Abundance and origin of the Chinook salmon (*Oncorhynchus tshawytscha*) spawning escapement in 2016 at Burman River, west coast Vancouver Island.

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Executive Summary

At Burman River between August 28, 2016, and November 8, 2016, Chinook salmon (*Oncorhynchus tschawytscha*) were marked, recaptured alive, observed during snorkel surveys, and recovered dead in carcass surveys. Some 2010 Chinook salmon >500 mm post-orbital hypural length were marked, the largest number of marks applied in seven study years, and 37% were female and 63% male. An open population mark-recapture analysis with POPAN (Schwarz and Arnason 1996) in Program MARK (White and Burnham 1999) produced an estimate of 10, 454 (SE=1103.6, 95%CI 7,567 – 13,343, CV = 10.5%) composed of 3,689 (SE= 479.1, 95% CI 2,750 - 4,268, CV=12.9%) females and 6,766 (SE=994.1, 95%CI 4,818 – 8,715, CV=14.7%) males. Previous work (2009-2015) demonstrated the population is demographically open at the marking site (Dunlop 2016). Three models received sufficient (>6%) of the AIC weight requiring model averaging and 77% of weight was assigned to model *{Φ (g) P (gt) Pent (t)}*, 20.1% to *{Φ (g-a2t) P (gt) Pent (t)}*, and 7.5% to *{Φ (g) P (t) Pent (t)}.* A Petersen estimate was generated for posterity although it is not valid due to failure of the population closure tenant. Thirty-five female carcasses bearing five (14%) marks and 29 males with three (13%) bearing marks were recovered in carcass surveys. Examination of saggitae (otoliths) from broodstock for thermal batch marks applied to local hatchery stocks indicated the following main components in the 2016 escapement: natural or natural or wild (0.14. SE=0.03), Burman River origin hatchery (0.73, SE=0.03) and other strays predominantly from Conuma River ere 0.13 (SE=0.03) Combining the open population and origin estimates produced component stock escapement estimates of: 1,584 (SE=429.5) natural spawners, 7,452 Burman broodstock hatchery origin fish, and stray spawners, that were predominantly from Conuma River facility sea-pen production of 1,408 (SE=405.1); and an estimated 178 (SE=127.1) .strays from other WCVI facilities. Monitoring age-origin and abundance at the Burman River provides a means of monitoring hatchery production practice changes while also monitoring the abundance of natural spawning Chinook salmon in Nootka Sound. Information on the freshet related spawning area survey life index for visual surveys is discussed.

Introduction

A mark-recapture experiment and snorkel surveys were conducted to estimate the number of Chinook salmon (*Oncorhynchus tschawytscha*) returning to spawn at the Burman River in 2016, the eighth year of study. The Burman River Chinook stock is highly introgressed by hatchery production from using non-selective broodstock propogation and es for strays largely from Conuma River (Ruth Withler, per. comm. WCVI Indicator Selection meeting, April 2017). Policy well water rearing for fish health likely bypasses the surface water brain sensitization exposure necessary for homing before sea-pen rearing. The population of natural spawners has ranged from a few hundred to several thousand in recent years. The fraction of Chinook salmon population of each origin class is estimated annually. Sea-pen reared hatchery smolts are released at sizes much larger (> 6 gm) than natural smolts (<1 gm) to maximize survivals but also may confer maturation acceleration skewing the age-structure to younger fish less vulnerable in some fisheries. In each Pacific Salmon Treaty (PST) agreement between Canada and the United States of America the Burman River Chinook stock has been is identified in Attachments to Chapter 3 as a bilaterally agreed *escapement indicator for WCVI naturally produced Chinook salmon*. Currently there is no bi-laterally agreed escapement goal for any WCVI Chinook stock which renders the subsequent conservation mechanisms in the PST requiring goals inapplicable. Canada has considered natural spawning WCVI Chinook salmon stocks as stocks of conservation concern for over two decades. Although the Burman River currently produces both natural spawning and hatchery phenotypes of Chinook salmon, it is the only system with demonstrably defensible escapement estimates for both phenotypes and strays in the Nootka-Kyuquot Chinook Salmon Conservation Unit (Holtby and Ciruna 2002) and has potential as a Coded-Wire Tag Exploitation Rate Indicator Stock. The program at Burman River also provides much needed opportunity to monitor the effect of SEP husbandry practices as efforts to reduce straying and its unintended consequences are explored.

Since 2009 the annual objectives of this study have been to: 1) conduct a mark-recapture experiment to estimate the spawning escapement of > age-2 Chinook salmon with a Coefficient of Variation of 15% or less, on average; 2) estimate relative and absolute abundance by age, and 3) incubation origin. Initially the study of otoliths was intended to assess hatchery strays that were a concern. Natural spawners were consistently identified from otoliths not bearing thermal batch marks codes applied at hatcheries that identify brood source and release treatment groups. Combining the proportions of natural origin Chinook salmon with the mark-recapture experimental results each year permits estimation of the spawning population of naturally produced Chinook salmon, the intended purpose of the Burman River Chinook salmon as PST indicator stock. Fish lacking thermal marks were assumed to be wild or natural Burman River Chinook salmon although no genetic testing as undertaken to confirm stock group of origin. This simple method will allow future evaluation of the escapement of natural spawners against a habitat–based spawning escapement goal in the near future as contemplated for this stock in the Pacific Salmon Treaty.

