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

Sentinel Stock Committee 2013

FINAL REPORT

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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 from 2010 to 2012. Chinook in several WCVI rivers were tagged with a combination of radio and purely visual tags, and then monitored using radio telemetry and an increased level of snorkel survey effort. 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. Both parameters were fairly consistent with the values used in recent years to generate WCVI Chinook escapement estimates. Self-reported observer efficiencies (OE) were generally underestimated, but some reports of OE greater than 95% when conditions were good were supported by the telemetry results. The effect of the underestimation on the escapement estimate was generally minor. In addition, estimates of discharge (Q) and horizontal visibility (HV) were collected for most surveys to help parameterize a relationship between discharge, visibility, and observer efficiency (OE). OE has a positive correlation with the proportion of the discharge that can be seen by swimmers (HV/Q). 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 15% lower than the quantitative AUC estimate.

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1.0 INTRODUCTION

Escapement to approximately 18 systems throughout the WCVI (Figure 6) is estimated using the area-under-the-curve (AUC) method (English et al. 1992). Surveys are scheduled for every 7-10 days during September, October and November, for a minimum of 4 surveys per system to generate an AUC-based estimate. Weather, water conditions, and water flows may impact this schedule. If systems are surveyed less than four times, the estimate is typically the peak-live plus dead count either raw or expanded for observer efficiency. 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.

The relationship between the number of fish observed by a crew snorkeling a river periodically and the total number of fish utilizing a river is a function of two main components, OE and SL. 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 initial estimates generated by the new model has been completed for some systems, but based on the results of the Escapement Workshop, 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:

- Quantify Chinook survey life and observer efficiency for selected systems;
- Determine potential environmental correlates with observer efficiency;

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

The main objective of the field study was to improve the parameterization of the AUC estimation methodology by evaluating the average Chinook SL and the survey crew's OE following similar methodology described by Korman et al. (2002, 2007) on the Marble, Tranquil and Sarita Rivers. Previous studies on the Kaouk, Marble, Leiner and Tranquil Rivers under the Southern Endowment Fund and Sentinel Stocks Program, 2010 thru 2012, allowed the method to be applied there.

2.1 FIELD STUDY

2.1.1 Tag Application

Fish were captured throughout the run timing in the marine approach waters, or in the rivers themselves and radio tags were applied to the captured Chinook and released back into those waters. The radio tags used for this project were coded motion or mortality tags (MCFT2-3A or similar) which emit a different signal when the animal stops moving for more than a given time (programmed by the user).

For tags applied in marine approach areas, application was proportionate to the estimated run-timing of those Chinook populations with the assumption 33% will be picked up entering the river based on the 2012 results. For tags applied in-river, the number of tags was determined based on the assumption of a 25% tagging mortality Tag release sample sizes, increased based on the previous outlined assumptions, were determined for the program through simulation in 2012. For 2013, the target number of 80 usable tags was carried over from 2012, but the effect of straying and mortality on tags applied outside that get to the river was updated based on the 2012 results.

2.1.2 Radio Telemetry

Fixed telemetry receivers were installed at the top and bottom of the survey sections in Marble and Tranquil. In Sarita, fixed receivers were installed at the bottom, on the South Sarita (a major tributary), and near the upper end of the survey section. The fixed receiver above the Sarita survey section was not required to ensure no fish passed beyond the survey section, because it begins at a 20 metre set of falls impassible to all fish. Mobile telemetry surveys were planned in conjunction with every spawner survey, and every two to three days during die-off.

2.1.3 Spawner Surveys

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. Discharge from the Marble was estimated using the methods described in the Discharge Survey Manual (Appendix 2). Tranquil discharge estimate was based on a bottom profile paired with a gauge reading and a speed of flow estimate based on the time it took a floating item to travel a known distance. Sarita discharge is monitored by Environment Canada at a gauging station within the survey area.

2.2 ANALYSIS

2.2.1 Survey Life Estimation

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

The average survey life for the study systems was estimated by dividing the number of tag days based on the results of the telemetry surveys by the number of tags applied in the Marble, Tranquil, and Sarita rivers. This survey life estimate should be a true estimate of the average survey life, if we assume the OE with the telemetry gear is 100% and the tagged fish are representative of the entire population. The length of time each tag was active in the area provided an estimate of the survey life of individual Chinook as well.

A third 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. 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).

2.2.2 Observer Efficiency Estimation

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

2.2.3 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 and Tranquil rivers were analyzed. Also, Environment Canada provides discharge estimates for Tofino Creek (near Tranquil) and Sarita.

2.2.4 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 2013 study results;
- The mark-resight method using the Immigration-Emigration Logit-Normal model described in McClintock and White (2012);

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.

2.2.4.1 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.

2.2.4.2 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 Immigration-Emigration Logit-Normal (IELN) model without individually identifiable marks described in McClintock and White (2012):

$$L(\boldsymbol{N}^*, \overline{\boldsymbol{N}}, \boldsymbol{\alpha}, \boldsymbol{p} | \boldsymbol{m}, \boldsymbol{M}, \boldsymbol{T}, \boldsymbol{T_u})$$
$$= \prod_{j=1}^{t} \left[\prod_{i=1}^{k_j} \mu_{ij}^{m_{ij}} \left(1-\mu_{ij}\right)^{M_{ij}-m_{ij}} \right]$$
$$\times \left[\prod_{i=1}^{k_j} \binom{T_{ij}}{M_{ij}} \left(\frac{\overline{N}_j + \alpha_{ij}}{N_j^*}\right)^{M_{ij}} \left(1 - \frac{\overline{N}_j + \alpha_{ij}}{N_j^*}\right)^{T_{ij}-M_{ij}} \right] \times \left[\prod_{i=1}^{k_j} \frac{f(T_{u_{ij}})}{\int_0^\infty f\left(T_{u_{ij}}\right) dT_{u_{ij}}} \right]$$

,

Data

t = number of primary sampling intervals

k_j = number of distinct secondary sampling occasions (without replacement) during primary interval j.

n_j = the exact number of marked individuals in the population during primary interval *j*.

T_{ij} = number of marked individuals in the super population during secondary occasion *i* of primary interval *j*.

M_{ij} = number of marked individuals that are within the study area during secondary occasion *i* of primary interval *j*.

m_{ij} = total number of marked individual sightings during secondary occasion *i* of primary interval *j*.

$T_{u_{ij}}$ = total number of unmarked individual sightings during secondary occasion *i* of primary interval *j*.

Parameters

N_j^* = super-population using the study area at any time during primary interval *j*.

$\overline{N}_j$ = mean population size in the study area during primary interval *j*.

α_{ij} = the difference relative to Nbar in population in the study area during secondary occasion *i* of primary interval *j*.

p_{ij} = intercept (on logit scale) for mean resighting probability of secondary occasion *i* during primary interval *j*.

${\sigma^2}_j$ = individual heterogeneity level (on the logit scale) during primary interval *j* (i.e. the variance of a random individual heterogeneity effect with mean zero).

Derived Parameter

μ_{ij} = mean resighting probability for secondary occasion *i* during primary interval *j*.

Assumptions:

1. No loss of marks
2. No errors in distinguishing between marked and unmarked
3. Independently and identically distributed sighting probabilities for marked and unmarked individuals.

Radio telemetry provided the number of tags present in the survey area during each survey. Tags known to be dead were removed from the super-population of tags (T).

3.0 RESULTS AND ANALYSIS

3.1 FIELD STUDY

3.1.1 Marble

Tag Application

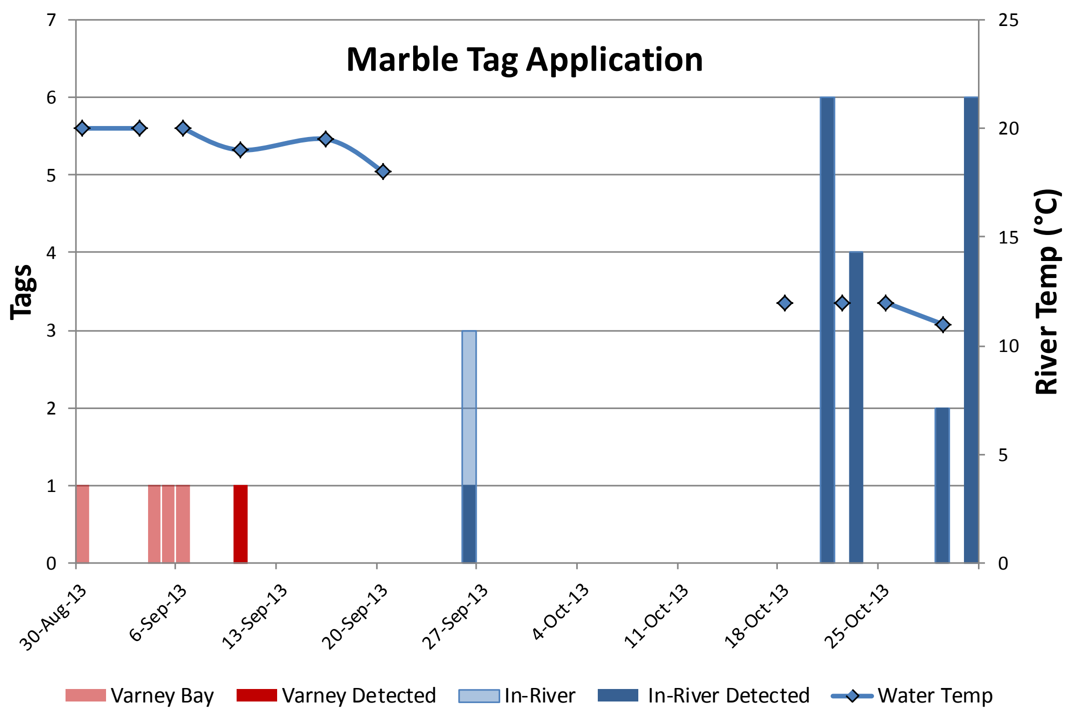

Figure 1 Tag application, subsequent detection and Marble River temperature. The pale portion of the column indicates tags applied that day and not detected in any subsequent survey. The solid portion of the column indicates tags applied on that day, that were detected at least once in a subsequent survey. Most of the tags applied prior to late October were not detected in any subsequent survey, indicating possible tag-related mortality.

