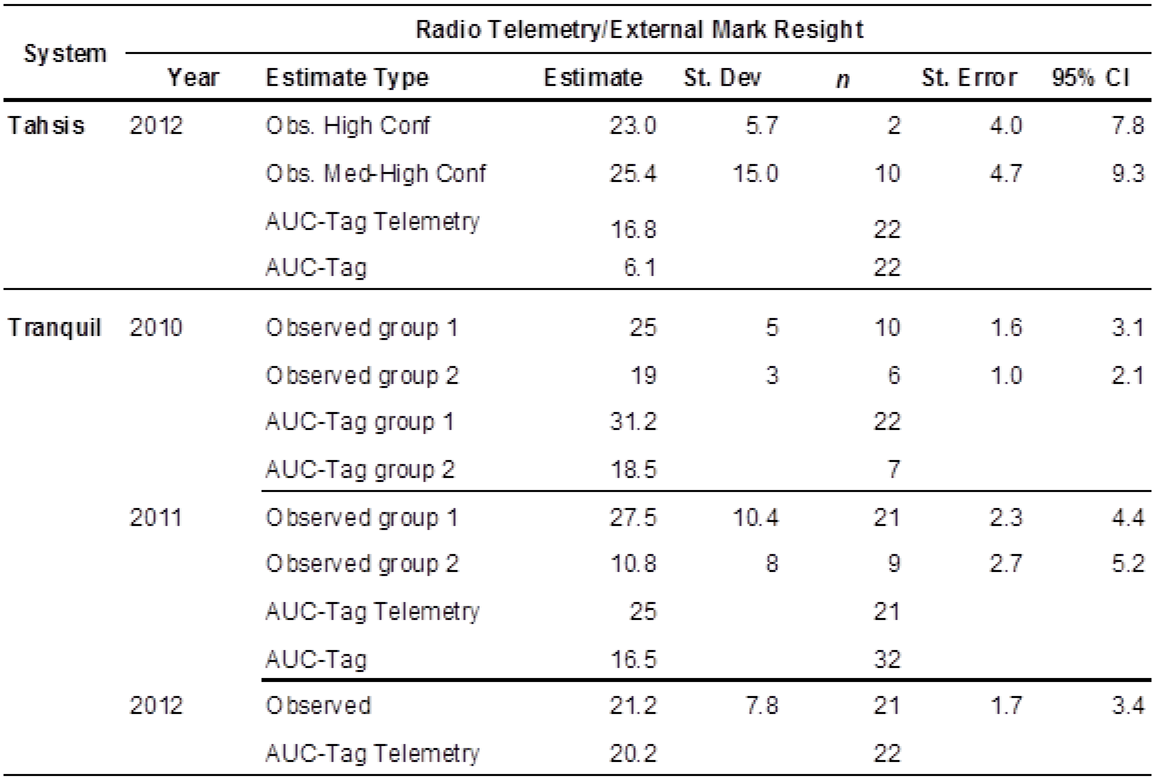
	Female POH (mm)			Age Dist					Male POH (mm)			Age Dist					
	Mean	SD	*n*	**2-1**	**3-1**	**4-1**	**5-1**	*n*	Mean	SD	*n*	**2-1**	**3-1**	**4-1**	**5-1**	**6-1**	*n*
Tranquil																	
2010	765.5	30	29			12%	88%	17	699.6	99	36		27%	27%	46%		26
2011	757.5	92	4						740	n/a	1						
2012	679	82	11	0%	27%	36%	36%	11	594	87	43	4%	50%	42%	4%	0%	24
Tahsis Inlet					0%	52%	48%	75					5%	83%	12%	0%	129
Leiner																	
2010	926.7	35	3			50%	50%	2	821.6	127	52	4%	24%	44%	28%	0%	25
2011	765	71	2			50%	50%	2	652.5	98	8		30%	40%	20%	10%	8
2012	706	53	28		0%	65%	35%	20	677	68	38	4%	13%	79%	4%	0%	24
	Female POF (mm)			Age Dist					Male POF (mm)			Age Dist					
Marble	Mean	SD	*n*	**2-1**	**3-1**	**4-1**	**5-1**	*n*	Mean	SD	*n*	**2-1**	**3-1**	**4-1**	**5-1**	**6-1**	*n*
2010			No Samples									No Samples					
2011	876	52	20			75%	25%	16	934	67	16			85%	15%		13
2012 brd	824	55	204		7%	39%	54%	187	824	73	156		5%	53%	42%		153
	Female total length (mm)																
2012 rvr	884	65	71	2%	19%	47%	33%	64	889	84	53	7%	30%	39%	25%		44

