Estimate of Chinook salmon (*Oncorhynchus tsawytscha*) escapement to the Burman River, 2006.

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Abstract

A Chinook salmon escapement estimation project was undertaken on the Burman River on the west coast of Vancouver Island to begin to calibrate the area-under-the curve method normally employed by Fisheries & Oceans Canada using increased swim frequency and mark- recapture techniques. One hundred and seven Chinook were tagged with visual tags and ten swim surveys and carcass recovery surveys were conducted between September 15 and November 2nd, 2006. The increased swim frequency over the normal escapement survey period resulted in a 23.7% increase in the escapement estimate. Failure to apply radio tags, due to late arrival of the tags, resulted in problems with the mark recapture estimates and estimation of survey life. This is believed due to unusually high emigration of tagged fish to the adjacent Gold River as observed in 2005. Carcass surveys results did not point to physical tag loss as a significant factor. The resulting AUC estimate of escapement based on a survey life of 5.2 days was 636 Chinook. This was similar to the Peterson mark-recapture estimate of 649 Chinook when 40% tag loss was assumed. The 95% lower confidence limit of 640 Chinook from a joint hypergeometric maximum likelihood estimate, with an assumed tag loss rate of 50%, is very near the AUC estimate and contains the Petersen estimate. The 2006 program demonstrated there was significant tag loss, likely from the movement of tagged fish out of the river,that must be addressed for future mark recapture programs in the Burman to be effective. An appended Bayesian assessment of the 2006 AUC estimate supports this conclusion. Recommendations to improve the program are included.

INTRODUCTION

Escapement goals are required to evaluate fishing impacts on Chinook salmon *(Onchorynchus tshawytscha)* under international and Canadian jurisdiction. This project was intended to begin the process of calibrating the escapement of Chinook salmon to the Burman River to allow the fitting of a habitat-based escapement goal. The Burman River is one of seven West Coast Vancouver Island (WCVI) Chinook indicator streams that represent an index of escapement to the main WCVI natural fall Chinook salmon spawning streams.

Parken et al. (2006) evaluated alternate habitat-based models to predict spawner habitat capacity at replacement (S_{REP}) and to provide for maximum sustained yield (S_{MSY}) for data limited Chinook stocks. The authors explored potential models by meta-analysis of stock-recruitment relationships from 25 populations between Central Alaska and northern Oregon. Predictive equations for stream-type and ocean-type life histories were developed. An allometric model based on watershed area was recommended as it explained more variation is spawning capacity than any other widely available measure. Parken et al. (2006) predicted 1500 spawners at S_{MSY} and 4500 spawners at S_{REP} for the Burman River ocean-type fall Chinook salmon. Spawning escapements of known accuracy are required to apply the Parken et al. (2006) model.

Accuracies of the escapement time series for the Burman River, and other WCVI Chinook streams, are unknown. Since 1995 weekly snorkel surveys have been employed to develop area-under-the-curve (AUC) estimates of escapement. The WCVI spawner abundance indices, including the Burman River, are of low to moderate quality. The indices are derived from an area-under-the-curve methodology based on usually five swim survey counts of live fish. The survey life values applied are poorly documented. Generally, swim survey data including the condition of fish, abundance of new fish, and rate of die off are recorded and used to estimate a minimum and maximum value for the index survey life on an annual basis. The average of the two values is then used as the annual survey life estimate. Observer efficiencies are assumed to be 100% accurate but are not measured.

This program was intended to begin to examine the relationship between the annual AUC estimate and total escapement to permit application of the escapement goal for the Burman River.

The objectives of this program were to estimate:

- Chinook salmon escapement using the AUC method normally employed on the Burman River.
- Chinook salmon escapement using the AUC method with an increased swim frequency.
- the survey life of Chinook salmon in the Burman River.
- Chinook salmon escapement using mark-recapture methods.
- Compare the estimates of escapement derived from the AUC and the mark-recapture methods.
- Identify problems with the methods that might be addressed in the future

<u>Study Area.</u>

The Burman River is located on the central west coast of the Vancouver Island, British Columbia. The river originates in the Vancouver Island Range in Strathcona Provincial Park. The river is a 5th order stream that drains 244.16 km^2. Glaciers occur on six surrounding mountains. Elevations range from 2195 m to 0 m ASL. Two lakes > 1 km^2 occur above 990 m elevation. Eighteen smaller lakes occur at elevations generally above 900 m. There are no barriers on the 5th order stream section. The watershed occurs in the Coastal Western Hemlock and Mountain Hemlock biogeoclimatic zones. Annual precipitation averages over 2.5 m. The river discharges to Muchalat Inlet in Nootka Sound (Figure 1).

The upper watershed is underlain by the Karmutsen formation composed of basalt, aquagene tuff and breccia. Granite, granodiorite and quartz diorite from the Island Intrusion dominate the underlying geology of the lower river (Muller

1975) where salmon spawning occurs. The riverbed is alluvial downstream of river kilometer (RKM) 13.0. The channel is occasionally confined. A large rock slide from Mount Matchlee at RKM 8.5 is a significant channel feature. Above this point the stream has a slope of 2-2.5 % and little spawning occurs in this reach. Downstream the channel gradient is <1% and suitable for spawning. Gravel dominates the stream substrate except where the channel contacts the valley walls and bedrock or colluvium is exposed.

The length of the main channel is 31.3 km. Anadromous fish access is limited by bedrock cascades at river kilometer (RKM) 13.0 with the exception of summer steelhead (*O. mykiss*) that ascend to RKM 16.3. Chinook, coho (*O. kisutch)*, ocean-type sockeye (*O. nerka*), pink (O. *gorbuscha*) and chum (*O. keta*) salmon generally are observed to RKM 8.5 (FHIIP 1990) but occasionally occur further upstream.

Much of the floodplain and parts of the lower valley slopes were logged during the 1950s and 1960s. The BC Ministry of Forests plans to resume road building and logging in the watershed in 2007.

METHODS

A non-stratified approach to sampling was used as the Burman River has a single channel that is very similar throughout its length in the anadromous section. Access to the starting point for snorkel surveys is by air only.

Tagging

Chinook were caught with a beach seine, placed in a knotless web cradle, and tagged while remaining submerged. All Chinook captured were tagged with Floy FT-4 30.5 cm spaghetti tags (Floy Tag and Manufacturing Inc., 4616 Union Bay Place, NE, Seattle WA, 98015). Spaghetti tags were sewn through the musculature at the rear of the dorsal fin and knotted. Tagged fish were marked with an upper caudal fin lobe punch for later determination of a tag loss rate. Tagged fish were immediately released. Data collection included the date time, tag color and number and sex to minimize handling time prior to release.

We were unable to apply Lotek Wireless model 7A radio tags as the transmitters did not arrive from the manufacturer until mid-October after Chinook were no longer available for tag application in the lower river.