Chinook in the study populations were captured and tagged through angling, trolling, and beach seining (Table 3). Fish were tagged starting in Late August prior to Chinook entering the river. 26 external radio tags were applied on Marble River fish, 5 in Quatsino Inlet and 21 in river. Angling in Quatsino Inlet began in Late August as planned, but the numbers of fish encountered were much lower than in 2012 during the same period. Applying tags in-river was difficult due to the majority of entry being delayed until mid-October. Marble river temperatures through mid-September were above average and may be responsible for the apparent delayed entry. When the river finally came up and the temperature down, the fish entered and distributed themselves throughout the river rather than holding in the beach seinable pools they usually hold in for a period prior to spawning, so tagging was delayed and occurred throughout the river. The hatchery crew was unable to collect any broodstock.

Of the tags applied prior to October, only a few were detected in any of the subsequent telemetry surveys, indicating a high mortality rate. 77% of all tags applied were later detected (25% of the pre-October tags and 100% of tags applied in late October) (Figure 1).

Survey Results

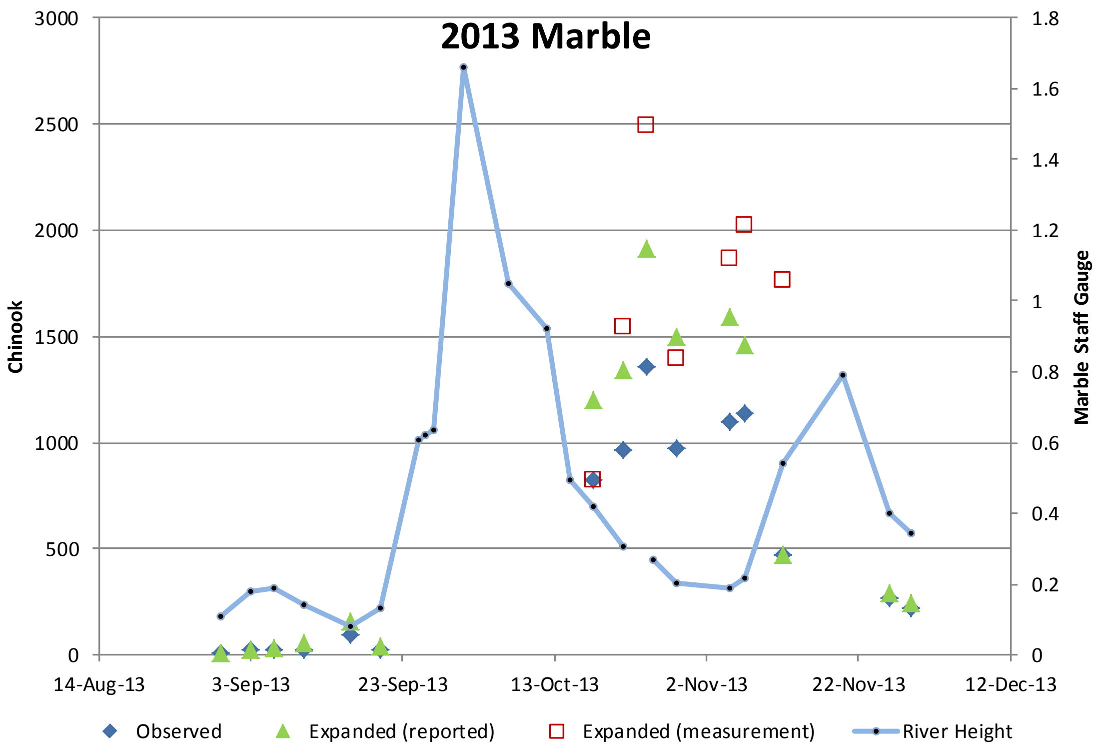

Figure 2 Snorkel survey timing and results and Marble River stage height. Observed is the raw number of Chinook observed by the crew, Expanded (reported) is the number of Chinook estimated based on the OE expansion provided by the crew, Expanded (measurement) is the number of Chinook estimated based on the proportion of the radio tags present, based on telemetry, that the crew reported seeing. Five tags applied prior to mid-September, three in-river Sept 26, the river peaked on Oct 1, and the remaining 18 were applied in-river between Oct 21 and 31.

High water levels in late-Sept to early October caused a 28 day gap in snorkel surveys. During a total of 15 spawner surveys were conducted on the Marble, the maximum number of Chinook observed was 1360 (Table 4). The maximum number of tags observed by the snorkel crew during a single survey was 10. A total of 18 telemetry surveys were conducted on the Marble River (Table 5), the maximum number of tags detected by the telemetry crew during a single survey was 17. Three of the telemetry surveys were not associated with a snorkel survey due to high water levels in mid-November.

3.1.2 Tranquil

Tag Application

Chinook in the study populations were captured and tagged through beach seining (Table 3). Internal radio tags were applied to 27 Chinook in the Tranquil River, 15 on September 26 and 12 on October 16. All were later detected by telemetry surveys. In addition, 27 Chinook were tagged with external tags only, 15 on September 26 and 12 on October 16.

Spawner Survey Results

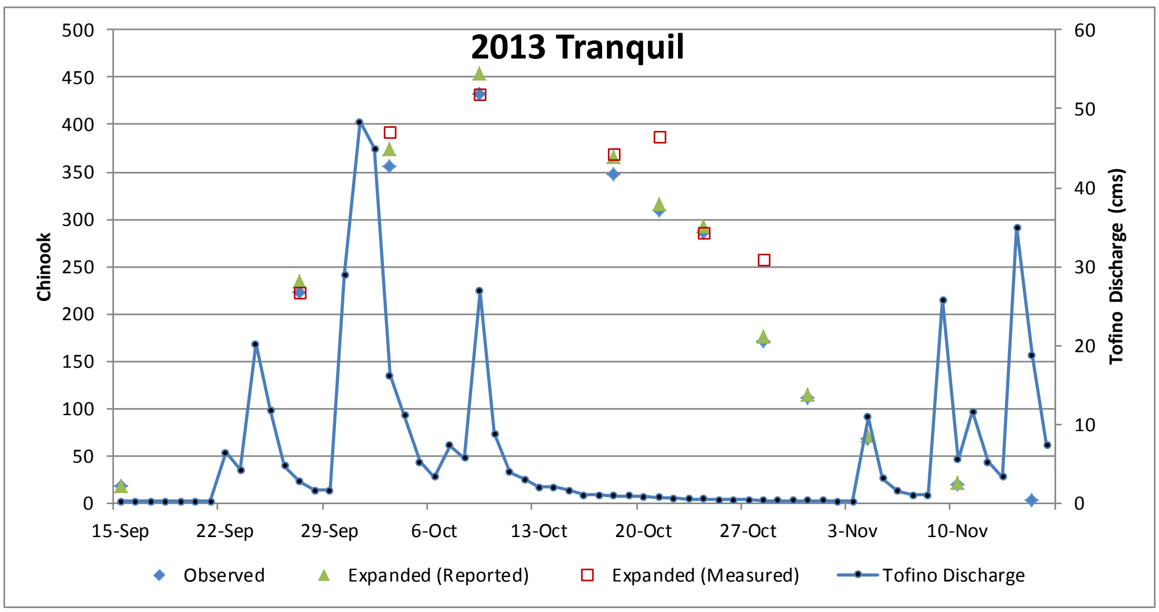

Figure 3 Snorkel survey timing and results and Tofino Creek discharge. Observed is the raw number of Chinook observed by the crew, Expanded (reported) is the number of Chinook estimated based on the OE expansion provided by the crew, Expanded (measurement) is the number of Chinook estimated based on the proportion of the radio tags present, based on telemetry, that the crew reported seeing. 15 radio tags applied Sept 26, 12 radio tags applied Oct 16.