	Age Dist					
Kaouk*	**3-1**	**4-1**	**4-2**	**5-1**	**6-1**	*n*
2010	41%	20%	1%	37%	1%	113

Table 7. Average estimated survey life Marble, Leiner and Tranquil Rivers, based on radio telemetry surveys and swims. Observed is the average number of days individual tags were active. AUC-Tag is the trapezoidal approximation of the area under the tag curve divided by the number of tags. AUC-Tag Tel is based on the tags detected via telemetry.



System	Radio Telemetry/External Mark Resight						
	Year	Estimate Type	Estimate	St. Dev	*n*	St. Error	95% CI
Kaouk	2010	Observed group 1	28.7	5.6	6	2.3	4.5
		Observed group 2	21.7	6.6	6	2.7	5.3
		AUC-Tag group 1	27.3		22		
		AUC-Tag group 2	16.0		39		
Marble	2011	Observed	34.0	16.2	4	8.1	15.9
		AUC-Tag	37.9		4		
	2012	Obs. Med Conf. Group 1	41.0	24.0	2	17.0	33.3
		Obs. Low Conf. Group 1	29.3	9.1	7	3.4	6.7
		Obs. High Conf. Group 2	26.3	16.1	6	6.6	12.9
		Obs. Med Conf. Group 2	17.0	9.9	2	7.0	13.7
		AUC-Tag Tel group 1	23.7		10		
		AUC-Tag Tel group 2	16.8		9		
		AUC-Tag	8.8		19		
Leiner	2010	Obs. group 1	20.8	6.8	11	2.0	4.0
		Obs. group 2	18.5	2.0	4	1.0	2.0
		AUC-Tag group 1	12.1		24		
		AUC-Tag group 2	5.4		24		
	2011	Obs.	15.5	3.4	21	0.7	1.5
		AUC-Tag Telemetry	11.4		21		
		AUC-Tag	17.9		16		
	2012	Obs. High Conf	28.1	10.8	18	2.6	5.0
		Obs. Med-High Conf	28.8	13.7	38	2.2	4.4
		AUC-Tag Telemetry	25.4		82		
		AUC-Tag	12.8		25		



System	Radio Telemetry/External Mark Resight						
	Year	Estimate Type	Estimate	St. Dev	*n*	St. Error	95% CI
Tahsis	2012	Obs. High Conf	23.0	5.7	2	4.0	7.8
		Obs. Med-High Conf	25.4	15.0	10	4.7	9.3
		AUC-Tag Telemetry	16.8		22		
		AUC-Tag	6.1		22		
Tranquil	2010	Observed group 1	25	5	10	1.6	3.1
		Observed group 2	19	3	6	1.0	2.1
		AUC-Tag group 1	31.2		22		
		AUC-Tag group 2	18.5		7		
	2011	Observed group 1	27.5	10.4	21	2.3	4.4
		Observed group 2	10.8	8	9	2.7	5.2
		AUC-Tag Telemetry	25		21		
		AUC-Tag	16.5		32		
	2012	Observed	21.2	7.8	21	1.7	3.4
		AUC-Tag Telemetry	20.2		22		

Table 8. Observer efficiency estimates for study populations. The average observer efficiency is weighted by the total number of adult Chinook observed during each survey.

System	Date	Total adult chinook observed	Known radio-tagged chinook	Observed radio-tagged chinook	Observer Efficiency
Marble	8/29/2012	20	0	0	
	9/4/2012	394	0	0	
	9/10/2012	474	1	1	100%
	9/14/2012	722	5	4	80%
	9/19/2012	596	8	5	63%
	9/24/2012	820	9	7	78%
	9/28/2012	885	8	0	0%
	10/4/2012	1092	7	7	100%
	10/9/2012	902	5	3	60%
	10/15/2012	633	8	1	13%
	10/31/2012	654	5	0	0%
					52%
Leiner	9/4/2012	30	2	0	0%
	9/14/2012	126	9	9	100%
	9/16/2012	143	15	10	67%
	9/23/2012	199	26	14	54%
	9/26/2012	192	21	9	43%
	10/4/2012	347	40	21	53%
	10/7/2012	247	43	14	33%
	10/24/2012	25	17	0	0%
	10/26/2012	14	17	0	0%
	11/2/2012	0	9	0	0%
	11/8/2012	0	4	0	0%
Weighted Average					54%