Study Area

The Burman River meets the Pacific Ocean 18 km south of the Village of Gold River on the west coast of the Vancouver Island (WCVI), British Columbia, Canada (Figure 1). This 5th order stream originates in the Vancouver Island Ranges and drains an area of 244 km^2 discharging to Matchlee Inlet in Nootka Sound. Strathcona Provincial Park protects the upper watershed from development. During the study small glaciers occurred on six surrounding mountain peaks where elevations range up to 2195 m ASL. The main river channel is 31.3 km long. Bedrock cascades above river kilometer (Rkm) 13.0 limit access to all but summer steelhead (*Oncorhynchus mykiss*). The riverbed is alluvial and occasionally confined downstream of Rkm 13.0. A large rock slide at Rkm 8.0 is a significant channel feature and increased gradient upstream of this location limits spawning gravel deposits. Chinook salmon (*O. tshawytscha)*, coho salmon (*O. kisutch)*, ocean-type sockeye salmon (*O. nerka*), chum salmon (*O. keta*) and pink salmon (O. *gorbuscha*) are observed to Rkm 8.5 but occasionally occur further upstream (FHIIP 1975; Dunlop 2016). Winter migrating steelhead, cutthroat trout (*O. clarkii*), Dolly Varden char (*Salvelinus malma*) and sculpins (*Cottus spp*.) also use the drainage. Annual precipitation averages over 2.5 m. Two lakes > 1 km^2 and 18 smaller lakes occur above the 900 m elevation. Access to the watershed requires boat or air transportation. The basin is a hybrid watershed where meltwater dominates the spring hydrograph and rainfall dominates flow the remainder of the year (Coulthard and Smith 2015).

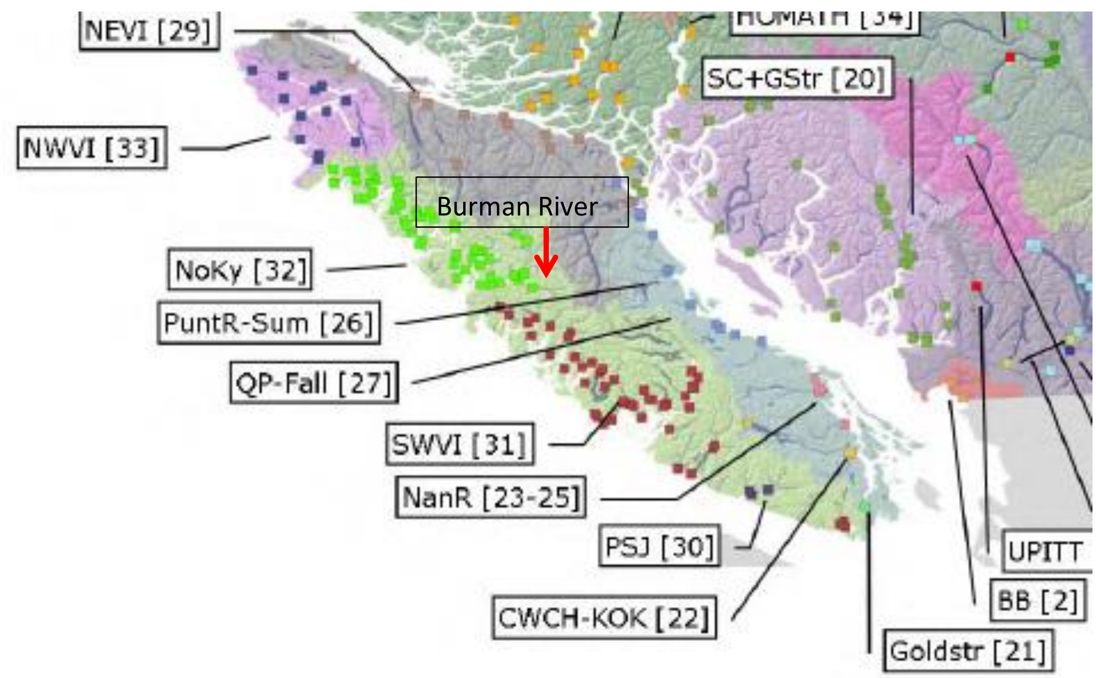

Figure 1. Location of the Burman River on the west coast of Vancouver Island (WCVI) and Chinook salmon Conservation Units (CU's) identified by Holtby and Ciruna (2007). Burman River Chinook salmon belong to the Nootka-Kyuquot Conservation Unit, one of three CU's on the WCVI.

Burman River Chinook salmon are a coastal stock with an ocean-type life-history adapted to coastal hydrology. An ocean type life history strategy is required due to infrequent but severe droughts that occur in the region (Coulthard and Smith 2015). The Burman River spawning population belongs to the Nootka-Kyuquot Conservation Unit (CU), one of three WCVI Chinook salmon groups defined by similarities among genetics, run timing and the oceanic provenances occupied described by Holtby and Ciruna (2006) and updated by DFO (2013). Hatchery supplementation of the stock began in the mid-1970's. The Burman River hatchery stock presently contributes about 13% of Nootka Sound hatchery Chinook production to aggregate abundance-based and individual stock-based fisheries managed under the Pacific Salmon Treaty.