Visual Surveys

Counting section markers were re-established every 500 m along the river channel prior to the first survey to permit consistent location references. Swim counts were performed on ten occasions between September 18, 2006, and November 2, 2006. Poor weather and high water precluded access to the river on one occasion and a failed dry suit required the crew to abort another swim count. As a result fewer than the twelve swim counts originally planned were successfully completed.

The counts occurred over 7.5 kilometers of the river above the tidally influenced lower pools that occur in the lower 1.0 km of the river. Although Chinook can ascend to river kilometer 13.0 rarely do they spawn above river kilometer 8.5, the starting point for swim counts.

Paired observers in dry suits used snorkel equipment to count Chinook in each 500 m counting section during each survey. Counts included the number of live and dead Floy tagged and untagged Chinook. Numbers of other salmon species observed were also recorded. Records for each swim survey included water clarity in the categories clear, tea, glacial silt, muddy, slightly turbid and iced. Relative water levels were estimated as flood, above normal, normal, below normal or extremely low.

AUC estimation of escapement

Survey Life

The area-under the curve estimation procedure requires an estimate of survey life to convert resulting total fish day estimates from the AUC to the number of fish. This estimate is normally derived by constructing a tag depletion curve. The number of tags observed at each sampling event are plotted over time and a curve fitted to the data points. Survey life is estimated by dividing the area under the tag fish curve (live tagged fish days) by the total number of tags deployed.

I attempted to estimate survey life in two different ways due to complications and for comparison. First, by constructing a ‘total tag curve’ including the known tag releases as the first data point as recommended by English et. al. (1992) including all tag releases. Second, by using the number of tags observed on the first swim survey plus the number of tags applied after the hatchery brood collection removed some of the tags.

Estimation of survey life and the mark re-sight estimates appear to have been complicated by loss of the effective tags in the system: removal, loss and/or by emigration of tagged fish. Consequently, the number of effective tags available to be counted, and critical to the mark-recapture estimation procedures, was uncertain. Hatchery brood collection of 112 Chinook occurred between the first tag application date (September 15, 2006) and the first visual survey (September 18th, 2006). The hatchery brood crew reported knocking off at least four tags. Some fish may have emigrated from the Burman River as observed in 2005.

In 2005 Chinook were tagged with Floy FD-68 anchor tags and released during the annual hatchery brood collection. Thirteen (26%) of the 50 tagged fish were subsequently observed in the Gold River. This is a minimum estimate of the number of tagged fish moving to the Gold River after “dipping in” to the Burman River. There was no tag recovery or escapement estimation program on the Gold River in 2005. Fish moving from the Burman River may also have entered other streams in the area. Consequently, the number of tags visible on the first swim survey was also used as a first data point for survey life estimation.

Fisheries & Oceans Canada staff estimated a ‘residence time’ on the Burman River of between 10-14 days and used the midpoint of 12 days for division of the AUC in 2006 (Seaton Taylor, Fisheries and Oceans Canada, personal communication, 250-756-7006).

AUC estimation

Chinook escapement was calculated using area-under-the-curve estimation (AUC) after Irvine et al. (1992). The mean number *f* chinook on the *i*th survey on date (ρ_i) in all sections was calculated using:

(1) $$\rho_i = \sum_{h=1}^{L} N_h * ns_{ih}^{-1} \sum_{j=1}^{ns_{ih}} fo_{ihj}$$

Where L is the number of strata, N_h is the number of 500 m sites in stratum h, ns_{ih} is the number of sites surveyed in stratum h on the ith survey, fo_{ihj} is the number of fish observed in site j in stratum h on the ith survey. No measurements were made to correct for observer efficiency.

The area under the curve plotted from these estimates was given by:

(2) $$AUC = 0.5 * \sum_{i=2}^{n} (t_i - t_{i-1}) * (p_i + p_{i-1})$$

Where t_i is the time of sampling measured from the day that fish entered the counting sections and was thus available to be counted, and *n,* is the number of observations. Escapement was calculated from division of AUC by the mean survey life of the population. The initial sampling date was taken to be the 18th of September, 2006, the date of the first survey.

As this program was not designed with probability sampling it is not possible to estimate the variance associated with the escapement estimate (Irvine et al. 1992).

I contrast the 2006 AUC estimate resulting from all ten 10 swim surveys with the data resulting from five survey swims. Normally, five or six swims are conducted on the Burman River. As the 2006 program increased the number of swim surveys it was necessary to document the effect it had on the AUC estimate. For this comparison I used the data from the first swim conducted in a given week.

Tag loss

Carcasses of all dead Chinook encountered were counted and examined for the presence of tags, and in the absence of a tag, the presence of a secondary mark, to estimate a tag loss rate and provide a carcass mark-recapture estimate.

Mark – Recapture Estimates

The Oceans, Habitat and Enhancement Branch of Fisheries and Oceans Canada reported the removal of four fluorescent green tags during a hatchery brood collection effort on September 16, 2006. One hundred and twelve Chinook salmon were collected and removed from river for use at the Conuma Hatchery. The hatchery removals are not included in the estimates of escapement.

Carcass survey estimate

The carcass survey mark-recapture estimate consisted of a simple Petersen estimate:

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

where N is the estimate of adult salmon, M is the number of adult salmon marked, C is the total number of adult salmon observed live or in the carcass surveys and R is the number of marked adult salmon observed live or in the carcass surveys (Ricker, 1975).

Joint hypergeometric maximum-likelihood estimate

Total escapement was estimated using an Excel worksheet that calculates the joint hypergeometric maximum-likelihood estimator of White (1996):

(3)

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

where $L(N \mid M, c_k, r_k)$ = likelihood of *N* conditional on the observed values of *M*, c_k, and r_k. *N* is the population size and *M* is the number of tagged fish in the survey area. c_k is the number of fish inspected for tags on the k^{th} survey, and r_k is the number of tagged fish counted in the k^{th} survey.

Catch and recapture data were provided by the visual swim counts of marked and unmarked fish.

Bayes estimate

Estimates of the population size at various levels of tag loss were also explored using the Bayes approach (Gazey and Staley 1986) as a supplement to the joint hypergeometric maximum-likelihood approach. These additional estimates were derived from swim survey observations using the sequential Bayesian approach. The Bayesian method determines the posterior distribution of probabilities associated with population size from the joint probabilities of mark recovery rates. Population parameters calculated include the Highest Probability Density (HPD) at 95% confidence and the mode as a maximum likelihood of the sampling distribution. The results in the form of a memorandum to the author from J.A Taylor are presented in Appendix 1.

RESULTS

A total of 107 Floy tags were applied to individual Chinook salmon on three occasions (Table 2). Ten swim survey counts were conducted between September 18 and November 2, 2006. Stream discharge during the survey period was generally below normal fall water levels (Figure 2). Water levels and clarity during the surveys are presented in Table 3. The resulting visual counts of marked and unmarked Chinook salmon are presented in Table 4.