A total of 14 spawner surveys were conducted on the Tranquil. During snorkel swims on the accessible length of the river, the maximum number of Chinook observed was 432 (Table 4).

11 spaghetti tags were recovered in the Tranquil while significant live Chinook were still in the system. Additionally, one fish was seen on two occasions with an antenna but no spaghetti tag, but none of the radio tags appear to have been lost prior to death. The majority were recovered from carcass piles or the woods nearby. A total of 10 telemetry surveys were conducted on the Tranquil River (Table 5), the maximum number of tags detected by the telemetry crew during a single survey was 17.

3.1.3 Sarita

Tag Application

Chinook in the study populations were captured and tagged through beach seining (Table 3). External radio tags were applied to 97 Chinook just below marker 0 on the Sarita (86 September 17th-19th, and 11 September 27th). Of those, two tags were lost, recovered and re-applied (~2%) and 13 tags were not detected in any subsequent telemetry survey.

Spawner Survey Results

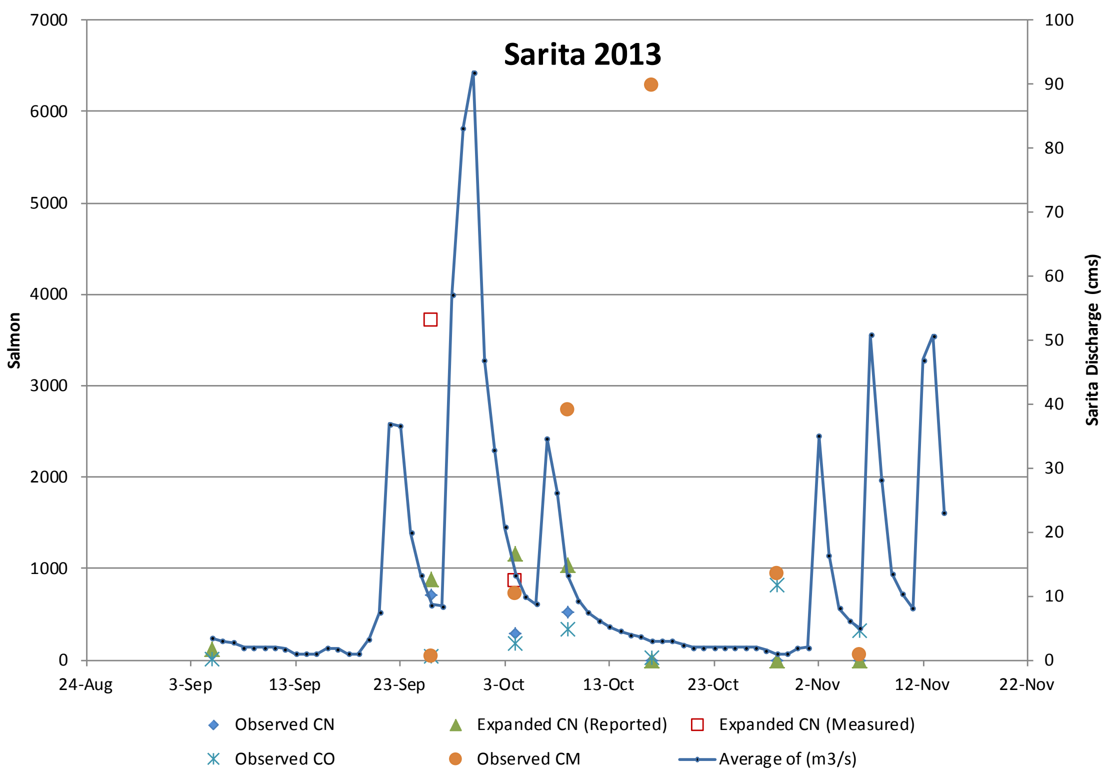

Figure 4 Snorkel survey timing and results and Sarita discharge. Observed is the raw number of Chinook observed by the crew, Expanded (reported) is the number of Chinook estimated based on the OE expansion provided by the crew, Expanded (measurement) is the number of Chinook estimated based on the proportion of the radio tags present, based

on telemetry, that the crew reported seeing. 85 tags applied Sept 17-19, 11 tags applied Sept 27. No tags were seen Oct 9, and no Chinook were reported after that date, coinciding with a large number of coho and chum entering the river.

A total of 7 spawner surveys were conducted on the Sarita River. During snorkel swims on the accessible length of the river, the maximum number of Chinook observed was 704 (Table 4). 24 carcasses were recovered from the Sarita, none had tags. A total of 7 telemetry surveys were conducted on the Sarita River (Table 5). They detected 87% of the tags at least once after they were applied. No Chinook were reported by the swim crew, after October 9th, but it is unlikely that no Chinook were present. Radio tags registering “alive” Chinook were detected in the river as late as November 6th. Roughly 10,000 chum and 1,200 coho entered the river in mid to late October, likely obscuring both tagged and untagged Chinook.

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 the Marble and Sarita, lengths were only collected from carcasses or when broodstock were collected (Table 6). Because no broodstock was collected from the Marble, we have no length data, but scales were taken from 21 tagged fish; 52% 4_1 and 48% 5_1 fish. Average post-orbital fork length for the Tranquil population was 692 and 654 mm for females and males, respectively. Average post-orbital fork length for the Sarita population was 680 and 613 mm for females and males, respectively. The average age composition for the Tranquil River females was 38%, 38%% and 25% age 3_1, 4_1 and 5_1 fish, respectively. The average age composition for the Tranquil River males was 30%, 61% and 9% age 3_1, 4_1, and 5_1 fish, respectively. The average age composition for the Sarita River females was 14%, 47%, 3% and 36% age 3_1, 4_1, 4_2, and 5_1 fish, respectively. The average age composition for the Sarita River males was 57%, 31%, 2%, and 11% age 3_1, 4_1, 4_2, and 5_1 fish, respectively.

3.2.2 Survey Life Estimates

Marble

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 (SL) (Table 8). In 2013, we were unable to apply tags throughout the run in the Marble. Relatively few tags were applied in September and they experienced a high level of mortality, possibly related to predation on the tags applied in the estuary and tagging stress related to the high river temperatures in late September. 18 of the 26 tags (~70%) were applied once the river returned to safe levels in Late October. The interpretation of the results is complicated by the application of tags after the likely mean entry date. If the date on which the tag is applied is taken as the entry date, the estimated SL in the Marble was 23 days given the Area Under the radio tag depletion Curve divided the number of tags ($SL|AUC_{tag}$), and had a mean of 25 days and a standard deviation of 7 days based on the individual observations. If the assumed entry date for the fish tagged in Late October is Oct 15th, the estimated $SL|AUC_{tag}$ was 30.9 days and had a mean of 34.7 days and a standard deviation of 8.9 days. If entry coincided with peak water levels on Oct 1, the $SL|AUC_{tag}$ would be 42.1 days and a mean of 47.4, standard deviation of 8.3 based on the individual observations.

Tranquil

The estimated survey life in the Tranquil was 16.4 based on the weighted average of the $SL|AUC_{tag}$ for the two tag events, had a mean of 17.5 and a standard deviation of 3.4 based on the individual observations, and 12.8 based on the visual tag depletion curve unexpanded for OE. For the tags applied September 26, the $SL|AUC_{tag}$ was 19 days, and 12 days for tags applied October 16th.

Sarita

The $SL|AUC_{tag}$ in the Sarita was 15 days, had a mean of 19 days and a standard deviation of 9 based on the individual observations, and 6 days based on the area under the curve of tags observed by the swim crew ($SL|\ AUC_{swimtag}$). However, due to long gaps between surveys the assumption of when fish died between observations has a large effect on the results. If, rather than assuming fish died halfway between an "alive" and a "dead" signal being detected, we assume they died the day following the last "alive" detection, the SL estimate becomes 13 days with a standard deviation of 7 days. If they died the day the "dead" signal was received, then the SL estimate is 25 days with a standard deviation of 13 days. The gaps between telemetry surveys in the other systems were much shorter, so the assumption applied made less difference. Tranquil: 17.5 days versus 15.5 to 19.5 depending on assumption. Marble (Oct 1 = Entry): 47 days versus 44 to 48 depending on assumption.

3.2.3 Observer Efficiency Estimates

Observer efficiency of the spawner survey crews was estimated for the Marble, Tranquil, and Sarita systems. Observer efficiency varied across surveys. Across surveys within a study population, the weighted average estimated observer efficiency was 60%, 87%, and 15% for the Marble, Tranquil and Sarita populations, respectively (Table 9). (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, water temperature, water flow, gauge height, and pool Secchi depth (Table 10). These data were used in regression analysis to develop a relationship between the environmental correlates and the estimated observer efficiency (OE).

The relationships between survey life and environmental correlates for the Marble, Tranquil and Sarita Rivers are displayed in Figure 7. For all systems there was a positive relationship between observer efficiency and the horizontal visibility/discharge (HV/Q) index within the normal range of HV/Q, however when discharge was very low, while visibility remained high (extremely high values for HV/Q) the relationship between OE and HV/Q was unclear (Figure 8).