Methods

From 2009-2016 Chinook salmon surveys were conducted at Burman River using three methods. These methods were live captures and recaptures at a freshwater migration stopover site, and both dead recoveries and visual snorkel observations over the 6.5 km spawning reach upstream (Figure 2). Chinook salmon were captured and recaptured by beach seine deployed from a motorized skiff by setting in the same pool. Fish when captured for the first time were tagged, measured for post-orbital hypural length (POH) to nearest 5 mm, and visually sexed before being released immediately. Tags were individually numbered with 80 lb monofilament core secured with a size 'J' metal fishing crimp sleeve and a tag batch-specific mutilation mark for recognition in the event of tag loss and random tag reassignment. Scale samples were collected systematically for ageing from each sex group with a target of 385 readable scale samples. Sampling commenced on September 2, 2016, and continued past October 2, 2016, when the last live Chinook salmon was captured. Seining continued for three sets per day on four additional occasions until October 15th in an attempt to ensure mark the latest entrants. Carcasses and broodstock were sampled to collect a target of 285 saggitae pairs (otoliths) to examine them for hatchery specific thermal codes and permit estimation of the natural spawning escapement, hatchery and strays present. Naturally produced fish without thermal marks were assumed to be local and were not subjected to further DNA analysis. Broodstock were sampled to supplement samples from carcass surveys that were difficult to obtain in 2016.

Twenty-two female and 17 male tagged fish removed in the hatchery broodstock collection were censored from the experiment data. An additional 66 unmarked female and 81 unmarked males removed during hatchery collections must be removed from the derived open population estimates to obtain a spawning escapement comparable to the snorkel based estimates. Strays must be estimated from the thermal mark proportions and the total escapement to obtain an estimate of the Burman River origin Chinook salmon by phenotype.

Snorkel surveys were conducted on 10 occasions between August 28 and October 29, 201, and occurred less frequently than desired due to high flow in October and November . Observers recorded an individual observation of the number of unmarked and marked by tag colour in reach 500 m counting section of the river from km 7.5 to km 0 ending. The visual survey ends at the riffle immediately above the stopover study pool. The stopover pool is excluded from snorkel observations as saltwater intrusions at very high tide makes regular counting impractical. Tag numbers were not visible to snorkelers so only tag colour could be recorded.

The AUC spawner curves were calculated with raw observations (OE=1.0) and in 2015 a non-zero last observation required calculation of the end date with the method of Bue et al. (1998) and Hilborn et al. (1999) by adding ½ the survey life to approximate the ending zero count date. Two curves one with all surveys and one with a sub-set of 6-8 surveys to mimic agency methods were constructed.

Carcass surveys occurred on 18 occasions from September 16, 2015, to November 8, 2015. Surveyors on foot followed the same route down the 7.5 km channel section retrieving, enumerating and sampling dead recoveries for sex by dissection, Post-orbital-hypural (POH) length, mark status and tag number, scales and saggitae, categorical egg retention rates in females, and carcass condition. Snorkelers recovered additional carcass from deeper water for sampling by the carcass crew.

Petersen estimates were developed for posterity from the number of effective marked fish released and recovered marked and unmarked carcasses by sex. Too few marks were recovered in either sex for a Petersen estimate but the field data results are presented for posterity. A total of 66 Chinook carcasses were recovered and eight were marked including five marked females among 35 carcasses, and three marked male fish among 29 male carcasses, and; of two jack carcasses, both marked. In 2016 we marked three very small males < 335 mm which was unusual. After deducting mark LOCs to broodstock collections there were 734 female and 1237 marked males at large. Less than 1% (0.68%) of marked females and 0.24% of marked males were among the carcasses. It is unlikely a carcass based estimate is accurate notwithstanding the fact the population is known to be open to both additions and losses.

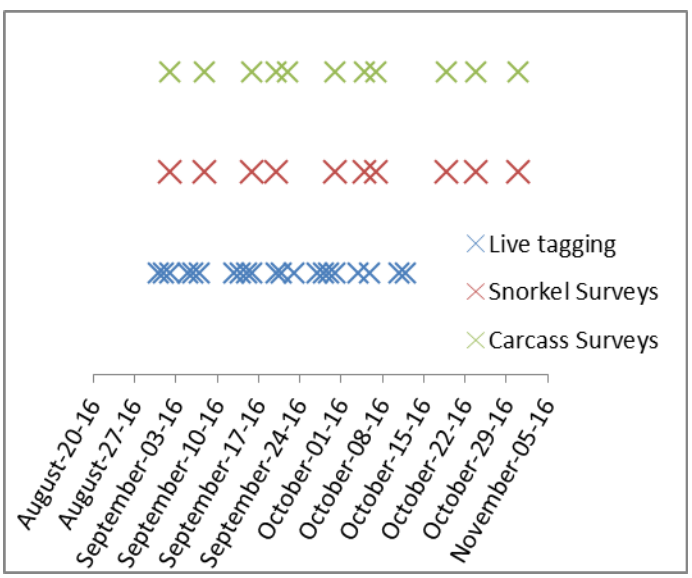

Figure 2. Timing of 2016 live marking and recapture events, snorkel surveys, and carcass recovery survey sampling events at Burman River.