The shape of the escapement curve was skewed (Figure 3) due to very low water levels preventing access to the river. Rain on September 16-17, 2006, elevated flows sufficiently to permit fish to access the river. The peak count of 198 live fish occurred during the first survey on September 18th. By October 2, the number of fish observed declined to 59, and 68% of all the Chinook observed had died. Rainfall on October 14-15 permitted more fish to enter the stream. The numbers of fish observed then remained low through to the last swim count on November 2nd when no tagged fish were observed.

Physical Tag loss

Three dead Chinook bearing tags (6.9 %) and forty unmarked fish were recovered. The number of tagged dead fish was within the range of the tagged proportions of live fish observed in swim surveys. None of the unmarked fish examined bore a secondary mark (Table 5). Although the number of carcasses examined for tag loss was low, physical tag loss was zero and does not appear to have been a significant factor.

Survey Life

The emigration rate of tagged fish was not directly quantified in 2006 due to late delivery of radio tags that were to be used to estimate this form of loss of marked fish. Consequently the estimate of survey life remains uncertain.

Survey life derived from the “total tag curve” of English et. al. (1992) (using all the tags deployed) with no correction for observer efficiency was 1.6 days. I rejected this estimate as too low to be reasonable. It was lower that the three-year average survey life of 6.3 days derived from the adjacent Gold River fall Chinook in the years 1998, 1999 and 2001 (Taylor and Dunlop 2002). The lowest Gold River Chinook survey life estimate was 5.2 days measured in 1998 (Taylor and Dunlop 1999).

Using tags observed in the first swim count (17 tags, September 18, 2006) plus those applied after brood fish removals by the hatchery (4 tags), produced a survey life estimate of 7.7 days. This estimate is more reasonable than that derived from the ‘total tag curve” but lower than the survey life derived by the method normally employed by DFO (12 days; range 10-15 days in 2006).

In the absence of confidence in the survey life estimates above I used the survey life estimate of 5.2 days as a substitute. This survey life was measured in the adjacent Gold River to derive an AUC estimate under similar water conditions in 1998 (Taylor and Dunlop 1999).

AUC

The routine method DFO employed since 1995 produced an estimate of 400 spawning Chinook, with a further 114 Chinook removed for hatchery propagation (S. Taylor, Fisheries and Oceans Canada, personal communication, phone (250) 756-7006).

The two swim count survey frequencies produced different estimates of the total number of fish days in the survey area. Employing ten swim counts resulted in an AUC of 3,310 fish days (Figure 3). Use of only the first swim count in each week, representing the normal frequency of surveys, resulted in an AUC of 2,674 fish days. Increasing the number of surveys to ten elevated the number of fish days in the curve by 23.7%.

The resulting AUC estimate of escapement was 636 Chinook using the ten swim count AUC curve and the 5.2 day survey life. Adjusting for 80% observer efficiency by the same observers measured in the Gold River under clear conditions (Taylor and Dunlop 2000), increased the AUC escapement estimate to 795 Chinook.

Mark – Recapture Estimates

Carcass survey estimate

The simple Petersen mark-recapture estimate from the carcass survey without adjustment for tag loss or emigration of tagged fish was 1078 Chinook salmon. This estimate is five times larger than the peak live observation. The estimate is unlikely to be accurate due to the uncertainty about the total number of effective tags at large. Accepting a tag loss rate of 40% as reasonable, (a figure 50% above the anecdotal observed movement to the Gold River of 26% in 2005), the resulting Petersen estimate is 649 adult Chinook salmon, similar to the AUC estimate.

Joint hypergeometric maximum-likelihood estimator

The joint hypergeometric maximum-likelihood estimate of escapement without adjustment for tag loss or emigration of tagged fish was 1620 Chinook (95% C.I. 1260 – 2180) (Figure 5). This estimate appears too high to be acceptable given a peak count of less than 200 fish and the general consensus that escapements of Burman River Chinook are suboptimal. This estimate of escapement was not considered reasonable due to uncertainty in the number of "effective" tags deployed.

Results of the application of some possible corrections for tag loss rates of 26%, 40%, 50% and 65% are provided in Table 6. If one accepts a 40% tag loss rate as reasonable the result yields a joint hypergeometric maximum-likelihood population estimate of 980 Chinook, with a lower 95% confidence level of 780 Chinook. Believing a slightly higher tag loss rate of 50% (roughly twice the anecdotal rate of movement of tagged fish to the Gold River observed in 2005), yields a population estimate of 800 Chinook with a lower 95% confidence interval of 640 fish (Figure 6). The confidence interval of this estimate encompasses both the Petersen carcass mark-recapture estimate of 649 Chinook with 26% tag loss and AUC estimate of 636 fish using a 5.2 day survey life.

Bayes Estimates

Bayesian estimates of escapement that consider possible corrections for tag loss at rates of 26%, 40%, 50% and 65%, and various observer efficiencies are presented and discussed in Appendix 1.

DISCUSSION

The overall goal of the study, to develop an adjustment factor for the AUC estimate to more accurately reflect total escapement was not achieved in 2006.

Further investigation is required and specific measurement of all sources of potential tag loss is required. The AUC estimate derived using the standard DFO survey life estimation method, was not in agreement with joint hypergeometric, Bayes and carcass mark-recapture estimates of escapement based on the actual number of tags deployed. Significant loss of tags, whether by physical loss from fish, selective predation on marked fish, or emigration of fish is believed responsible. Mark-recapture procedures require precise knowledge of the number of tags available for recapture to produce a reliable estimate. AUC estimation is subject to different sources of bias than the mark-recapture methods, but also requires precise knowledge of the number of tags at large as it is critical for estimating survey life.

In order to assess the accuracy of the mark recapture estimates the primary assumptions employed must be evaluated and found valid. These assumptions are:

1. The population was closed and immigration, emigration and death did not influence the population size.

It is unlikely that this most critical assumption was met in the study. A significant number of tags are believed to have been lost due to emigration of tagged fish, physical tag loss/removal, predation and/or movements from the survey section of the river, or combinations of these error sources.

Opportunistic tagging in 2005 resulted in the recovery of 13 of the 50 (26%) tags in the Burman River by a single First Nation fisherman in the Gold River. No formal recovery program was in place on the Gold River. It is very likely the number of fish that immigrated to the Gold River was higher than the anecdotal information from 2005 suggests. No estimate of the emigration rate of tagged fish could be made in 2006 as the radio-tags that were to be used to address this source of potential bias did not arrive from the manufacturer in time.

The loss of a minimum of four tags was reported by a local hatchery enhancement program during collection of brood fish. More tags may have been displaced during netting operations than reported. Fish may have moved above the survey sections or left the Burman River entirely. Tag loss by removal of fish by predators may also have significantly affected the results. Following the first two swim surveys the number of fish observed in the lower river declined very sharply. Bears were frequently observed fishing in or adjacent to the shallow lower reaches or the river where most of the chinook were observed spawning in the first two surveys.