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 11, Table 12). 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 2,080. The trapezoidal AUC method with quantitative assessment of observer efficiency and survey life based on 2013 measurements yielded an escapement estimate of 2,240. The mark-resight estimate based on the Oct 22 to Nov 12 surveys was 1,901 (1,669-2,308), the peak number of tags observed was 12. The bimodal maximum likelihood escapement estimation model yielded an estimate of 2,568. The survey life implied by the mark-resight estimate of abundance (Area Under the Curve divided by Escapement Estimate) is 38 days based on the counts expanded by the self-reported OE or 27.5 based on the raw counts.

For the Tranquil River, the trapezoidal AUC method with qualitative assessment of observer efficiency and survey life yielded an escapement estimate of 684. The trapezoidal AUC method with quantitative assessment of observer efficiency and survey life based on 2013 measurements yielded an escapement estimate of 824. The mark-resight based on the Sep 27 to Oct 24 surveys yielded an estimate of 493 (95% CI 475-526),the peak number of tags observed was 28. The unimodal maximum likelihood escapement estimation model yielded an estimate of 836. The survey life implied by the mark-resight estimate of abundance (Area Under the Curve divided by Escapement Estimate) is 27.5 days based on the counts expanded by the self-reported OE or 26.5 based on the raw counts.

For the Sarita River, the trapezoidal AUC method with qualitative assessment of observer efficiency and survey life yielded an escapement estimate of 1,432. The trapezoidal AUC method with quantitative assessment of observer efficiency and survey life based on 2013 measurements yielded an escapement estimate of 4,220. The mark-resight based on the Sep 26 and Oct 4 surveys yielded an estimate of 4,766 (95% CI 4,388-5,483), the peak number of tags observed was 8.The bimodal maximum likelihood escapement estimation model yielded an estimate of 1,017. The survey life implied by the mark-resight estimate of abundance (Area Under the Curve divided by Escapement Estimate) is 6 days based on the counts expanded by the self-reported OE or 3.5 based on the raw counts. The large influx of coho and chum in early October made estimates of Chinook more challenging than in the systems with either fewer coho and chum, or less temporal and geographical overlap.

3.2.6 Comparison of Escapement Estimates with Provisional Habitat Based Escapement Targets

The maximum estimated escapement estimates for 2013 were compared with provisional habitat-based escapement targets that are defined for WCVI Chinook populations using the model of Parken et al. (2006). Based on the additional information collected, escapements to the study systems were above the provisional escapement targets. This observation is consistent with the conclusions based on the current, qualitative, stock assessment methodology for 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 were within the range that is typically applied for WCVI systems (i.e. 15 to 35 days).

Crews assess their observer efficiency based on a qualitative assessment of survey conditions. Crews tend to over-estimate their observer efficiency, particularly when survey conditions deteriorate, but self-assessments of OE near 100% are not unwarranted when conditions are good (Figure 5).

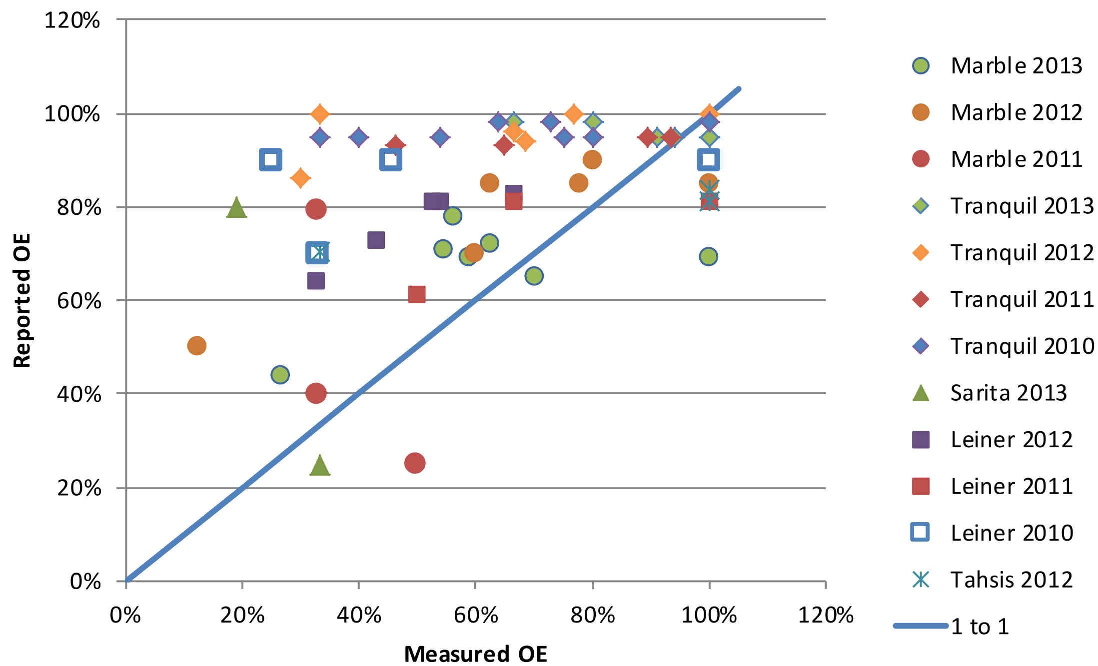

Figure 5 Measured versus reported OE for swim surveys paired with telemetry surveys.

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 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) may 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; or iii) mark-resight, all the methods produced estimates within the similar range, including the 'quantitative' AUC estimate using directly measured OE and SL. In 2013 the results of the multiple estimation methods were generally comparable, except for Sarita, where large numbers of coho and chum and gaps between surveys caused problems.

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, the results of the 2013 study show that the qualitative AUC estimate is a reasonable number on which to base management decisions.

High rainfall during the peak river migration is typical of the study area and, along with isolation, is one of the logistical challenges 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 and predation 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 radio telemetry 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 a 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 work conducted in 2010-2013 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

Several people were instrumental in the completion of this work including Brenda Wright; Andrew Pereboom; Pieter Van Will; Al Eden and Associates; Doug Palfrey and the Tofino Enhancement Society; Stefan Ochman of the Huu-ay-aht Fisheries Department; and the Northern Vancouver Island Salmon Enhancement Association. This study builds on a previous studies completed by Nicole Trouton, Seaton Taylor and Chuck Parken in 2007 and Cora Moret, Lyanne Burgoyne, Marc Labelle, Doug Palfrey, Al Eden, Mike Wright and Associates and Roger Dunlop in 2010.

7.0 TABLES AND FIGURES

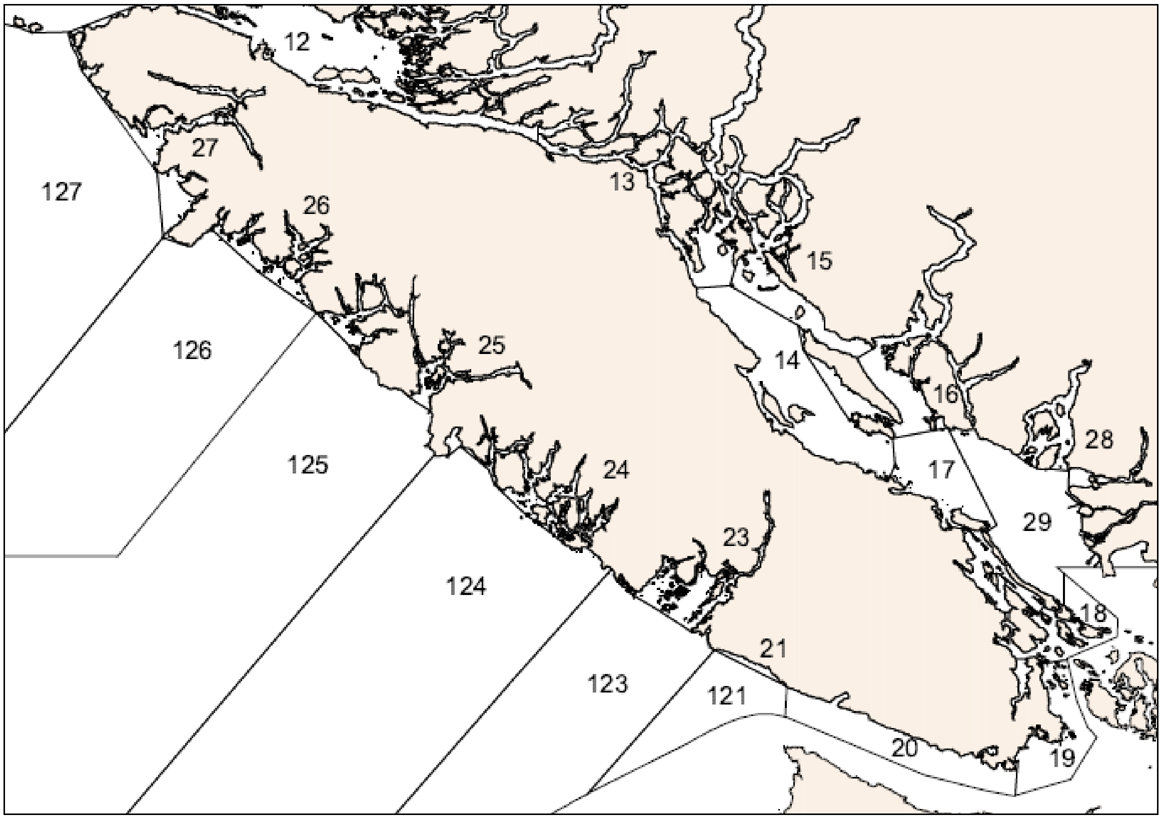

Figure 6. Vancouver Island and DFO Statistical Areas.