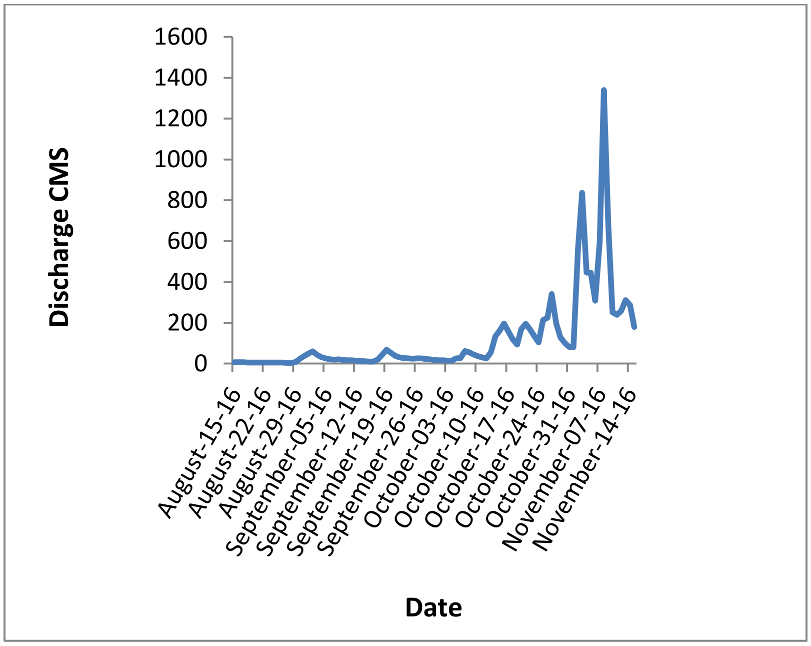

Figure 3. Discharge (cms^{-1}) of adjacent Gold River at Water Survey of Canada gauge below the Ucona River confluence from August 15 to November 15, 2016. Flows > 50 cms^{-1} occurred on September 2, September 18, and October 7th, 2016, and remained high after October 13, 2016.

Results and Discussion

More Chinook salmon were marked in 2016 than in any previous year at Burman River. Individually numbered tags and a secondary mutilation mark were applied to 2,010 large Chinook salmon (>500 mm POH). The groups consisted of 756 females and 1,254 large males and an additional 66 jacks (≤ 500 mm POH). There were 231 live recaptures of females and 304 live recaptures of males used in the Jolly-Seber population estimation procedure. Seven of a further 66 jacks (< 500 mm POH) marked were seen again alive.

Individual encounter histories (IEHs) of Chinook salmon captured and recaptured were constructed in the following steps that are described here to inform reconstruction of IEHs; sexes of live and carcasses were cross-checked and corrected from dissection results; tagged fish killed and removed as broodstock were censored from the experiment as it was not possible to mark all fish released in those sets with a larger net. There were 21 sampling events with captures from Day of Year 243 or August 31, 2016 to October 12, 2016 (Day 285) after which no Chinook salmon were captured in the daily three set maximum on five more occasions The intervals were 1, 1, 3, 1, 1, 6, 1, 1, 1,4,1,2,4,1,1,4,1,2,5 and 1 days. The live stopover study is informed by 46 times the number of female recaptures and 100 times the number of male recaptures than in the carcass surveys. No Chinook salmon were captured live after October 12, 2016.

Data from DFO brood set captures are not included in the population size estimates generated with POPAN and must be subtracted from derived population sizes to represent spawners for contrasting AUC –based estimates.

IEHs were modeled in POPAN (Arnason and Schwarz 1999; Schwarz et al. 1993) in Program MARK (White and Burnham 1999) to estimate population size. IEH INP files with adults and another file of only jacks were constructed for use in Program MARK (Table 1). Two additional INP files without '-'signed group identifiers indicating any LOCs were required for U-Care GOF testing. CloseTest required a separate file for each group consisting only of the IEH strings without group identifiers, semi-colon suffix of the MARK format, and without file header text information. U-CARE will digest data in MARK or BIOMENCO format provided any text or file header information has been removed from the INP file.

Table 1. INP files constructed for goodness of fit to assumption testing and population estimation of Burman River Chinook salmon in 2016.

File name	**CloseTest**	**RELEASE**	**U-Care**	**POPAN**
2016BRCN all grps with transient LOCs.inp		X		X
2016BRCN adults no jacks with transient LOCs.inp		X		X
2016BRCNFemales for CloseTest.inp	X			
2016BRCN Males for CloseTest.inp	X			
2016BRCN Jack for CloseTest.inp	X			
2016BRCN all grps no transient LOCs for UCARE BRCN2016.inp			X	

IEHs were examined in the following manner. First, normally data must be tested with CloseTest (Stanley and Burnham 1999; Stanley and Richards 2005) to identify if closed or open populations models were the correct starting point. General data structure was examined with RELEASE (Burnham et al. 1987) in Program MARK (White and Burnham 1999). U-Care was relied on to assess goodness of fit to transient and trap dependence behaviour models, before assessing if these key homogeneity assumptions extended far enough to legitimize the use of the fully time variable (global) starting model as described by Choquet et al.(2005, 2009). Results of the U-Care tests for heterogeneity in survival (3.SR, 3.SM), and capture probabilities (2.CT, and 2.CL), and Sum of Tests over groups were appropriately summed to provide the GOF test scores and P-values to evaluate the two most common causes of violations which are transient and trap dependent behaviour testing (Pradel et al. 1997). If the data failed to meet and extend beyond the two key assumptions, the data cannot support fully time variable models. In these cases models to address transient or trap avoidance behaviour can be applied (Pradel et al. 1993, 1997, Sasso et al. 2006). These are age models that can be thought of as time-since-marking models with all the first encounters considered a single age class and all subsequent encounters included in a second. The age model can be applied to the apparent survival terms {*Φ*(a2-t)} in the case of transient behaviour and to capture P parameters {*P*(a2-t)} to address trap avoidance behaviour. The proportion of transients is estimable from 1 - the ratio of apparent survival between the 'ages', and the proportion exhibiting trap avoidance. Fortunately, significant violations of these assumptions did not occur in 2015 (Table 4) although the P-value of 0.15 for trap dependence was suggestive of some level of trap avoidance behaviour. Bernard et al. (1999) observed similar trap avoidance behaviour in radio tagged Chinook salmon following handling which they describe as sulking.