Immigration of new fish was not considered a significant source of error as few new fish were observed in the river after the early October surveys.

Emigration of tagged fish is believed the most significant source of error to be addressed for future mark-recovery and survey life estimates on the Burman River.

2. Marked and unmarked fish were equally likely to be recaptured.

A key assumption is that tagged and unmarked fish were equally observable, behaved similarly, and thus were recaptured at similar rates. Tagged fish appeared to have been well mixed in the population. Fish marked with fluorescent green tags were likely more visible than unmarked fish. However, visibility conditions were excellent in all but one survey late in the program. Observers could routinely see across the entire streambed in all areas except in riffle areas where shallow depths restrict lateral views. Mark rates observed in the swim surveys and carcass surveys were similar. In the visual surveys 6.6 % of the fish observed (range 4 – 9%) were marked. Similarly, three (6.9%) of the carcasses recovered were marked fish.

3. Tag loss was not a source of error.

Tag loss was calculated from the examination of dead fish during carcass surveys. No instances of recaptures of tagged fish or fish having lost a tag occurred during subsequent tagging operations. Three carcasses with tags were recovered in the carcass survey. There were no instances of fish bearing a secondary mark among the 40 carcasses recovered without tags. A lack of recoveries of fish carcasses missing a tag suggests that loss of tags was not an important bias. As the number of dead fish recovered was low there remains potential for tag loss error simply due to the small sample examined.

During the hatchery brood capture on September 16, 2006, four tags were reported having been displaced. More tags may have been displaced than observed and reported. Physical tag loss cannot be ruled out as a source of error.

In conclusion, the 2006 program did not meet all of the objectives intended to be addressed. The program demonstrated that increasing the number of swim surveys alone, intended to better provide more recapture observations and a better survey life estimate, increased the AUC estimate of fish days in the system in 2006 by 23.7%. The AUC estimate of escapement based on a survey life of 5.2 days was 636 Chinook. This was similar to the Petersen mark-recapture estimate of 649 Chinook with 40% tag loss assumed. Similarly when the joint hypergeometric maximum likelihood estimate is produced with assumed 50% tag loss the resulting 95% lower confidence bound (640 Chinook) is very near the AUC estimate and contains the Petersen estimate. The 2006 program demonstrated there was significant tag loss, likely from the movement of tagged fish out of the river, that must be addressed for future mark recapture programs to be effective and permit accurate calibration of the AUC escapement estimates in the Burman River. The appended Bayes assessment of the 2006 AUC estimate supports this conclusion.

Recommendations.

The following recommendations are meant to improve the program in order to achieve the desired objectives in future years.

1. Petersen disk tags of a neutral color should be used instead of fluorescent tags to reduce the possible introduction of bias from increased visibility of fish with highly visible tags and reduce potential for physical tag loss.

2. In future programs on the Burman River the estimation of tag loss due to emigration of marked fish and other sources of tag loss is critical for the mark recapture estimates and in deriving the survey life for the AUC estimate.

3. Radio tags should be used and applied proportionally to the visual tags to permit discounting the number of effective visual tags available for recapture and account for emigration of tagged fish out of the system.

4. Observer efficiency should be measured directly each year.

5. The number of Chinook salmon carcasses examined must be increased to better estimate physical tag loss as a source of bias. This includes carcass surveys outside of the river channel where they may be moved by predators.

6. Repeat the program for at least two more years and attempt to use an average of the estimates of tag losses (due to 'dip-ins') to estimate the number of effective tags that were present in 2006 and recalculate the mark-recapture estimates.

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References

CTC. 2007. Annual report on catch, escapement, exploitation rate analysis and model calibration of Chinook salmon under Pacific Salmon Commission jurisdiction, 2006. Report of the Joint Chinook Technical Committee to the Pacific Salmon Commission, TCChinook (07)-1.

English, K.K., R.C. Bocking and J.R. Irvine. 1992. A robust procedure of estimating salmon escapement based on the area-under-the curve method. Can. J. Fish. Aquat. Sci. 49: 1982 – 1989.

Fish Habitat Inventory and Information Program. 1990. Stream Summary Catalogue. Subdistrict 25, Tahsis. Department of Fisheries and Oceans, Vancouver, B.C.

Irvine, J.R., R.C. Bocking, K.K. English and M. Labelle. 1992. Estimating coho salmon (*Onchoryhnchus kisutch*) spawning escapements by conducting visual surveys in areas selected using stratified random and stratified index sampling designs. Can. J. Fish. Aquat. Sci. 49: 1972 – 1981.

Muller, J.E. 1975. Map 1537A. Geology, Nootka Sound, British Columbia. Geological Survey of Canada, Ottawa.

Parken, C.K., R.E. McNicol and J.R. Irvine. Habitat methods to estimate escapement goals for data limited Chinook salmon stocks in British Columbia, 2004. Canadian Science Advisory Secretariat Research Document 2006/083. 67 pp.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Department of Environment, Fisheries and Marine Service. Ottawa.

Taylor, J.A. and R. Dunlop. 2002. Application of an index sampling design to estimation of chinook salmon (*Oncorhynchus tshawytscha*) escapement to the Gold River watershed. Unpublished report for Nuu-chah-nulth/WCVI Regional Aquatic Management Society and Mowachaht/Muchalaht First Nation, by J.A. Taylor and Associates Ltd.

Taylor, J.A. and R. Dunlop. 2000. Assessment of the 1999 chinook salmon (*Oncorhynchus tshawytscha*) escapement to the Gold River watershed, using mark-recapture and area-under-the-curve estimation. Unpublished report for Nuu-chah-nulth/WCVI Regional Aquatic Management Society and Mowachaht/Muchalaht First Nation, by J.A. Taylor and Associates Ltd.

Taylor, J.A. and R. Dunlop. 1999. Mark-recapture and area-under-the-curve estimation of the 1998 chinook salmon (*Oncorhynchus tshawytscha*) escapement to the Gold River watershed, including migration timing and distribution of spawners. Unpublished report for Nuu-chah-nulth/WCVI Regional Aquatic Management Society and Mowachaht/Muchalaht First Nation, by J.A. Taylor and Associates Ltd.

White. G.C. 1996. NOREMARK: Population estimation from mark-resighting surveys. Wildlife Society Bulletin 24:50-52.

Table 1. Counting section locations measured to lower site boundary the estuary treeline.

Stream	Stratum	Section	Location (m)
Burman River	1	1	1000
Burman River	1	2	1500
Burman River	1	3	2000
Burman River	1	4	2500
Burman River	1	5	3000
Burman River	1	6	3500
Burman River	1	7	4000
Burman River	1	8	4500
Burman River	1	9	5000
Burman River	1	10	5500
Burman River	1	11	6000
Burman River	1	12	6500
Burman River	1	13	7000
Burman River	1	14	7500
Burman River	1	15	8000
Burman River	1	16	8500

Table 2. Timing and location of tag applications to Burman River Chinook.