System	Date	Total adult chinook observed	Known radio-tagged chinook	Observed radio-tagged chinook	Observer Efficiency
Tahsis	9/6/2012	0	0	0	
	9/15/2012	15	2	2	100%
	9/25/2012	18	1	1	100%
	10/5/2012	10	7	0	0%
	10/23/2012	109	12	4	33%
	11/9/2012	0	7	0	0%
					46%
Tranquil	9/4/2012	1	19	13	68%
	9/11/2012	3	13	10	77%
	9/18/2012	9	12	8	67%
	9/29/2012	9	10	3	30%
	10/9/2012	10	6	2	33%
	10/21/2012	181	1	1	100%
	10/25/2012	168	2	2	100%
	10/27/2012	135	0	0	
	11/2/2012	67	0	0	
	11/6/2012	41	0	0	
	11/10/2012	22	0	0	
	11/15/2012	10	0	0	
	11/22/2012	3	0	0	
	11/26/2012	2	0	0	
	12/6/2012	0	0	0	
Weighted Average					46%

Table 9. Environmental data collected by spawner survey crews.

System	Date	OE	Secchi Horizontal Vis (m)	Effective Horizontal visibility (m)	River Height (m)	Distance (m)	Time for flow (s)	River flow (m\s)	Wetted area (m^2)	SEF discharge (m^3/s)	EC station height	EC station Discharge (m^3/s)	SEF HV/Q	EC HV/Q
Marble											Klashkish	Klashkish		Vis/level
2012	10-Sep	33%	12		0.095					4.67	3.78		2.57	3.17
	14-Sep	80%	10.5		0.07					4.00	3.62		2.63	2.90
	19-Sep	63%	13		0.045					3.42	3.58		3.80	3.63
	24-Sep	78%	14		0.01					2.89	3.57		4.84	3.92
	4-Oct	88%	12		0.005					2.67	3.67		4.49	3.27
	9-Oct	60%	13		-0.1					2.45	3.60		5.30	3.61
	15-Oct	33%	10		0.45					20.50	4.15		0.49	2.41
									%bankfull					
2011	09/02		8.5		normal				70%		3.708	0.632		2.29
	09/14	33%	12		below norm				50%		3.64	0.255		3.30
	09/21	33%	6.3		normal	20	8.15	2.45	60%		5.73	54.30		1.10
	10/21	50%	7.2		above norm				85%		4.58	16.80		1.57
Leiner											McKelvie Crk			Eff Vis/leve
2012	09/14	100%		10	60%						2.104			4.75
	09/16	67%		10	70%						2.092			4.78
	09/23	54%		5	extremely low						2.101			2.38
	09/26	43%		7	60%	10	4.6	0.22			2.101			3.33
	10/04	53%	18	8	0.53					1.20	2.119		6.67	3.78
	10/07	33%	14	6	0.49	10		0.24		0.97	2.117		6.19	2.83
	10/24	0%	17	8						3.30	2.106		2.42	3.80
	10/26	0%	16	7						4.30	2.115		1.63	3.31
	11/08	0%	16	8						7.00	2.200			3.64
2011	09/09			10	0.53	11.44	28.1	0.36	19.42	6.91	n/a		1.45	
	09/16			15	0.51	11.44	33.9	0.30	19.21	5.67	n/a		2.64	
	09/18	100%		9	0.58	11.44	24.9	0.40	19.94	8.01	n/a		1.12	
	09/29	50%		5	0.7	11.44	13.0	0.77	21.20	16.26	n/a		0.31	
	10/02	67%		7	0.58	11.44	20.8	0.48	19.94	9.60	n/a		0.73	
	10/07			6	0.63	11.44	13.8	0.73	20.47	14.89	n/a		0.40	