A number of terms require careful definition and understanding in the stopover site mark-recapture experiment. Losses-on-capture (LOCs) are given a negative group identifier to signify they are removed from the experiment, such as for broodstock if included or handling mortalities. LOCs can also be coded to address transient tag groups or cohorts with an *operational definition* of zero survival probability to the next sampling occasion if necessary. At the Burman River in the past two cases where zero survival probability was identified it was simply due to fast-moving fish and because sampling ceased and a longer interval between events ensued perhaps with a flood. Transient animals (rapid movers), death and losses to permanent emigration are not separable from but are included in the term *apparent survival* (*Φ*). In this case *apparent survivor* 's are fish that lingered at the stopover pool long enough to have a capture P > zero, and contribute to stopover residence time calculations of Manske and Schwarz (2000). The proportions of transient or fast-migrators are estimated as 1 – residents and the resident proportion is the ratio of *Φ*1/*Φ*2 in a two-age (time-since-marking) survival model (Pradel et al. 1993, 1997, Sasso et al. 2006). Adjustments for transients were incorporated through including at survival time-since-marking model and then model averaging.

Closure and Petersen estimation

The population in the stopover site was not closed in the preceding six years but was open with additions (5 years) and losses (6 years) occurring. For this reason it can be safely assume the Burman River population Chinook salmon is open like most salmon populations (Parsons and Skalski 2002, Velez-Espino et al. 2016). This fact dictates that closed population models like the Petersen method are not appropriate to the data collected at this river. An estimate is provided below simply because it was a study objective and deliverable. The closed population estimate should not be used as the key assumption required is violated by the behaviour of the migrating population.

Relatively few carcasses were recovered in 2016 due to early and higher water levels limiting access and flushing carcasses more frequently than in recent years thus reducing carcass recovery probabilities.

After deducting marked fish removed for hatchery broodstock, the number of marked subjects at large for a potential Petersen carcass estimate included 2010 adults made up of 734 females and 1,237 males, and an additional 66 jacks. Thirty-five females with five marked and 29 males with three marks were recovered with two marked jacks <500 mm POH. Once again this was the largest number of marks released since the project began.

The Petersen estimates and resulting precision measured by the coefficient of variation or percent standard error was 30% and did not achieve the precision goal due to scarcity of carcasses. The number of Chinook salmon in each group was estimated by the carcass survey (Table 2) for posterity although the population was known to be open and no way to properly assess assumptions of no transience or trap dependence is available. The Petersen group estimates are both larger than the open Jolly-Seber values and far less precise. Two marked and no un-marked jacks were recovered so an estimate of 66, the number marked resulted.

Table 2. Petersen estimates based on carcass recoveries of marked Chinook salmon at the Burman River in 2015. **These estimates are not valid as the closure assumption failed.**

Group	Petersen carcass estimate	SE	95% Confidence interval	Coefficient of Variation
Females	4,409	1,515.4	1,439 – 7,379	34 %
Males	9,284	3,859.4	1,720 – 16,848	42 %
Females + Males	13,693	4,146.2	5,566 – 21,820	30%

Snorkel surveys, AUC integral and survey life

Ten snorkel surveys occurred between September 1, and November 8, 2016. A final zero count was missing and estimated per Bue et al. (1998) of November 15, 2016 (Table 3).

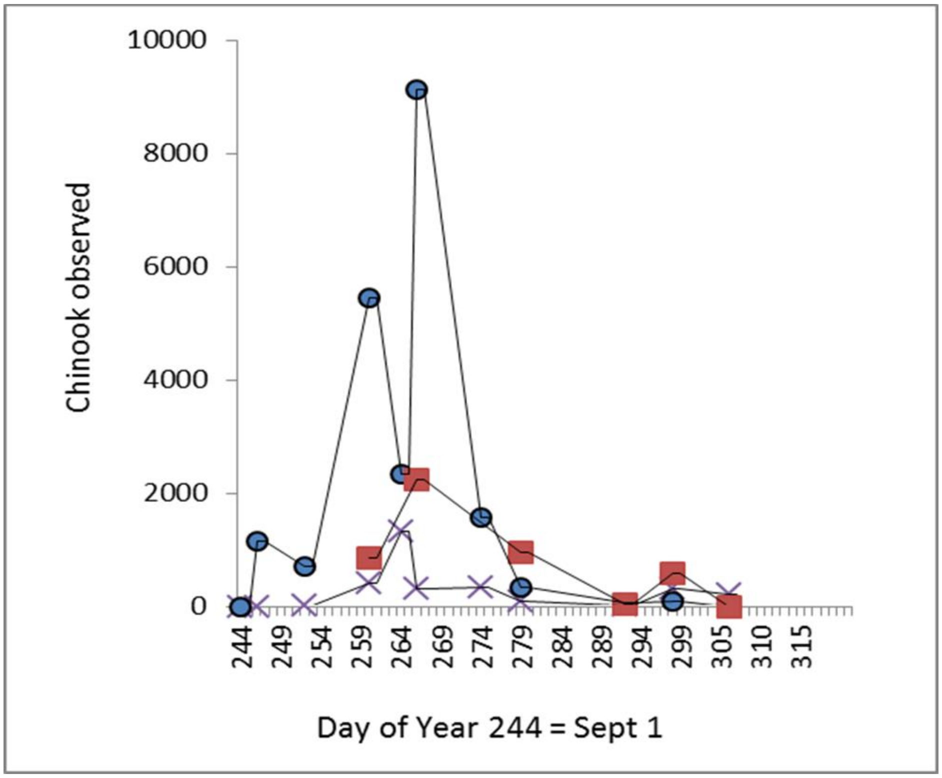

Figure 4. The Chinook salmon (solid circles) unadjusted area-under-the-curve integral was 106,453 fish-days at Burman River in 2016. Coho salmon (X's) and sockeye salmon (squares) unadjusted visual observation curves are also shown. There were four apparent movements of Chinook salmon into the spawning reach in 2016.