Date	Floy colour	Number tagged	Tagging location
15 –Sep-2006	Flour. Green	101	estuary
27-Sep-2006	Flour. Orange	2	estuary
5-Oct-2006	Flour. Pink	4	estuary

Table 3. Swim survey dates, water level and general visibility conditions.

Swim #	Date	Water level	Visibility
1	18-Sep-2006	Extremely low	Clear
2	21-Sep-2006	Extremely low	Clear
3	26-Sep-2006	Extremely low	Clear
4	2-Oct-2006	Below normal	Tea
5	7-Oct-2006	Extremely low	Clear
6	11-Oct-2006	Below normal	Clear
7	16-Oct-2006	Extremely low	Clear
8	20-Oct-2006	Below normal	Clear
9	24-Oct-2006	Below normal	Slightly turbid
10	2-Nov-2006	Normal	Clear

Table 4. Summary of observations of live Chinook from all sites.

Swim #	Date	Floy Tagged Fl. Green	Floy Tagged Fl. Orange	Total Count
1	18-Sep-2006	42	0	198
2	21-Sep-2006	8	0	194
3	26-Sep-2006	6	0	129
4	2-Oct-2006	3	0	59
5	7-Oct-2006	3	0	33
6	11-Oct-2006	1	0	11
7	16-Oct-2006	2	0	48
8	20-Oct-2006	3	0	35
9	24-Oct-2006	1	0	14
10	2-Nov-2006	0	0	31

Table 5. The number of marked and unmarked Chinook examined

Swim #	Date	Tag present	Tag lost	Unmarked	Total Dead
1	18-Sep-2006	0	0	0	0
2	21-Sep-2006	0	0	0	0
3	26-Sep-2006	0	0	3	3
4	2-Oct-2006	1	0	1	2
5	7-Oct-2006	0	0	26	26
6	11-Oct-2006	0	0	10	10
7	16-Oct-2006	1	0	0	1
8	20-Oct-2006	1	0	0	1
9	24-Oct-2006	0	0	0	0
10	2-Nov-2006	0	0	0	0
Totals		3	0	40	43

Table 6. Joint hypergeometric maximum- likelihood estimates of escapement at various rates of tag loss.

% Tag loss	Escapement estimate	95% confidence interval
0	1620	1260 -2180
26	1220	940 – 1620
40	980	940 – 1300
50	800	640 – 1080
65	560	440 - 760

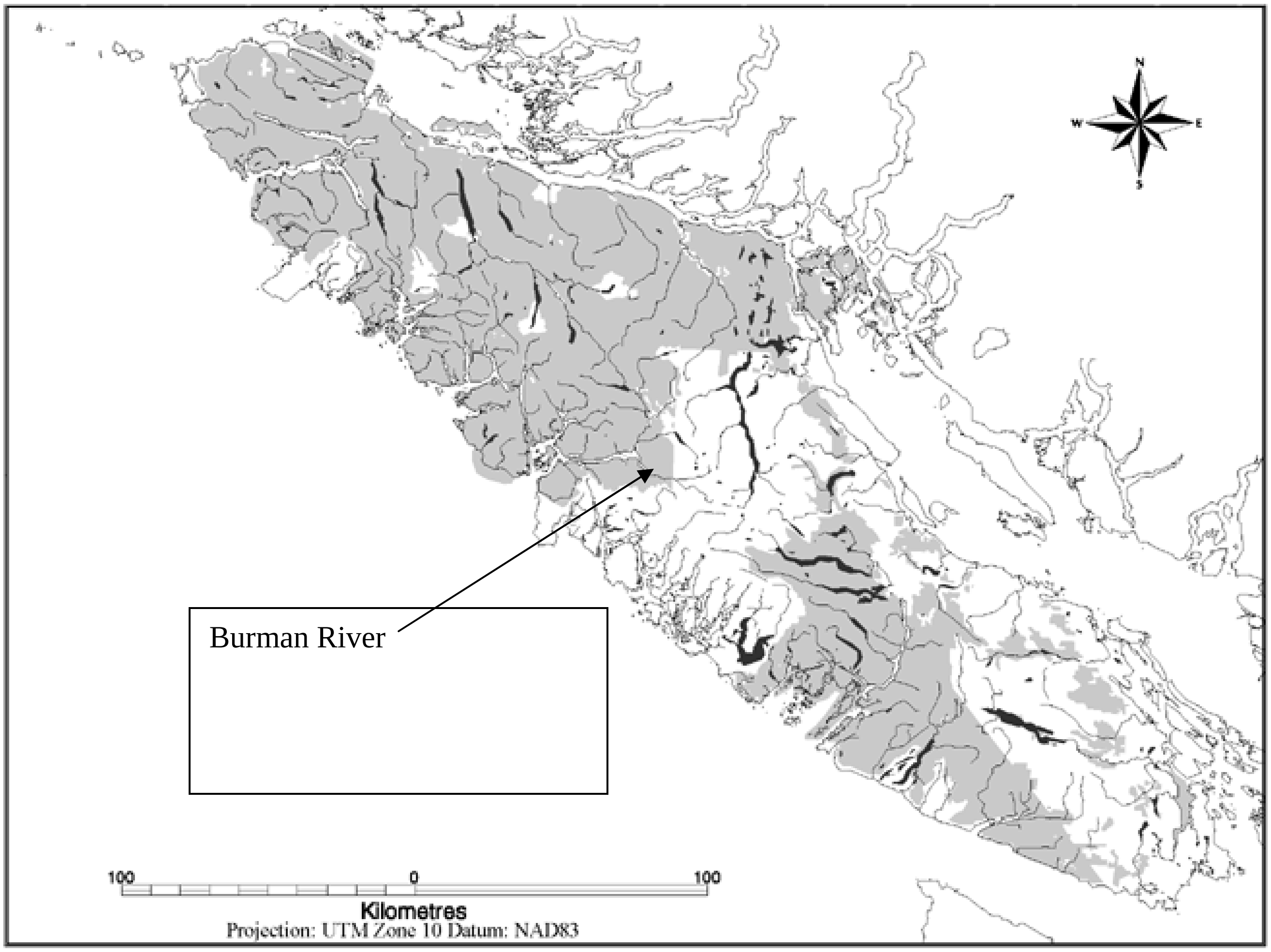

Figure 1. Location of the Burman River, Vancouver Island, British Columbia.