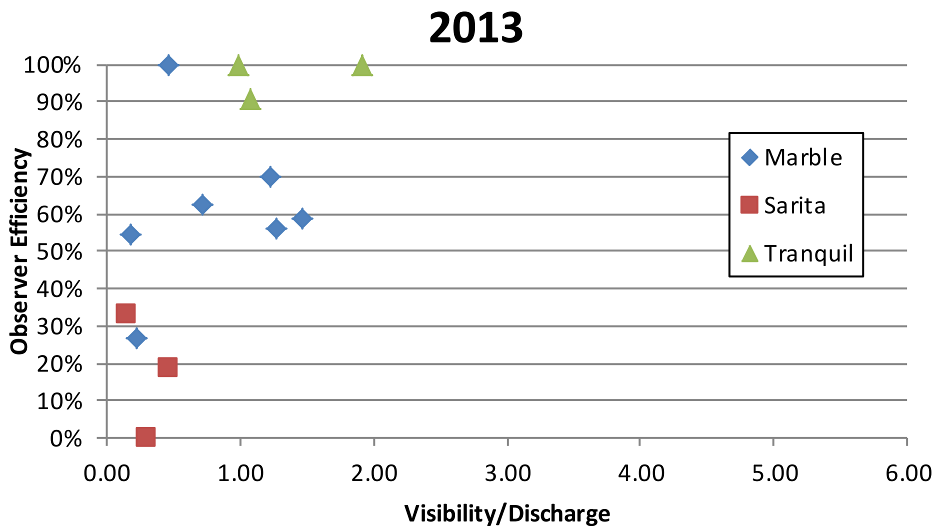

Figure 7 2013 Relationship between river conditions and observer efficiency of Chinook for the Marble, Tranquil, and Sarita Rivers. Extremely low flow conditions in the Tranquil in late-October (HV/Q greater than 10) are not included in this figure.

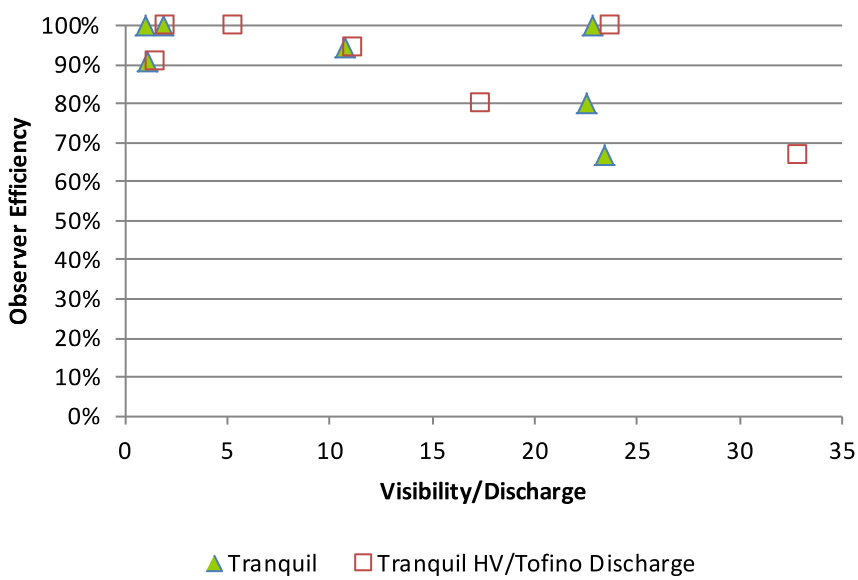

Figure 8 Complete Tranquil 2013 results, including extremely low flow conditions. Tranquil results are compared to results based on using discharge estimates from the nearby Tofino Creek.

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

Statistical Area	System	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	*Average*
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	Location
Marble	8/30/2013	1	**Varney Bay (Troll)**
	9/4/2013	1	**Varney Bay (Troll)**
	9/5/2013	1	**Varney Bay (Troll)**
	9/6/2013	1	**Varney Bay (Troll)**
	9/10/2013	1	**Varney Bay (Troll)**
	9/26/2013	3	**River Section 0-1**
	10/21/2013	6	**River Section 2-3**
	10/23/2013	4	**River Sections 1-2 to 4-5**
	10/29/2013	2	**River Section 3-4**
	10/31/2013	6	**River Sections 6-7 to 10-11**
	Total	**26**	
Sarita	9/17/2013	22	**River below section 0-1**
	9/18/2013	30	**River below section 0-1**
	9/19/2013	34	**River below section 0-1**
	9/27/2013	11	**River below section 0-1**
	Total	**97**	
		Radio Tags	**Spaghetti Tags**
Tranquil	9/26/2013	15	15
	10/16/2013	12	12
	Total	**27**	**27**

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

System	Survey Date	Total Adult CN	Unmarked	Marked
Marble	30-Aug-13	8	8	0
	3-Sep-13	24	24	0
	6-Sep-13	25	25	0
	10-Sep-13	28	28	0
	16-Sep-13	95	95	0
	20-Sep-13	26	26	0
	18-Oct-13	827	825	2
	22-Oct-13	966	961	5
	25-Oct-13	1360	1354	6
	29-Oct-13	976	969	7
	5-Nov-13	1100	1090	10
	7-Nov-13	1140	1131	9
	12-Nov-13	470	466	4
	26-Nov-13	267	267	0
	29-Nov-13	224	224	0
Total	15			

System	Survey Date	Total Adult CN	Unmarked	Marked
Sarita	5-Sep-13	61	61	0
	26-Sep-13	704	697	7
	4-Oct-13	291	283	8
	9-Oct-13	522	522	0
	17-Oct-13	0	0	0
	29-Oct-13	0	0	0
	6-Nov-13	0	0	0
Total	7			

System	Survey Date	Total Adult CN	Unmarked	Marked
Tranquil	15-Sep-13	18	18	0
	27-Sep-13	222	194	28
	3-Oct-13	356	336	20
	9-Oct-13	432	411	21
	18-Oct-13	348	318	30
	21-Oct-13	310	286	24
	24-Oct-13	286	262	24
	28-Oct-13	172	158	14
	31-Oct-13	112	107	5
	4-Nov-13	68	68	1
	10-Nov-13	20	20	1
	15-Nov-13	3	3	0
Total	12			

Table 5. Telemetry survey dates Marble, Tranquil, and Sarita Rivers.

System	Survey Date	System	Survey Date
Marble	30-Aug-13	Tranquil	27-Sep-13
	3-Sep-13		3-Oct-13
	6-Sep-13		9-Oct-13
	10-Sep-13		18-Oct-13
	16-Sep-13		21-Oct-13
	20-Sep-13		24-Oct-13
	18-Oct-13		28-Oct-13
	22-Oct-13		31-Oct-13
	25-Oct-13		4-Nov-13
	29-Oct-13		10-Nov-13
	1-Nov-13	Tranquil Total	10
	5-Nov-13		
	8-Nov-13	Sarita	26-Sep-13
	12-Nov-13		1-Oct-13
	15-Nov-13		4-Oct-13
	19-Nov-13		9-Oct-13
	22-Nov-13		17-Oct-13
	26-Nov-13		28-Oct-13
Marble Total	18		6-Nov-13
		Sarita Total	7

Table 6 Length and age data collected from study populations.

	Female POH (mm)			Age Dist					Male POH (mm)			Age Dist				
	Mean	SD	*n*	**3-1**	**4-1**	**4-2**	**5-1**	*n*	Mean	SD	*n*	**3-1**	**4-1**	**4-2**	**5-1**	*n*
Tranquil	692	49	25	38%	38%	0%	25%	16	654	71	28	30%	61%	0%	9%	23
Sarita-tags	789	34	22						772	60	68					
Sarita	680	64	121	14%	47%	3%	36%	102	613	64	156	57%	31%	2%	11%	131

	Age Dist					
	2-1	**3-1**	**4-1**	**4-2**	**5-1**	*n*
Marble			52%		48%	21

Table 7 Mark status and hatchery of origin, if applicable, for samples collected from the Sarita River.