The first freshet commenced on August 28, 2016, and was the earliest observed since the study began so the migration delay index of survey life was again earlier and outside the range observed in the relationship. Other effects or interactions with survival (spawning life) need to be considered. A large number of smaller bodied males in the population might also reduce average $\hat{S}$ in addition to the lower capture probabilities of smaller carcasses (Zhou 2002). These animals may have lesser lipid reservoirs to draw from due to smaller size (Mann et al. 2008).

As in the previous year the first freshet occurred before the entire population had arrived and arrival timing must be considered and integrated with the relationship between spawning area survey life and freshet date. It stands to reason that those individuals that spawned early had a more lengthy survey life than later fish as they were relatively few animals. The presence of a few early migrating spawners does not have much weight to affect the annual average survey life greatly.

Using all ten surveys (Figure 4) produced an unexpanded (OE=1.0) AUC integral of 106,453 fish-days, similar to 2015. Division by the mark-recapture estimate (below) yields an average spawning area survey life of 10.2 days, nearly double than of 2015 which was considered very low at 4.8 days given the early initial freshet.

Mark-recapture estimation

Assumption testing for survival and capture

As in 2015 we assumed the population was open as demonstrated with CloseTest from 2009-2014. There was no evidence of transient or trap avoidance behaviour in 2016 data (Table 4). Overall the data was robust enough to meet the survival and capture probability assumptions thus permitting the use of the fully time variable (Cormack-Jolly-Seber) starting model for both females and males. Although the tests were non-significant there was support for transients and group survivals as well (Table 5).

Table 4. Testing for homogeneity of survival and capture probability assumptions of homogeneity among groups of Chinook salmon in 2016 at Burman River.

Goodness of fit test		***Φ* (a2*t), *P*(t)**	***Φ* (t)*P* (m*t)**	***Φ* (t), *P* (t)[a]**
Females	**df**	44	49	60
	χ^2	21.63	32.77	35.80
	P	1.00	0.96	0.99
Males	**df**	49	53	65
	χ^2	43.34	53.72	61.54
	P	0.70	0.45	0.60

[a] fully time variable Cormack-Jolly-Seber model

Open population estimates

The model with the greatest support in 2016 *was* {*Φ* (g) *P* (gt) *P*ENT (t)}, as in 2015 where apparent survival was constant within but not among groups, and capture probability was variable both among and within groups with time (Table 5). Entry probabilities were not different between groups but varied with time. Model averaging was required due to support for models correcting for survival (transients) and constant survival within groups.

Table 5. Table of model results for open population Jolly-Seber models from POPAN in Program MARK for Burman River Chinook salmon escapement in 2016.

Model	AICc	Delta AICc	AICc Weights	Model Likelihood	Num. Par	Deviance
{ Phi (g) P(gt) pent (t)}	4200.201	0	0.71487	1	66	0
{P(gt) phi (g-a2t) pent (t)}	4202.656	2.4552	0.20945	0.293	68	0
{P(t) phi (g) pent (t)}	4204.692	4.4914	0.07567	0.1059	45	0
{P(gt) phi (g) pent (gt)}	4223.302	23.1014	0.00001	0	86	0
{P(gt) phi (gt) pent (gt)}	4231.125	30.9241	0	0	124	0
{P(g) phi (gt) pent (gt)}	4262.909	62.7079	0	0	84	0
{P(g-a2t) phi (g-a2t) pent (t)}	4443.520	243.3188	0	0	30	0
{P(g-a2t) phi (g) pent (t)}	4445.968	245.7668	0	0	28	0
{P(g-a2t) phi (g) pent (gt)}	4477.622	277.4212	0	0	48	0

Figure 5 illustrates the daily abundance of Chinook salmon by sex group in the lower Burman River stopover site pool in 2016 during the study.