	10/14			6	0.66	11.44	14.8	0.68	20.78	14.04	n/a		0.43	
2010	09/08													
	09/19	100%		8.5	0.35	11.44	33.72	0.34	17.91	6.08	n/a		1.40	
	09/29	11%		8.5	0.72	11.44	15.98	0.72	21.64	15.49	n/a		0.55	
	10/03	45%		8	0.58	11.44	29.35	0.39	19.55	7.62	n/a		1.05	
	10/04	25%		8	0.56	11.44	39.5	0.29	19.25	5.58	n/a		1.43	
	10/15			9.2	0.74	11.44	13.97	0.82	21.93	17.96	n/a		0.51	
	10/16			9.2	0.66	11.44	16.01	0.71	20.74	14.82	n/a		0.62	
	10/28			7.4		11.4	10.3	1.11		0.00	n/a			
Tahsis														Eff Vis/leve
	09/06	0%		5	extremely low				40% bankful		2.10			2.38
	09/15	100%		5	extremely low				60% bankful		2.10			2.38
	09/25	100%	31	8	extremely l	10		0.80	30% bankfu	0.50	2.10		16.00	3.81
	10/23	33%	20	8	0.26	10		0.72	60%	2.20	2.16		3.64	3.70
Tranquil												Tofino discharge		
	09/04			12	0.58	2	73	0.03	27.7	3.8		0.31	3.16	38.71
	10/21	68%		10	0.76	2	9	0.22	33.5	7.4		3.56	1.34	2.81
	10/25	77%		12	0.66	2	20	0.10	30.2	3.0		1.51	3.97	7.93
	10/27	67%		10	0.78	2	6	0.33	34.1	11.4		10.38	0.88	0.96
	11/02	30%		6	0.88	2	6	0.33	37.4	12.5		13.43	0.48	0.45
	11/06	33%		9	0.78	2	8	0.25	34.1	8.5		4.17	1.06	2.16
	11/10	100%		10	0.68	2	20	0.10	30.9	3.1		1.89	3.24	5.30
	11/15	100%		10	0.72	2	14	0.14	32.2	4.6		2.79	2.18	3.58
2011	09/15			12	0.56	2	42	0.05	28.03	1.33	0.33	8.99		1.33
	10/07	89%		9	0.73	2	11	0.18	33.47	6.09	3.90	1.48	2.31	6.09
	10/14	93%		8	0.74	2	12	0.17	33.79	5.63	3.93	1.42	2.04	5.63
	10/23	46%		6	0.77	2.0	7.0	0.29	34.76	9.93	4.87	0.60	1.23	9.93
	10/31	65%		6.5	0.75	2.0	8.0	0.25	34.1	8.53	4.21	0.76	1.54	8.53
2010	10/01	95%		10	0.68	2.0	15.0	0.13	31.25	4.17		2.00	2.40	5.00
	10/03	100%		12	0.625	2.0	31.0	0.06	29.49	1.90		1.21	6.31	9.92
	10/15	80%		10	0.73	2.0	10.0	0.20	32.69	6.54		3.26	1.53	3.07
	10/18	64%		10	0.73	2.0	10.0	0.20	30.45	6.09		2.15	1.64	4.65
	10/21	73%		12	0.66	2.0	16.0	0.13	32.69	4.09		2.27	2.94	5.29
	10/28	54%		10	0.77	2.0	8.0	0.25	33.96	8.49		5.90	1.18	1.69
	10/30	40%		10	0.78	2.0	8.0	0.25	34.28	8.57		18.50	1.17	0.54
	11/03	75%		10	0.79	2.0	6.0	0.33				4.58		2.18
	11/06	33%		12	0.76	2.0	6.0	0.33				6.70		1.79
Kaouk														
	09/23	100%		*5*	0.755	4.9	56.4	0.09	17.30	1.50			3.33	
	10/06	67%		3.75	1.4	4.9	102.19	0.05	32.78	1.57			2.39	
	10/07	50%		3.25	1.4	4.9	102.19	0.05	32.78	1.57			2.07	
	10/20	0%		4.3	1.5	4.9	6.47	0.76	35.18	26.64			0.16	
	10/21	33%		3.5	1.5	4.9	13.6	0.36	35.18	12.67			0.28	