Hatchery of Origin	*n*	%
Sarita	176	64.2%
Nitinat	37	13.5%
Conuma	1	0.4%
Unmarked	60	21.9%
	274	

Table 8. Survey life estimates for Marble, Tranquil, and Sarita 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. Estimates based on swim surveys are not expanded for observer efficiency and are not included in the weighted average SL estimates.

System	Survey Life Estimates						
	Survey Type	**Estimate Type**	**Estimate**	**St. Dev**	***n***	**St. Error**	**95% CI**
Marble	Swim	AUC-Tag	12		22		
	Telemetry	AUC-Tag	23		22		
		AUC-Tag, Oct 1 = entry	42		22		
		Obs: Varney Bay Tag	32		1		
		Obs: In-river September Tag	59		1		
		Obs: Oct tags, if tagged=entry	25	11	19	2.5	4.9
		Obs: Oct tags, if Oct 15=entry	35	9	19	2.1	4.0
		Obs: Oct tags, if Oct 1=entry	47	8	19	1.8	3.6
		Average	34.5				
Tranquil	Swim	AUC-Tag Group 1	14.7		30		
	Swim	AUC-Tag Group 2	10.4		24		
	Telemetry*	AUC-Tag Group 1	19.1		15		
		AUC-Tag Group 2	12.6		12		
	Telemetry**	Observed Group 1	21.6	7.8	12	2.3	4.4
		Observed Group 2	13.4	3.4	12	1.0	1.9
		Observed Combined	17.5	3.4	24	0.7	1.4
		Average	17.0				
Sarita	Swim	AUC-Tag	6		82		
	Telemetry*	AUC-Tag Group 1	15.6		74		
		AUC-Tag Group 2	8.5		8		
	Telemetry**	Observed	17.2	8.9	82	1.0	1.9
		Average	16.1				

** Assuming subsequent observation of live tag indicated the fish was alive during all previous surveys*

*** Assuming death occurred halfway between the last "live" obs and the first "dead" observation, and fish not seen again died just prior to the next full telemetry survey*

Table 9. 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	8/30/2013	8	0	0	
	9/3/2013	24	0	0	
	9/6/2013	25	0	0	
	9/10/2013	28	0	0	
	9/16/2013	95	0	0	
	9/20/2013	26	0	0	
	10/18/2013	827	2	2	100%
	10/22/2013	966	8	5	63%
	10/25/2013	1360	11	6	55%
	10/29/2013	976	10	7	70%
	11/5/2013	1100	17	10	59%
	11/7/2013	1140	16	9	56%
	11/12/2013	470	15	4	27%
	11/26/2013	267	2	0	0%
	11/29/2013	224	0	0	
					62%
Tranquil	9/15/2013	18	0	0	
	9/27/2013	222	14	14	100%
	10/3/2013	356	11	10	91%
	10/9/2013	432	9	9	100%
	10/18/2013	348	17	16	94%
	10/21/2013	310	15	12	80%
	10/24/2013	286	12	12	100%
	10/28/2013	172	9	6	67%
	10/31/2013	112	3	0	0%
	11/4/2013	68	0	0	
	11/10/2013	20	0	0	
	11/15/2013	3	0	0	
					87%
Sarita	9/5/2013	61	0	0	
	9/26/2013	704	37	7	19%
	10/4/2013	291	24	8	33%
	10/9/2013	522	21	0	0%
	10/17/2013	0	0	0	
	10/29/2013	0	0	0	
	11/6/2013	0	0	0	
					15%

Table 10. Environmental data collected by spawner survey crews.

System	Date	Observer Efficiency	Horizontal Visibilty [HV] (m)	River Height (m)	Field discharge [Q] (m^3/s)	EnvCan Discharge [ECQ] (m^3/s)	HV/Q	HV/ECQ
Marble								
	16-Sep-13		15	0.083	4.40		3.41	
	20-Sep-13		10.6	0.133	5.48		1.93	
	18-Oct-13	100%	9.6	0.42	20.54		0.47	
	22-Oct-13	63%	9.9	0.305	13.84		0.72	
	25-Oct-13	55%	10.1	0.605	52.89		0.19	
	29-Oct-13	70%	10.1	0.205	8.23		1.23	
	5-Nov-13	59%	10.9	0.19	7.41		1.47	
	7-Nov-13	56%	10.6	0.215	8.35		1.27	
	12-Nov-13	27%	9.1	0.54	38.88		0.23	
	26-Nov-13		0	0	20.04		0.00	
Tranquil								
	15-Sep-13		12	0.57	0.44	0.14	27.40	83.92
	27-Sep-13	100%	9	0.71	4.69	1.70	1.92	5.30
	3-Oct-13	91%	8	0.8	7.38	5.24	1.08	1.53
	9-Oct-13	100%	8	0.77	8.08	4.00	0.99	2.00
	18-Oct-13	94%	9	0.6	0.84	0.81	10.76	11.14
	21-Oct-13	80%	10	0.58	0.44	0.58	22.57	17.33
	24-Oct-13	100%	10	0.57	0.44	0.42	22.83	23.70
	28-Oct-13	67%	10	0.55	0.43	0.30	23.36	32.89
	31-Oct-13	0%	10	0.555	0.86	1.60	11.61	6.24
	4-Nov-13		8	0.675	2.45	1.58	3.26	5.07
	10-Nov-13		7	0.79	8.23	5.19	0.85	1.35
	15-Nov-13		7	0.78	8.15	3.89	0.86	1.80
Sarita								
	5-Sep-13					3.45		0.00
	26-Sep-13	19%	4			8.55		0.47
	4-Oct-13	33%	2			13.45		0.15
	9-Oct-13	0%	4			13.44		0.30
	17-Oct-13		4			3.35		1.19
	29-Oct-13		4			1.39		2.87
	6-Nov-13		2			5.15		0.39

Table 11. 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						
First 0	8/25/2013			0		0
	8/30/2013	8	100%	8		8
	9/3/2013	24	89%	27		27
	9/6/2013	25	66%	38		38
	9/10/2013	28	57%	49		49
	9/16/2013	95	60%	158		158
	10/18/2013	827	69%	1199	100%	827
	10/22/2013	966	72%	1342	63%	1546
	10/25/2013	1360	71%	1915	55%	2493
	10/29/2013	976	65%	1502	70%	1394
	11/5/2013	1100	69%	1594	59%	1870
	11/7/2013	1140	78%	1462	56%	2027
	11/12/2013	470	44%	N/A*	27%	1763
	11/26/2013	267	92%	290		290
	11/29/2013	224	91%	246		246
Last 0	12/15/2013			0		0
Total	15					
Max Observed		1360		1915		2493
Survey Life				35		34.5
AUC Estimate				2080		2240

* Poor survey conditions Nov 12, survey dropped from Qualitative AUC Estimate

System	Survey Date	Raw Total Adult CN	Qualitative Observer Efficiency	Qualitative Expanded Adult CN	Quantitative Observer Efficiency	Quantitative Expanded Adult CN
Tranquil						
First 0	9/1/2013			0		0
	9/15/2013	18	98%	18		18
	9/27/2013	222	95%	234	100%	222
	10/3/2013	356	95%	375	91%	392
	10/9/2013	432	95%	455	100%	432
	10/18/2013	348	95%	366	94%	370
	10/21/2013	310	98%	316	80%	388
	10/24/2013	286	98%	292	100%	286
	10/28/2013	172	98%	176	67%	258
	10/31/2013	112	98%	114		114
	11/4/2013	68	95%	72		72
	11/10/2013	20	95%	21		21
	11/15/2013	3	95%	3		3
Last 0	11/20/2013			0		0
Total	12					
Max Observed		432		455		432
Survey Life				20		17
AUC Estimate				684		824

System	Survey Date	Raw	Qualitative AUC		Quantitative AUC	
		Total Adult CN	Observer Efficiency	Expanded Adult CN	Observer Efficiency	Expanded Adult CN
Sarita						
First 0	9/1/2013			0		
	9/5/2013	61	50%	122		122
	9/26/2013	704	80%	880	19%	3721
	10/4/2013	291	25%	1164	33%	873
	10/9/2013	522	50%	1044	0%	1044
	10/17/2013	0	100%	0		0
	10/29/2013	0	100%	0		0
	11/6/2013	0	100%	0		0
Last 0	12/1/2013			0		
Total	7					
Max Observed		704		1164		3721
Survey Life				20		16.1
AUC Estimate				1432		4220

Table 12. Comparison of escapement estimates for study systems generated through different analytical models.

System	No. Surveys	Max. Observed	AUC (Qual)	AUC (Quan)	ML - Unimodal	ML - Bimodal	Mark-Resight	Mark-Resight 95% CI
Marble	14	1360	2080	2240		2568	1901	(1669-2308)
Tranquil	12	432	684	824	836		493	(475-526)
Sarita	7	704	1432	4220		1017	4766	(4388-5483)

Table 13. Comparison of maximum estimated escapement (2013) and qualitative AUC estimate.