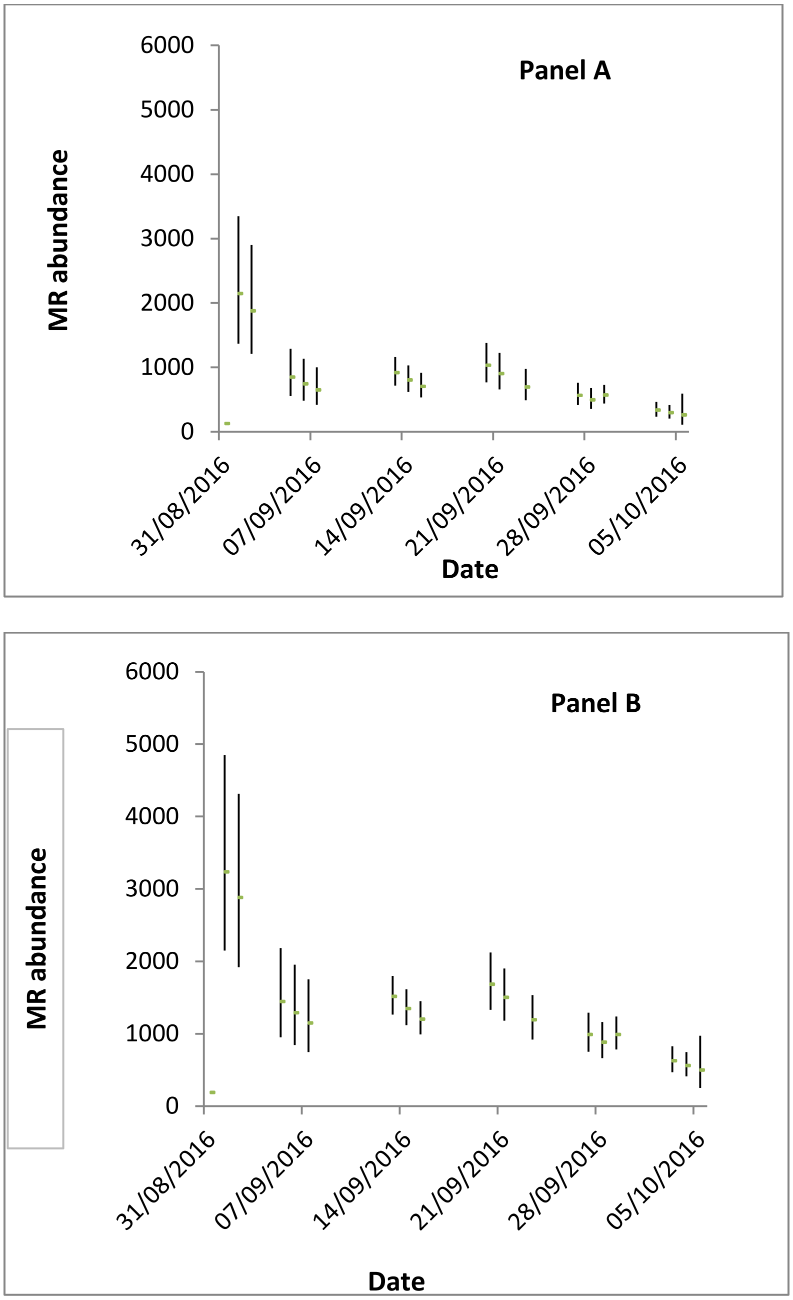

Figure 5. Daily female (Panel A) and male (Panel B) Chinook salmon live POPAN Jolly-Seber mark-recapture abundance estimates, at the Burman River migration stopover site in 2016. Bars are 95% confidence intervals.

The total return of Chinook salmon of all origins, natural, Burman hatchery and strays from other WCVI regional hatcheries was 10,455 (SE=1,103.6, CV=11%) and exceeded the precision criteria of the CTC for escapement estimates (Table 6).

Table 6. Model-averaged population sizes for Chinook salmon at Burman River in 2016.

Group	N*-hat	Standard Error	95% Confidence Limits Lower	Upper	CV%
Females	3,689	479.1	2,750	4,628	13
Males	6,766	994.2	4,818	8,715	15
Adults	10,455	1,103.6	7,567	13,343	11

Origin and Age

Examination of saggitae (otoliths) from broodstock for thermal batch marks applied to local hatchery stocks indicated the following main components in the 2016 escapement: natural or wild (0.14. SE=0.03), Burman River origin hatchery (0.73, SE=0.03) and other strays predominantly from Conuma River ere 0.13 (SE=0.03)

Combining the open population and origin estimates produced component stock escapement estimates in Table 7 and from 2009 - 2016 in Figure 6.

Table 7. Estimated abundance of Burman River Chinook salmon by origin in 2016.

Origin	**N-hat (Pop size)**	**SE**	**Coefficient of Variation%**
Naturals	1,584	430.8	23%
Burman Hatchery	7,452	932.9	11%
All Burman	9,036	1027.5	11%
Conuma/ Strays	1,408	406.3	29%
All origins	10,455	1104.9	11%

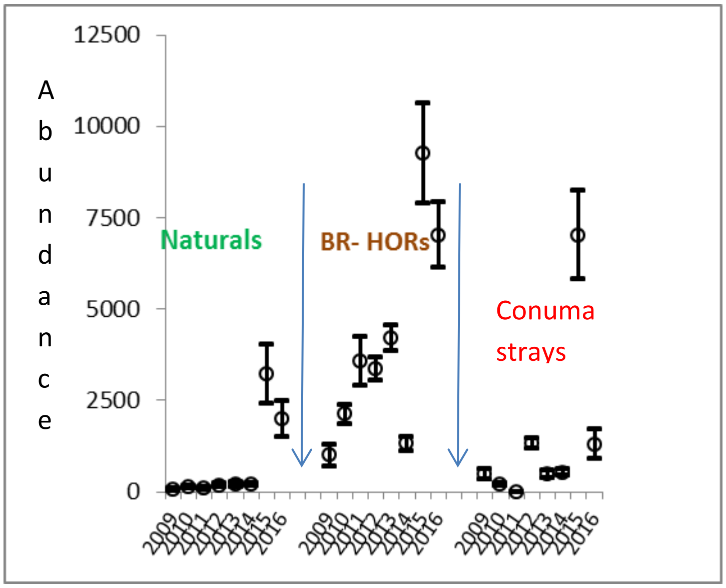

Figure 6. Abundance of natural spawning, Burman River hatchery, and stray Chinook salmon at Burman River from 2009-2016 estimated by combining live mark-recapture estimates with annual origin proportions from thermal skeletal marks applied at hatchery. Bars are 95% confidence intervals.