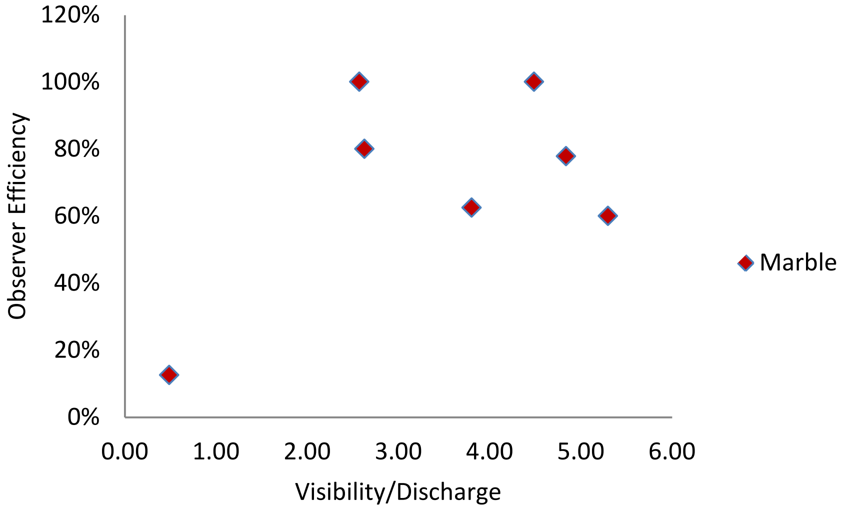


Figure 2 2012 Relationship between river conditions and observer efficiency of Chinook for the Marble River. Due to the faulty tags, some estimates of observer efficiency may be imprecise or biased.

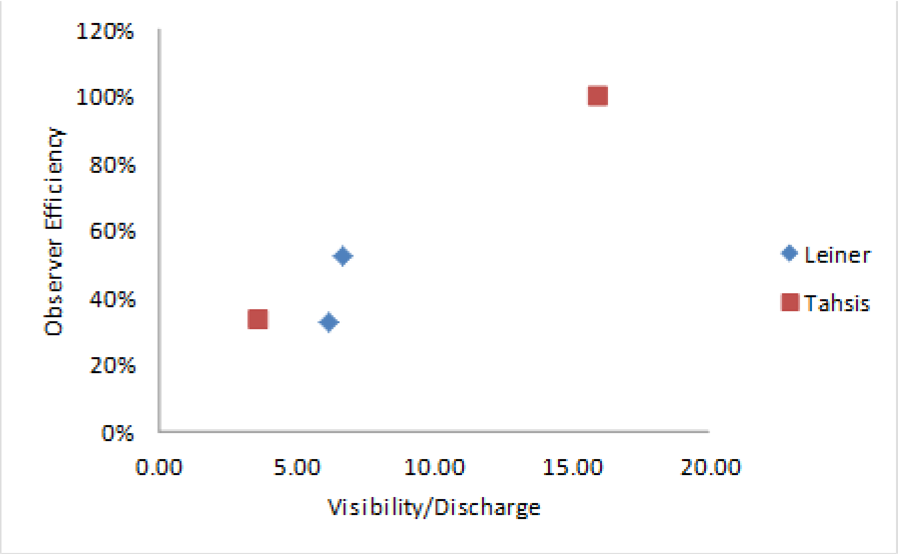


Figure 3. 2012 Relationship between river conditions and observer efficiency of Chinook for the Leiner River and Tahsis River.

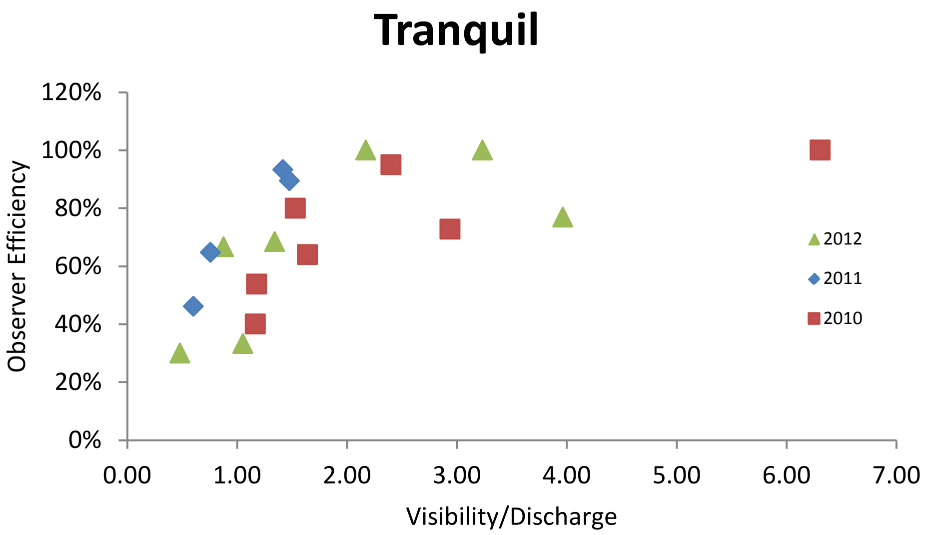


Figure 4. Relationship between river conditions and observer efficiency of Chinook for the Tranquil River in 2010-2012.