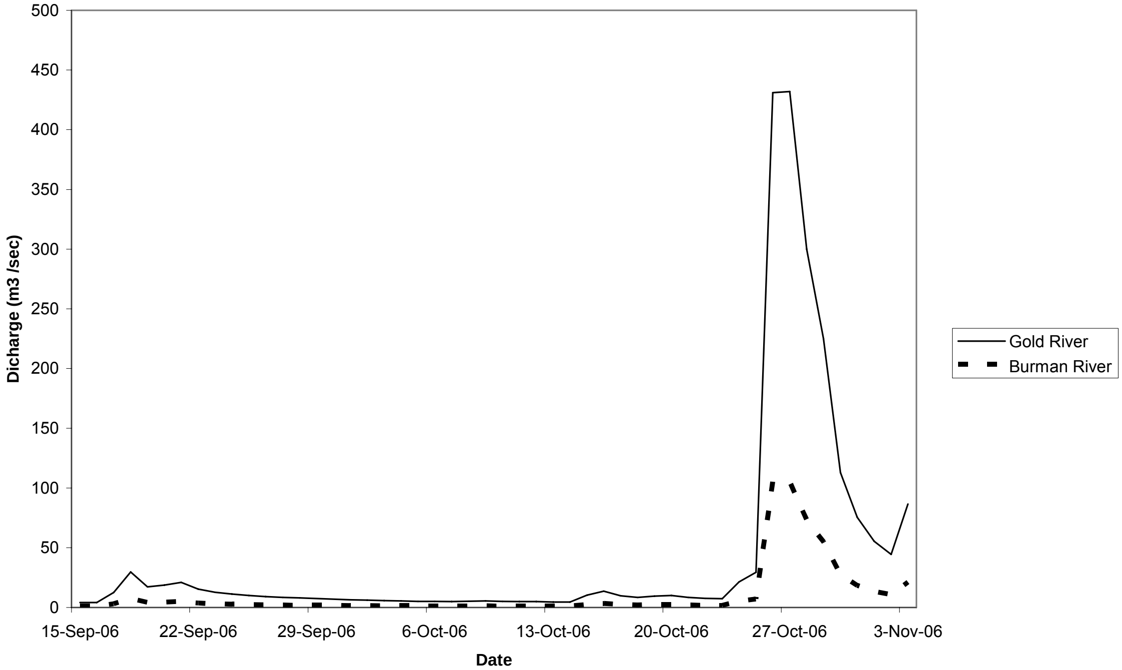

Figure 2. Estimated Burman River and Gold River WSC guage 08HC001 discharge, September 15 - November 3, 2006.

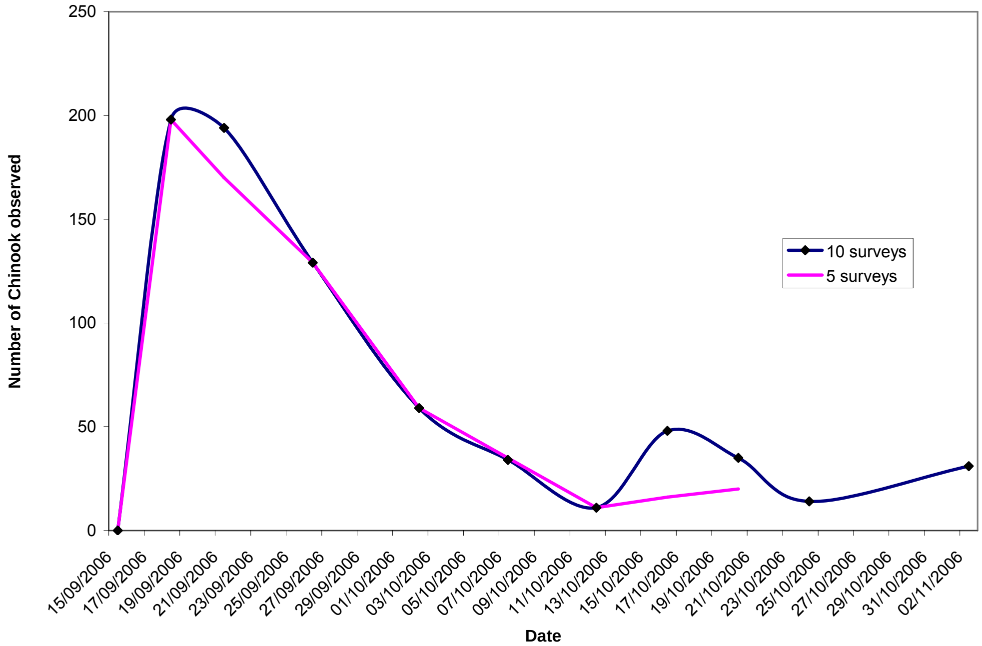

Figure 3. AUC Chinook salmon escapement curves for weekly (2,674 fish days) and twice-weekly (3,310 fish days) swim surveys of the Burman River, 2006.Twice weekly surveys produced an AUC 23.7% greater than weekly swim counts.

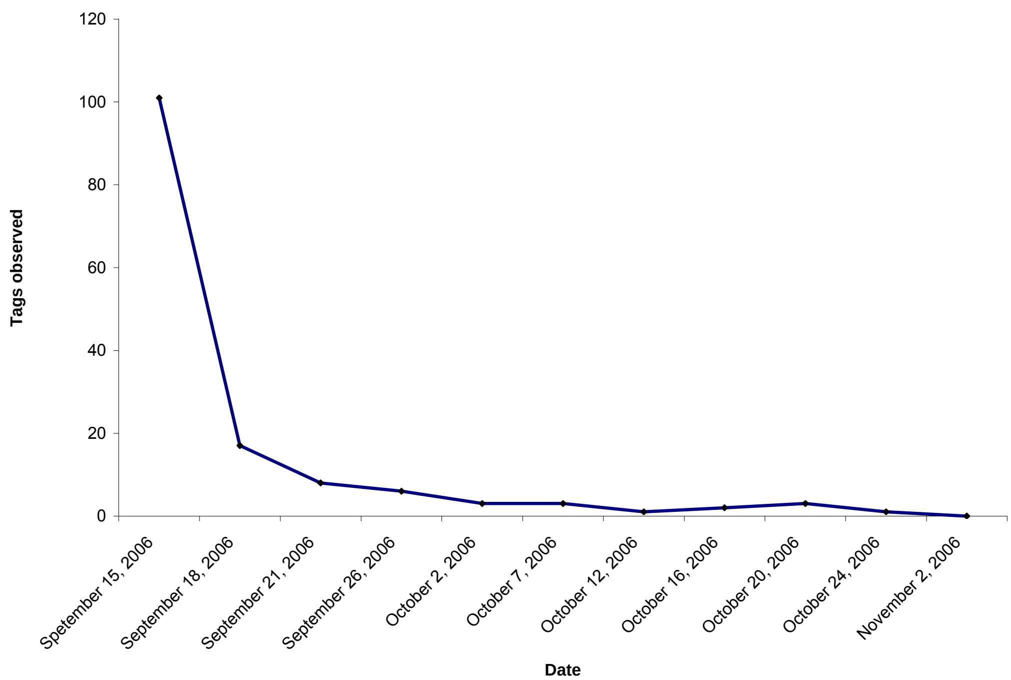

Figure 4. Tag depletion curve for Burman River fall Chinook, 2006.