System	2013 Max Estimated Escapement	2013 Qualitative AUC Escapement	Ratio (Qual AUC: Max Est.)
Marble	2,568	2,080	0.81
Tranquil	836	684	0.82
Sarita	4,766	1,432	0.30

Table 14. Comparison of provisional S_{MSY} Chinook escapement targets for study systems with maximum estimated escapement in 2013.

System	Optimal CN Escapement (Smsy)	80% confidence interval	2013 Max Estimated Escapement	Ratio (Observed: Optimal)
Marble	1191	990-1434	2568	2.2
Tranquil	415	331-521	836	2.0
Sarita	643	522-791	4766	7.4

8.0 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 2013.
- 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 the 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 have provided increased confidence in the current WCVI chinook escapement estimation.
- 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)

9.0 APPENDIX 2 TELEMETRY AND MARK-RESIGHT DETAILS

Table 15 Tranquil telemetry detailed results

Tranquil Tag Number	27-Sep-13	3-Oct-13	9-Oct-13	18-Oct-13	21-Oct-13	24-Oct-13	28-Oct-13	31-Oct-13	4-Nov-13	10-Nov-13
67	1	1	.	.	.	.	.	.	.	.
68	1	.	.	.	.	.	.	.	.	.
69	1	1	1	1	1	1	1	.	.	.
70	1	1	.	.	.	.	.	.	.	.
71	1	1	1	.	.	.	.	.	.	.
72	1	1	1	1	.	.	.	.	.	.
73	1	.	.	.	.	.	.	.	.	.
74	1	1	1	1	.	1	.	.	.	.
75	1	1	1	.	.	.	.	.	.	.
76	1	1	1	.	.	.	.	.	.	.
77	1	.	.	.	.	.	.	.	.	.
78	1	1	1	1	.	1	0	.	.	.
79	1	1	1	.	.	.	.	.	.	.
80	1	0	0	0	1	.	.	.	.	.
81	.	0	0	0	1	0	.	.	.	.
	1	1	.	.	.	.	.	.	.	.
	1	.	.	.	.	.	.	.	.	.
	1	1	1	1	1	1	1	.	.	.
	1	1	.	.	.	.	.	.	.	.
	1	1	1	.	.	.	.	.	.	.
	1	1	1	1	.	.	.	.	.	.
	1	.	.	.	.	.	.	.	.	.
	1	1	1	1	1	1	.	.	.	.
	1	1	1	.	.	.	.	.	.	.
	1	1	1	.	.	.	.	.	.	.
	1	.	.	.	.	.	.	.	.	.
	1	1	1	1	1	1	1	.	.	.
	1	1	1	.	.	.	.	.	.	.
	1	0	1	0	1	.	.	.	.	.
	.	0	0	0	1	1	1	.	.	.
82	.	.	.	1	1	1	1	.	.	.
83	.	.	.	1	1	1	1	1	.	.
84	.	.	.	1	1	1	1	1	.	.
85	.	.	.	1	1	1	1	.	.	.
86	.	.	.	1	1	1	0	.	.	.
87	.	.	.	1	1	1	0	.	.	.
88	.	.	.	1	1	1	.	.	.	.
89	.	.	.	1	1	1	.	.	.	.
90	.	.	.	1	0	1	0	.	.	.
91	.	.	.	1	0	.	.	.	.	.
92	.	.	.	1	0	.	.	.	.	.
93	.	.	.	1	0	.	0	.	.	.
	.	.	.	1	1	1	1	1	1	1
	.	.	.	1	1	1	1	1	.	.
	.	.	.	1	1	1	1	1	.	.
	.	.	.	1	1	1	1	1	.	.
	.	.	.	1	1	1	1	1	.	.
	.	.	.	1	1	1	0	.	.	.
	.	.	.	1	1	1	.	.	.	.
	.	.	.	1	0	1	.	.	.	.
	.	.	.	1	0	0	0	.	.	.
	.	.	.	1	0	.	.	.	.	.
	.	.	.	0	0	.	.	.	.	.
	.	.	.	0	0	.	0	.	.	.
m	28	20	17	20	16	16	8	2	0	0
n	28	24	20	24	20	17	13	2	0	0
T	30	26	26	36	34	30	21	7	1	1
Tu	194	336	411	318	287	262	159	107	68	20

The colour of the dates indicate the primary occasions used in the Mark-Resight analysis, green indicates the tagged fish was alive during the survey, orange indicates tagged fish was dead, a green “1” indicates the fish was in the survey area and seen by the swimmers, a green “0” indicates a fish was in the survey area but was not seen by the swimmers, “.” indicates the

```
/*Tranquil 2013-superpop = tags that were applied,*/
/*accounting for deaths, 2 primary with */
/*3 and 3 secondary, intervals (0,0,1,0,0,) */
11.... 1;
1..... 1;
111111 1;
11.... 1;
111... 1;
1111.. 1;
1..... 1;
1111.1 1;
111... 1;
111... 1;
1..... 1;
1111.1 1;
111... 1;
10001. 1;
.00010 1;
11.... 1;
1..... 1;
111111 1;
11.... 1;
111... 1;
1111.. 1;
1..... 1;
111111 1;
111... 1;
111... 1;
1..... 1;
111111 1;
111... 1;
10101. 1;
.00011 1;
...111 1;
...111 1;
...111 1;
...111 1;
...111 1;
...111 1;
...111 1;
...111 1;
...101 1;
...10. 1;
...10. 1;
...10. 1;
...111 1;
...111 1;
...111 1;
...111 1;
...111 1;
...111 1;
...111 1;
...101 1;
...100 1;
...10. 1;
...00. 1;
...00. 1;

Marked Superpopulation Group=1;
30 26 26 36 34 30  ;

Unmarked Seen Goup=1;
194 336 411 318 287 262  ;

/* End Input File */
```

tagged fish was not available to be resighted due to death, emigration, or the tag had not yet been applied and released. The yellow "." indicates tags that were not detected by subsequent surveys either alive or dead. Un-numbered tags are non-radio, assumed to follow the pattern of availability exhibited by the radio tags except where visual counts were inconsistent.

MARK input file at left used to generate estimate based on Sep 27-Oct 9 and Oct 18-24 surveys.

	Models Evaluated					AICc
a	p(n*t),	sig(n)=0,	Nbar(*),	a(n*t)	Nstar(*)	254
b	p(n*t),	sig(n)=0,	Nbar(n),	a(n*t)	Nstar(n)	255
c	p(n*t),	sig(n)=0,	Nbar(*),	a(n*t)=0	Nstar(*)	257
d	p(n*t),	sig(n)=0,	Nbar(n),	a(n*t)=0	Nstar(n)	258
e	p(n),	sig(n)=0,	Nbar(n),	a(n*t)	Nstar(n)	400
f	p(*),	sig(n)=0,	Nbar(n),	a(n*t)	Nstar(n)	416
g	p(*),	sig(n)=0,	Nbar(*),	a(n*t)	Nstar(*)	423
h	p(n),	sig(n)=0,	Nbar(n),	a(n*t)=0	Nstar(n)	441
i	p(*),	sig(n)=0,	Nbar(*),	a(n*t)=0	Nstar(*)	460
j	p(*),	sig(n)=0,	Nbar(n),	a(n*t)=0	Nstar(n)	461

Estimates of average abundance in survey area during primary interval (Nbar) and Super-population using the survey area sometime during the primary interval (N*):

	Nbar(1)	Nbar(2)	N*(1)	N*(2)
a	449 (436-497)		493 (475-526)	
b	434 (431-632)	378 (360-454)	504 (469-582)	399 (384-461)
c	462 (447-492)		505 (489-532)	
d	450 (437-493)	395 (373-442)	512 (483-571)	421 (407-451)

Table 16 Marble telemetry detailed results

Marble Tag Number	Sep21-Oct17	18-Oct-13	22-Oct-13	25-Oct-13	29-Oct-13	5-Nov-13	8-Nov-13	12-Nov-13	26-Nov-13	29-Nov-13
56		1	1	1	.	.	.	.	.	.
53	High Water Period - no swims	1	1	1	1	1	1	1	.	.
51		.	1	0	1	.	.	.	.	.
52		.	1	1	1	1	1	0	.	.
50		.	1	1	1	1	1	0	.	.
49		.	0	0	1	1	1	0	0	.
48		.	0	1	1	0	1	.	.	.
47		.	0	1	0	1	0	0	.	.
46		.	.	0	0	0	0	0	.	.
45		.	.	0	0	0	0	0	.	.
43		.	.	0	1	1	0	0	.	.
42		.	.	.	.	0	0	0	.	.
41			.	.	.	1	1	0	.	.
40			.	.	.	1	0	1	0	.
39		.	.	.	.	1	1	0	.	.
38		.	.	.	.	1	.	.	.	.
37		.	.	.	.	1	0	1	.	.
36		.	.	.	.	0	1	0	.	.
35		.	.	.	.	1	1	1	.	.
	m	2	5	6	7	12	9	4	0	0
	n	2	8	11	10	17	16	15	2	0
	T	2	8	11	10	17	16	15	2	0
	Tu	825	961	1354	969	1090	1131	466	267	224

The colour of the dates indicate the primary occasions used in the Mark-Resight analysis, green indicates the tagged fish was alive during the survey, orange indicates tagged fish was dead, a green "1" indicates the fish was in the survey area and seen by the swimmers, a green "0" indicates a fish was in the survey area but was not seen by the swimmers, "." indicates the tagged fish was not available to be resighted either due to death or the tag had not yet been applied and released. Unlike the Tranquil, all tags that were not available to swimmers had died rather than leaving the study area, so the number of tags available (n) equal the super-population of tags (T).