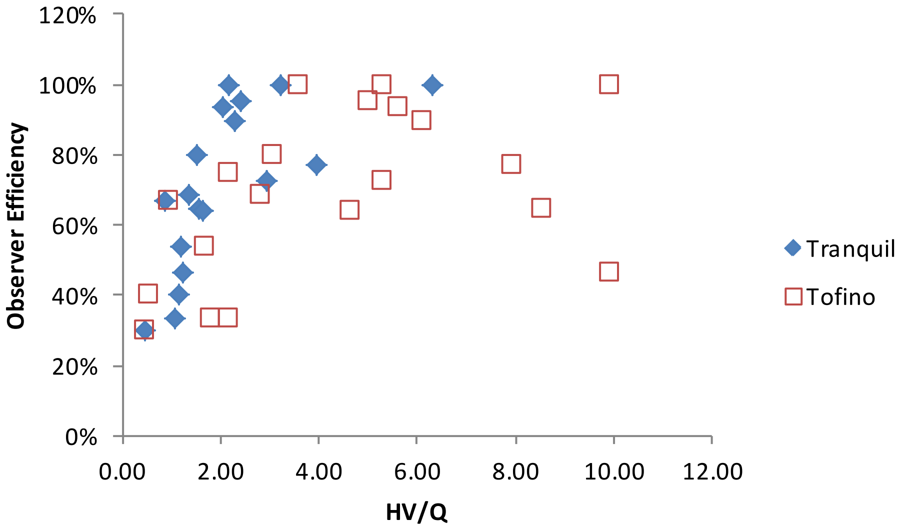


Figure 5. Measured Observer Efficiency versus HV/Q, with the discharge estimate (Q) coming from either a direct estimate from the river or an Environment Canada gauging station in the nearby Tofino Creek (2010-2012).