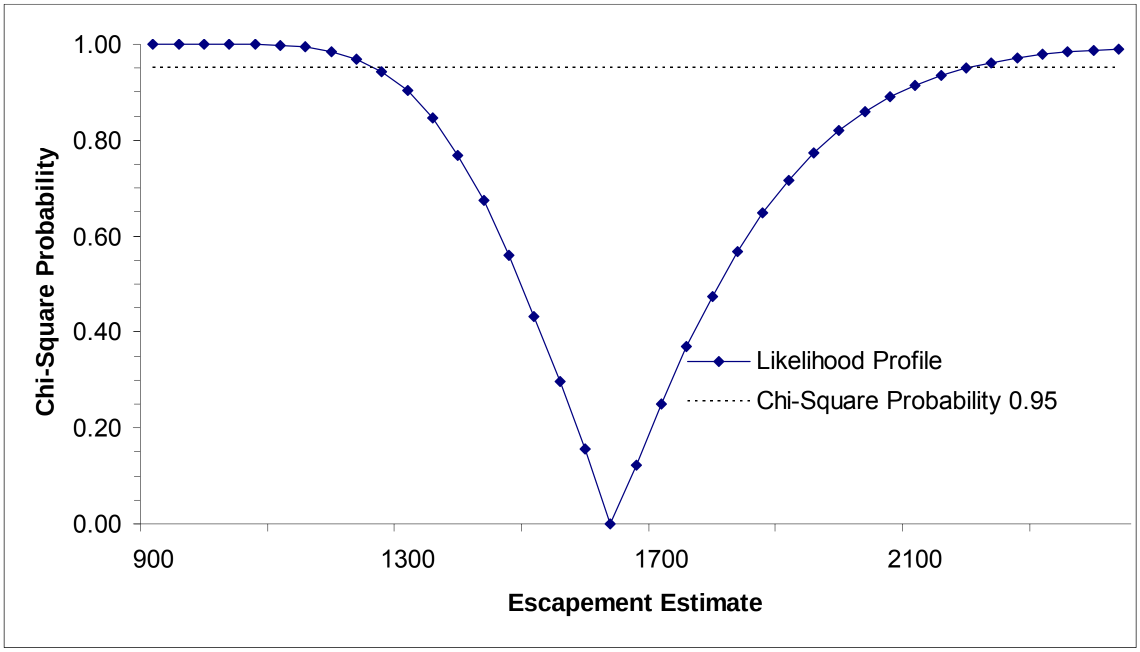

Figure 5. The mark re-sight maximum likelihood estimate with zero tag loss was 1620 Chinook salmon in the Burman River in 2006. The lower 95% confidence interval estimate was 1260 and upper limit was 2180.

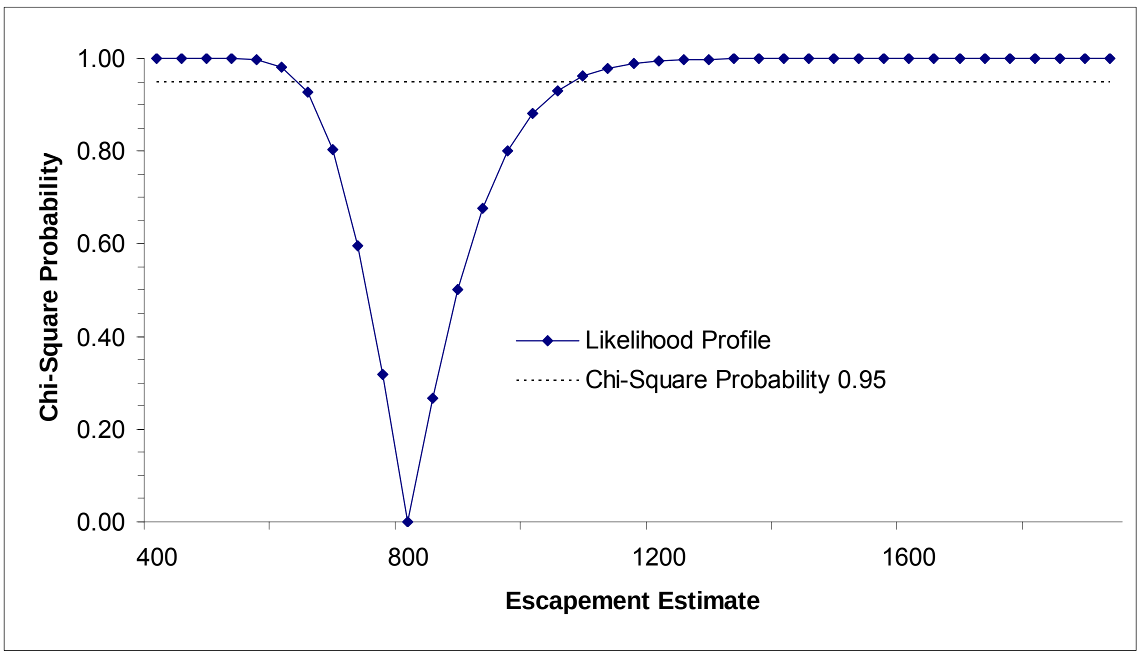

Figure 6. Mark-resight maximum likelihood estimate of 800 Chinook salmon in the Burman River in 2006 with assumed tag loss of 50%. The 95% C.I. range was 640 – 1080.

APPENDIX 1.

BURMAN RIVER CHINOOK SALMON (*Onchorynchus tshawytscha*) AREA-UNDER- THE-CURVE AND BAYES MARK RECAPTURE ASSESSMENT 2006

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BURMAN AUC ASSESSMENT 2006

In the absence of information on the fate of tags applied to chinook, some indication of the order of magnitude of escapement can be made through manipulation of the various estimates, AUC and Bayes. However, this analysis leans heavily on the “believability” of the various scenarios. It is necessary to first adopt realistic approximations to parameters that were not measured, namely observer efficiency and survey life. The first might reasonably be assumed to be similar to that measured for Gold River under clear water conditions, so 70% seems reasonable for the same swim crew in Burman River. I have adopted 6 days as not unlikely for survey life, again based on the 1998 Gold River value.

The Bayes estimate (Gazey and Staley 1986) derived from the data with no acknowledgement of tag loss was constructed from 801 discrete population levels between bounds of 200 – 2,600 individuals. These data produced a modal population estimate for adults located at 1,715 – 1,721 (95% highest probability density 1,313 – 2,327). Sequential plots of the posterior distribution with time are illustrated in Fig. 1. It is not uncommon for the initial curve to depict a lower population than later in the time series, as fish enter the system. However, this may also indicate the loss of tags from the Burman, with subsequent overestimation of escapement. Obviously, the Bayes estimate far exceeds expectations for the system and a primary parameter driving high escapement is the effective tag count. The degree to which we can accept tag losses as reasonable, while producing lower population estimates is explored below.