Figure 6 shows similar patterns of survival in Burman origin groups and variable but large and constant incursions of strays from the Conuma Hatchery. The low abundance of Burman Hatchery origin fish in 2014 simply reflects that in 2011 the hatchery brood capture was unsuccessful due to early upstream migration. The Burman River program provides a unique opportunity to monitor the response of Chinook salmon to alterations of agency husbandry practices initiated to address straying and genetic introgression. Age-origin frequencies, relative abundances and estimated absolute abundances follow in Tables 7,8 and 9.

Table 7. Age and origin frequencies of Chinook salmon spawning at the Burman River in 2016 estimated from thermally marked otoliths (n=205) recovered from 208 hatchery broodstock.

	Burman River origin				Strays						
Age	**Not Marked**	**Burman H4,2**	**Sum Burman**	**Prop 0f Burman**	**Conuma Early H5-2**	**Conuma Late H5-3**	**Tlupana/Sucwoa H3**	**Gold Sea Pen H2,5**	**Robertson 3H**	**Sum strays**	**Prop strays**
21											
31	1	19	20	0.15	2	2	1			5	0.24
41	19	92	111	0.83	7	3		2	1	13	0.62
51	1	1	2	0.015	2	1				3	0.14
61	1	0	1	0.007							
Total	22	112	134	0.87	11	6	1	2	1	21	0.23

Table 8. Relative abundance by age and origin estimated from thermally marked otoliths recovered from broodstock collected at Burman River in 2016.

Age	Burman Naturals-Not Marked	SE	Burman Hatchery H4,2	SE	Conuma Early sea-pens H5-2		Conuma Late sea-pens H5-3		Gold River sea pen H2,5		Muchalat Lake pen on Gold		Robertson Creek 3H	
31	0.007	0.007	0.100	0.025	0.013	0.009	0.013	0.009	0		0		0	
41	0.127	0.027	0.613	0.040	0.047	0.017	0.020	0.011	0.013	0.009	0.000		0.007	0.007
51	0.007	0.007	0.007	0.007	0.013	0.009	0.007	0.007	0		0		0	
61	0.007	0.007	0	0	0	0	0	0	0		0		0	

Table 9. Estimated absolute abundance (SE) of Chinook salmon by origin identified from hatchery and brood source specific thermally marks in the escapement at Burman River in 2016. Burman River natural and hatchery fish totalled 9,036 (SE=1024.4, CV=11%) and strayed Conuma early and late release groups totalled 1,408 (SE=405.1, CV=29%). About 278 more strayed half from Gold River sea-pen stocks and Robertson Creek. Muchalat Lake pen on the Gold River is noticeably absent from Burman River from 2009-2016, but has double the relative abundance of sea-penned fish in the brood collections, suggesting better imprinting and apparent survival from lake pen rearing.

Age	Burman Naturals-Not Marked	SE	Burman Hatchery	SE	Conuma Early & Late - Sea-pens	SE	Gold River sea pen	SE	Muchalat Lake pen on Gold	Robertson Creek	SE
			H4,2		H5-2		H2,5			3H	
31	72	89.8	1035	340.5	196	148.3	0		0	0	
41	1368	400.4	6348	861.1	1199	375.0	139	127.1	0	139	127.1
51	72	89.8	69	87.6	13	38.2	0		0	0	
61	72	89.8	0	0.0	0	0.0	0		0	0	
Totals	1584	429.5	7452	930.1	1408	405.1	139	127.1	0	139	127.1

CONCLUSION

For the eighth consecutive year the POPAN open population mark recapture technique was successfully applied to a WCVI ocean-type Chinook salmon population by sampling in a single migration stopover pool. To our knowledge this eight year study is the first application of POPAN to Chinook salmon using only live encounters. The program achieved the SSP precision goal as the coefficient of Variation of the estimate was 10%, less than the target average of <u><</u>15%. Testing for the most common assumption violations allowed application of the fully global starting model unrestricted to age or time-since marking models and survival and capture rates were sufficient. However there was support for both limited transient behaviour and group constant survivals so model averaging was required.

Snorkel survey fish-day integral when divided by the open mark-recapture estimate to generate an estimate spawning area survey life again did not fit the expected relationship suggesting another factor(s) may contribute to an altered form of the relationship related to the arrival timing of the stock. Future work is required to integrate early spawning migration timing with the spawning area survey life index.

AUC integrals generated from observations at Burman in 2015 and at Conuma in 2014 suggest a density effect causes shadowing but also a shift to estimating group size rather than carefully counting individuals by observers occurs. Radio telemetry at the later site gave a detection probability (OE) of 0.30, lower than at Burman in 2012 (0.5) under lower density conditions. This issue needs to be explicitly addressed in the field program by recording in which habitat feature or 500 m counting section records were actual *counts* and which were *estimated* group sizes. A procedure should be explored and adopted if informative that tests the validity of methods to estimate a missing peak observation, with the proviso of sufficient survey frequency, and by fitting an appropriate spawner curve. This may improve the relationship with freshet date.
I note this may be why some spawner curves are unimodal and others bi-modal. The curve has a single peak if the first freshet is late and all of the fish have arrived and a bimodal form if there are movements to freshets both before and after the bulk of spawners have arrived. Four peaks or movements of Chinook salmon into the spawning area occurred In 2016.

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