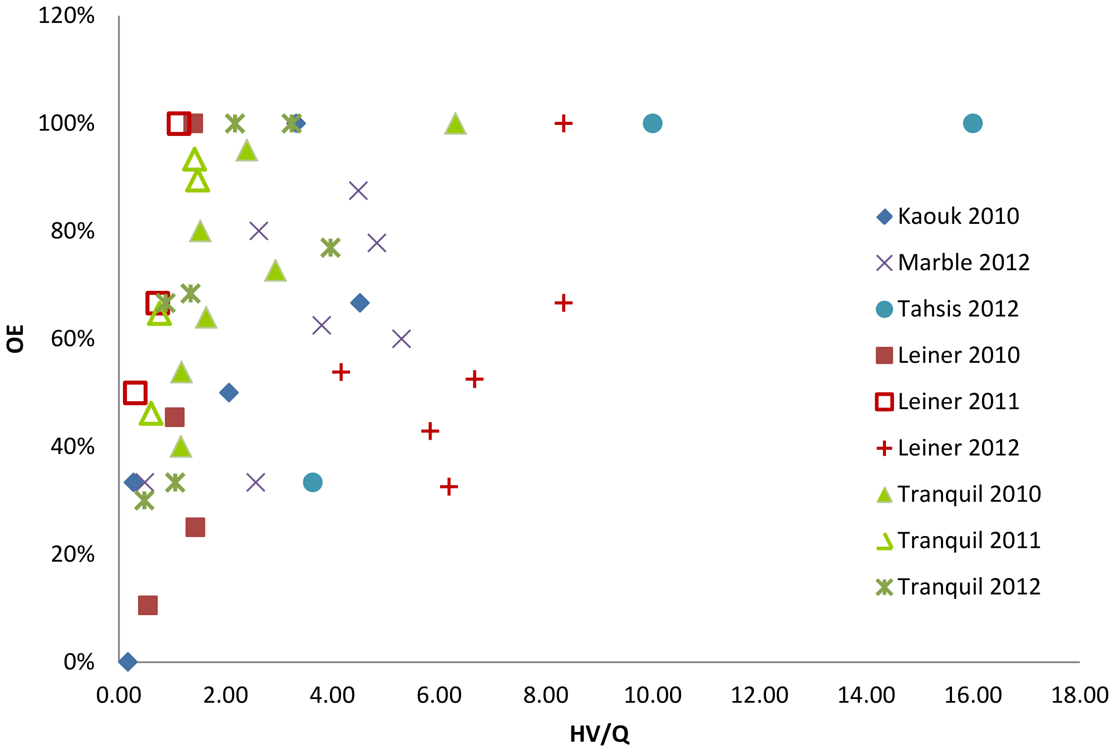


Figure 6 Relationship between river conditions and observer efficiency for all studied systems 2010-2012.

Table 10. Area-under-the-curve (AUC) estimates for study systems.

System	Survey Date	Raw	Qualitative AUC		Quantitative AUC	
		Total Adult CN	Observer Efficiency	Expanded Adult CN	Observer Efficiency	Expanded Adult CN
Marble	8/29/2012	20	100%	20	*100%*	20
	9/4/2012	394	90%	438	*100%*	394
	9/10/2012	474	75%	634	*100%*	474
	9/14/2012	722	90%	802	*80%*	903
	9/19/2012	596	85%	701	*63%*	954
	9/24/2012	820	85%	965	*78%*	1054
	9/28/2012	885	85%	1041	*100%*	885
	10/4/2012	1092	85%	1285	*100%*	1092
	10/9/2012	902	70%	1289	*60%*	1503
	10/15/2012	633	50%	1266	*12.5%*	5064
	10/31/2012	654	50%	1308	*100%*	654
Total	11					
Max Observed		1092		1308		5064
Survey Life				30		41
AUC Estimate				2363		2509
Leiner	9/4/2012	30	82%	37	*100%*	30
	9/14/2012	126	81%	156	*100%*	126
	9/16/2012	143	83%	173	*67%*	215
	9/23/2012	199	81%	246	*54%*	370
	9/26/2012	192	73%	263	*43%*	448
	10/4/2012	347	81%	428	*53%*	661
	10/7/2012	247	64%	386	*33%*	759
	10/24/2012	25	74%	34	*100%*	25
	10/26/2012	14	66%	21	*100%*	14
	11/2/2012	0		0	*0%*	
	11/8/2012	0		0	*0%*	
	11/12/2012	0		0	*0%*	
Total	12					
Max Observed		347		428		759
Survey Life				20		28.8
AUC Estimate				566		772

System	Survey Date	Raw	Qualitative AUC		Quantitative AUC	
		Total Adult CN	Observer Efficiency	Expanded Adult CN	Observer Efficiency	Expanded Adult CN
Tahsis	6-Sep-12	0	90%	0	*100%*	0
	15-Sep-12	15	84%	18	100%	15
	25-Sep-12	18	81%	22	100%	18
	5-Oct-12	10	82%	12	*100%*	10
	23-Oct-12	109	70%	155	*33%*	327
	9-Nov-12	0	90%	0		0
Total	6					
Max Observed		109		155		327
Survey Life				20		25.4
AUC Estimate				163		227
Tranquil	9/4/2012	1	100%	1	*100%*	1
	9/11/2012	3	98%	3	*100%*	3
	9/18/2012	9	88%	10	*100%*	9
	9/29/2012	9	95%	9	*100%*	9
	10/9/2012	10	100%	10	*100%*	10
	10/21/2012	181	89%	203	68%	265
	10/25/2012	168	98%	171	77%	218
	10/27/2012	135	86%	156	67%	203
	11/2/2012	67	69%	97	30%	223
	11/6/2012	41	95%	43	33%	123
	11/10/2012	22	95%	23	*100%*	22
	11/15/2012	10	98%	10	*100%*	10
	11/22/2012	3	95%	3	*100%*	3
	11/26/2012	2	98%	2	*100%*	2
	12/6/2012	0	100%	0	*100%*	0
Total	15					
Max Observed		181		203		265
Survey Life				15		21.2
AUC Estimate				262		268

Table 11. Comparison of escapement estimates for study systems generated through different analytical models.