Using English’s approach (English et. al. 1992) where all tags are initially included, the tag depletion curve for the data, based on 70% observer efficiency and 26% tag loss as a starting point, gives a survey life estimate of 3.8 days. This results in an AUC estimate of 1,017 chinook. This is not too dissimilar from a Bayes estimate corrected for 26% tag loss (Table 1: mode 1,271 – 1,277 95% HPD 968 – 1,733). The minimum population size with 95% probability from the Bayes probability distribution is 1,040 fish.

Calculation of survey life using the first swim as the initial observation gives 2.9 days and elevates the AUC escapement estimate to 1,307, much closer to the Bayes estimate. Therefore, if the actual survey life is 6 days, the two methods of calculation indicate that the respective rate of tag loss would have to be 54% (45 functional tags) and 64% (35 functional tags). Table 1 provides Bayes estimates and minimum population sizes for three additional levels of tag loss, 40%, 50% and 65%.

Given the general consensus that Burman River chinook are substantially below MSY, the higher levels of tag loss are necessary to produce escapement estimates that fall to an equivalent level to the AUC estimate based on a 6 day survey life (642 chinook). Since the maximum tags observed (17 on the first swim) are well below expectation for an observer efficiency of 70%, it appears that the data can support high tag losses, in that fewer tags were seen than were available. In contrast, the average value for survey life adopted by DFO for the 2006 data was 12 days, requiring the loss of 76% and 81% of tags by the English and first survey tag depletion methods. In particular the latter estimate suggests that observer efficiency was 89% in the first swim, for the sighting of 19 tags.

It should be noted that observer efficiency is a determinant of survey life, but has little impact on the estimate of escapement. Changing observer efficiency to 30% from 70% elevates the initial AUC estimate from 1,017 to 1,132 fish, but survey life is now 7.9 days. The effect on the Bayes estimate is similar, decreasing from 1,274 chinook to 1,296. It is still necessary to eliminate a substantial number of tags to lower the escapement estimate.

In terms of believability, I have difficulty with accepting an extremely high straying rate of chinook from the Burman system, partly since the only measure available is 26%: it is noted that this represents anecdotal information, but approximately half as many again migrants would have to have been seen to lower the escapement estimate to at least 708 fish from 1040. While a straying rate of even 50% seems excessive, I suspect that the rates required to support a survey life of 12 days are improbable: these suggest that only one in 4 chinook in the lower Burman are in the right river and will continue upstream to spawn. If true, this has obvious implications for the local hatchery program.

Obviously, tag losses may result from predation, movement beyond the survey strata and physical loss/removal of the tag, as well as migration to a new river. While the various other factors that contribute to tag loss may be substantial, I am inclined to believe that the Burman population, at least in 2006, was considerably higher than current estimates and a minimum escapement level of 700 to 800 is quite reasonable, if not conservative.

If I chose to believe that the swimmers saw only half the fish on each swim, the resulting survey life is a respectable 5 days. Combined with a reasonable estimate of tag loss of 40% both the AUC and Bayes estimates are similar, respectively 1,071 and 1,010 (95% HPD 850 – 1224). The probability that the escapement contained at least 884 chinook is 95%.

REFERENCES

English, K.K., R.C. Bocking and J.R. Irvine. 1992. A robust procedure of estimating salmon escapement based on the area-under-the-curve method. Can. J. Fish. Aquat. Sci. 49: 1982 – 1989.

Gazey, W.J. and M.J. Staley. 1986. Population estimation from mark-recapture experiments using a sequential Bayes algorithm. Ecology 67: 941-951.

Table 1. Bayes modal estimate of escapement and associated minimum population size for various levels of tag loss.

% tag loss	mode	95% HPD	minimum population
0	1715 - 1721	1313 - 2327	1400
26	1271 - 1277	968 - 1733	1040
40	1022 - 1026	782 - 1388	840
50	859 - 862	662 - 1160	708
65	593 - 595	463 - 793	494

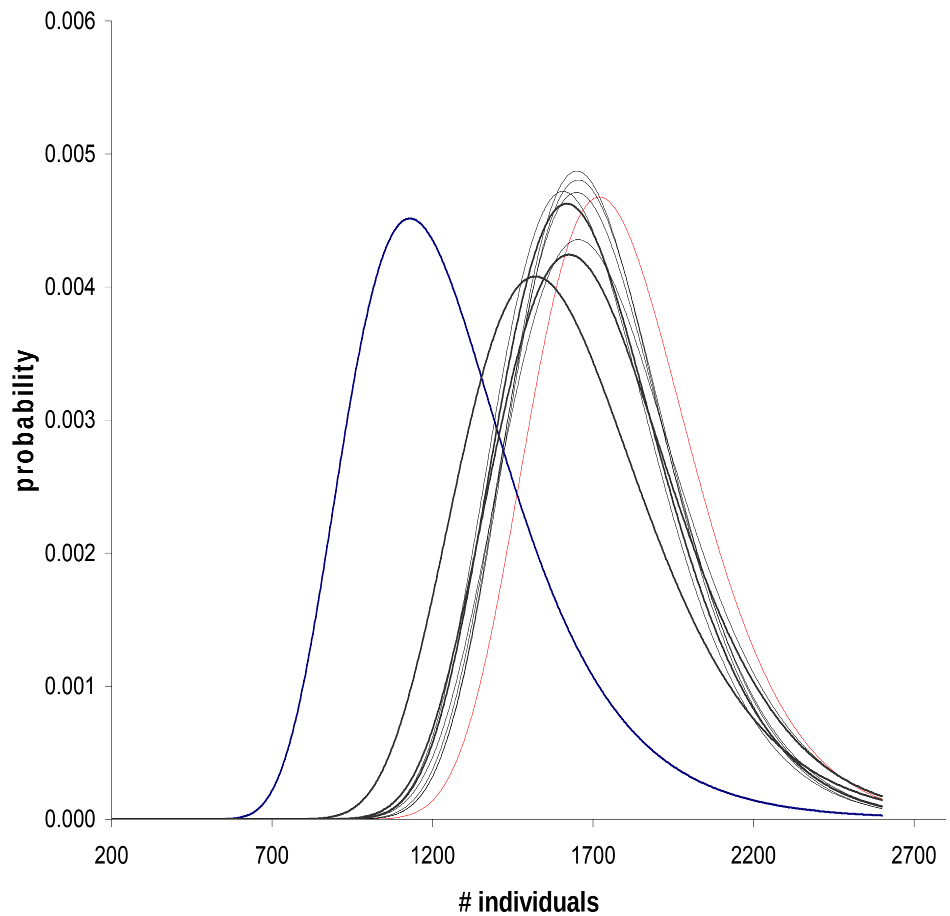

Figure 1. Sequential plots of the posterior distribution of the total population estimate based on zero tag loss. Initial and final sequences are shown in blue and red, respectively.