MARK input file used to generate estimate based on Oct 22-29 and Nov 5-12 surveys:

```
Marble 2013
/*Marble 2013-superpop = tags alive */
/*2 primary with 3 and 3 secondary*/
/* intervals (0,0,1,0,0) */
11.... 1;
111111 1;
101... 1;
111110 1;
111110 1;
001110 1;
01101. 1;
010100 1;
.00000 1;
.00000 1;
.01100 1;
...000 1;
...110 1;
...101 1;
...110 1;
...1.. 1;
...101 1;
...010 1;
...111 1;

Marked Superpopulation Group=1;
8 11 10 17 16 15;

Unmarked Seen Goup=1;
961 1354 969 1090 1131 466;

/* End Input File */
```

	Models Evaluated					AICc
a	p(n*t),	sig(n)=0,	Nbar(.),	a(t*n)=0	Nstar(.)	167
b	p(n*t),	sig(n)=0,	Nbar(n),	a(t*n)=0	Nstar(n)	172
c	p(n*t),	sig(n)=0,	Nbar(.),	a(t*n)	Nstar(.)	178
d	p(n*t),	sig(n)=0,	Nbar(n),	a(t*n)	Nstar(n)	190
e	p(n),	sig(n)=0,	Nbar(n),	a(t*n)=0	Nstar(n)	697
f	p(.),	sig(n)=0,	Nbar(n),	a(t*n)	Nstar(n)	699
g	p(.),	sig(n)=0,	Nbar(n),	a(t*n)=0	Nstar(n)	699
h	p(n),	sig(n)=0,	Nbar(n),	a(t*n)	Nstar(n)	705

Estimates of average abundance in survey area during primary interval (Nbar) and Super-population using the survey area sometime during the primary interval (N*):

	Nbar(1)	Nbar(2)	N*(1)	N*(2)
a	1901 (1669-2308)		1901	
b	1851 (1559-2583)	1714 (1429-2287)	1851	1714
c	1861 (1593-2446)		1864	
d	2697 (1692-6791)	1578 (1358-2030)	2722 (2699-2995)	1581

Single values indicate the 95% CI could not be estimated because some of the parameters for the last sampling interval are confounded for some models.

Table 17 Sarita telemetry detailed results

```
/*Sarita 2013-superpop = tags applied */
/*accounting for deaths, 2 occasions*/
/* interval (0) */
0. 1;          0. 1;
1. 1;          0. 1;
0. 1;          .. 1;
.. 1;          00 1;
.. 1;          00 1;
00 1;          0. 1;
11 1;          0. 1;
00 1;          00 1;
0. 1;          0. 1;
11 1;          00 1;
.. 1;          01 1;
00 1;          0. 1;
.. 1;          00 1;
00 1;          01 1;
00 1;          0. 1;
1. 1;          0. 1;
0. 1;          0. 1;
0. 1;          .1 1;
00 1;          0. 1;
0. 1;          0. 1;
0. 1;          01 1;
0. 1;          0. 1;
0. 1;          01 1;
10 1;          01 1;
0. 1;          0. 1;
0. 1;          00 1;
1. 1;          00 1;
1. 1;          00 1;
0. 1;          00 1;
0. 1;          0. 1;
.. 1;          00 1;
00 1;          00 1;
.. 1;          .0 1;
00 1;          .0 1;
00 1;          .. 1;
0. 1;          .0 1;
0. 1;          .0 1;
.0 1;          .0 1;
0. 1;          00 1;
.0 1;          00 1;
0. 1;          0. 1;
Marked Superpopulation Group=1;
68 57;
Unmarked Seen Goup=1;
697 283;
/* End Input File */
```

The Sarita analysis was complicated by gaps in the mobile telemetry surveys as well as some telemetry surveys being incomplete. However the fixed telemetry receivers paired with the mobile telemetry did provide some information about the stream lives of the tagged fish.

Because tags were observed in only two surveys, the mark-resight estimate was based on only those two surveys.

	Models Evaluated					AICc
a	p(t)	sig(n)=0	Nbar(*)	a(t)=0	Nstar(*)	147
b	p(t)	sig(n)=0	Nbar(*)	a(t)	Nstar(*)	148
c	p(*)	sig(n)=0	Nbar(*)	a(t)	Nstar(*)	325
d	p(*)	sig(n)=0	Nbar(*)	a(t)=0	Nstar(*)	326

Estimates of average abundance in survey area during primary interval (Nbar) and Super-population using the survey area sometime during the primary interval (N*):

	Nbar(*)	Nstar(*)
a	3966 (2598-6354)	4766 (4388-5483)
b	3817	4567

Legend

Tag	Tag applied
M	Tag detected alive near the Mine Pool (Bottom of Section 0)
T	Tag detected alive near the Trestle (Section 9)
S	Tag detected alive near the South Sarita tributary (Section 4)
M	Tag detected dead by the Mine Pool reciever
5	Tag detected alive be the mobile telemetry crew in section 5
4	Tag detected dead by the mobile telemetry crew in section 4
1	Tag confirmed in survey area by telemetry crew and observed by swim crew
0	Tag confirmed in survey area by telemetry crew and not observed by swim crew
.	Tag confirmed dead by mobile telemetry crew
	Tag alive based on subsequent detection of live tag
	Tag dead based on previous detection of death
	Tag not detected in any subsequent telemetry survey
	Period between last "alive" detection and first "dead" detection

Sarita	September														October														Nov
Tag Number	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	13	17	29	6-Nov
67	Tag				M			T	T	0							T												
68	Tag														6			1									.	.	.
69	Tag										T	T						0									.		.
70	Tag												S		5												.	.	.
71	Tag								T		S	S	T	T														.	
72	Tag								T	0		T			T	T		0									.	.	.
73	Tag			T	T	T			T	0		T			6												.	.	.
74	Tag									1	S	S															.		.
75	Tag							S	S	0	S	S	S	S															
77	Tag				T					0	T																		.
78	Tag														T	T													.
79	Tag																	.											.
80	Tag				T				T	0	T	T			5												.	.	.
81	Tag															T		0	T			T	0	S		S			
82	Tag					T	S			1					4			.									.		.
83	Tag							T					T	T	3														
87	Tag							S		0	T	S			3			.									.		.
96	Tag											T						0	T										
97	Tag								T				T		T			0					.						.
98	Tag					T		T										.									.	.	.
99	Tag			T	T					0								.									.		.
35	.	Tag								0					2			.									.		.
36	.	Tag								1					3			.									.		.
37	.	Tag	M							1			T		2			.											.
38	.	Tag								0		M																	
39	.	Tag													2			.				M	.						
41	.	Tag								.					M														
43	.	Tag	M	M									S	S	S			0			M	T							.
44	.	Tag	M							0								.											.
46	.	Tag	M		M					.					M														
48	.	Tag																0									.		.
49	.	Tag																									.		.
50	.	Tag			M	M						M	M																
53	.	Tag			M					0								.											
54	.	Tag	M						T	0								1					.						.
55	.	Tag	M									S	S		6			1									.		.
57	.	Tag	M							0					0			.						M	M	M	.		
58	.	Tag												M	1													.	.
59	.	Tag	M									M						1									.		.
60	.	Tag							S	0	M	S																	
61	.	Tag								0																			
62	.	Tag					T		T	1																			
64	.	Tag									M		M		0														
65	.	Tag													0												.		

Sarita	September														October														Nov
Tag Number	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**13**	**17**	**29**	**6-Nov**
66	.	Tag	M										M					1									0		.
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11	.	.	Tag			M				1	S	S		S	2			0					.	M	M	M	.	.	.
12	.	.	Tag							0	M	M	M	S	6			0									.		.
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18	.	.	Tag							.					M			.									.		.
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31	.	.	Tag							0																			
32	.	.	Tag							0			M																
33	.	.	Tag		M					1						T	T	0	T	S	S						.		.
34	.	.	Tag			T		T	T	0	T	S	T																
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90	.	.	.	.	.	.	.	.	.	.	Tag	T		S	8	T	T	1	T										
91	.	.	.	.	.	.	.	.	.	.	Tag	T	T	S	8			0										.	.
93	.	.	.	.	.	.	.	.	.	.	Tag	S			8	S		0											.
94	.	.	.	.	.	.	.	.	.	.	Tag	S			4	S													.
95	.	.	.	.	.	.	.	.	.	.	Tag	S						0									.		.