System	No. Surveys	Max. Observed	AUC (Qual)	AUC (Quan)	ML - Unimodal	ML - Biomodal	Mark-Resight	Mark-Resight 95% CI
Marble	11	1,092	2,363	2,509	1,092	2,157	1,340	(1090-3470)
Leiner	12	347	566	772	347	523	563	(490-665)
Tahsis	6	109	163	227	109	182	249	(165-500)
Tranquil	15	181	262	268	262	365	200	(180-230)

Table 12. Comparison of maximum estimated escapement (2012) and qualitative AUC estimate.

System	2012 Max Estimated Escapement	2012 Qualitative AUC Escapement	Ratio (Qual AUC: Max Est.)
Marble	2509	2363	0.94
Leiner	772	566	0.73
Tahsis	249	163	0.65
Tranquil	365	262	0.72

Table 13. Comparison of provisional S_{MSY} Chinook escapement targets for study systems with maximum estimated escapement in 2012.

System	Optimal CK Escapement (Smsy)	80% confidence interval	2012 Max Estimated Escapement	Ratio (Observed: Optimal)
Marble	1,191	990-1434	2,509	2.1
Leiner	681	555-837	772	1.1
Tahsis	512	412-636	249	0.5
Tranquil	415	331-521	365	0.9

APPENDIX 1

OPERATIONAL SUMMARY

Project Deliverables

Field study work was completed, as the modeling objectives were largely completed in 2010.

The specific objectives of the field study were to:

- Estimate total escapement of adult Chinook through a mark-resight study on selected systems;
- Quantify Chinook survey life and observer efficiency for selected systems;
- Determine potential environmental correlates with observer efficiency;
- Compare the mark-resight, normative AUC (5 swims surveys) and extended AUC (10-12 swims surveys) escapement estimates.

The specific objectives of the analytical model development were to:

- Identify and use scientifically defensible procedures to provide AUC escapement estimates and associate levels of uncertainty for selected WCVI systems surveyed recently.
- Based on the results obtained, assess the relative merits of alternative survey procedures that can be used to estimate total escapement to selected WCVI conservation units (CUs).
- Determine the relative benefits of complementary surveys to be initiated shortly in terms of gains in accuracy and precision of future AUC escapement estimates for selected CUs.

Project Schedule

- Field implementation ran per schedule. However, full implementation of the study design (particularly on the Marble River), was impeded due to extreme weather conditions.
- Reporting on the project (i.e. to the SEF, PSC) did not ran per schedule. Key issues/challenges are related to staff turnover and completing priorities within DFO.

QA/QC

- All contractors working on the project were trained prior to implementation – i.e. a one-day work shop was conducted to communicate objectives, methodology, protocols, etc.
- Field work conducted by contractors is monitored periodically by DFO technicians through an auditing process – i.e. DFO technicians conduct site visits to monitor crew work.

Monitoring and evaluation

- All contract performance is monitored under normal Government of Canada procedures.
- Field crews and contractors are given feedback on the quality of their work through audit reports.
- The quality of data sets is monitored through the evaluation of the data (i.e. analysis is conducted by DFO staff). Contractors are required to submit data weekly so that it can be evaluated in a timely fashion.

Benefits

There have been several benefits generated from this project:

- The analytical work resulted in the development of a robust model that can be used to explore and describe the uncertainty in WCVI chinook escapement estimates. It is a significant improvement over previous models that have been used and will be used to examine past data sets as well.
- The modeling work resulted in several recommendations to improve the survey design WCVI escapement monitoring. These recommendations were implemented in 2011.
- The field work has provided empirical data to better understand the variation in observer efficiency and survey life. This information is required to estimate uncertainty in escapement estimates (either modeled or through a direct ‘AUC’ estimate).
- Preliminary results of the field studies show a promising relationship between environmental correlates and observer efficiency. The further development of this relationship in 2012 field will allow improved application of estimation models without annual implementation of expensive field studies to directly estimate observer efficiency.
- The preliminary results of this study (and related SSP studies) have provided increased confidence in the current WCVI chinook escapement estimation. After a presentation of the results of this study, members of the Chinook Technical Committee conceded that they agree the abundance of WCVI wild chinook is low.
- Given the results of these studies, the Sentinel Stock Committee has now moved toward the model implemented under this design (i.e. they recognized the value of the work completed so far and better understand the challenges of implementing escapement surveys on the WCVI).

Financial Statement (EXCEL workbook, submitted)