Abundance and origin of the Chinook salmon (*Oncorhynchus tshawytscha*) spawning escapement in 2015 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 1,917 Chinook salmon >500 mm post-orbital hypural length were marked, the largest number of marks applied in seven study years. Marked fish were 27 % female and 73% male. Fifty-eight female carcasses bearing seven (12%) marks and 131 males with 17 (13%) bearing marks were recovered in carcass surveys. An open population mark-recapture analysis with POPAN (Schwartz and Arnason 1996) in Program MARK (White and Burnham 1999) produced an estimate of 3,732 (SE=545.7, 95%CI 2,807-4,964, CV=15%) females and 16,430 (SE=1,936.4, 95%CI 13,052 - 20,684, CV=12%) males. Previous work demonstrated the population is demographically open at the marking site (Dunlop 2016). The total escapement of Chinook salmon of all origins was 20,163 (SE=2011.8, 95%CI 15,859 – 25,647, CV= 10%). The estimate exceeded the target precision standard (CV =≤15% on average). Virtually all model weight was assigned to the model {*Φ(g) P (gt) Pent (t)*} with an AICc score of 0.9997. A closed population Petersen estimate, although not valid due to failure of the critical closure tenant, was generated for posterity. Examination of saggitae (otoliths) from broodstock for thermal batch marks applied to local hatchery stocks indicated the following main components in the 2015 escapement: natural or wild (0.167. SE=0.026), Burman River origin hatchery (0.463, SE=0.035) and other strays predominantly from Conuma River were 0.365 (SE=0.033). Combining the open population and origin estimates produced component stock escapement estimates of: 3,219 (SE =805.5, CV= 25%) natural spawned Chinook salmon; 9,266 (SE =1,367.7, CV= 15%) Burman River origin hatchery fish; and stray spawners, that were predominantly from Conuma River facility sea-pen production of 7,023 (SE=1,198.1, C17%); and an estimated 390 (SE=280.3 CV= 71%) strays from other WCVI facilities. Natural spawners had averaged 5.5% (SE=2.3%) of the return from 2009 to 2014. Interestingly, the relatively higher proportion of natural Burman River spawners in 2015 resulted from good early survival combined with a complete lack hatchery production at Burman River in 2011. The age-2 jack males (≤ 500 mm POH) return was very low and was estimated to have been 183 (SE=27.3, 95%CI 137 – 245, CV= 15%) salmon. This was the lowest escapement of jacks observed since the study began in 2009 which forebodes little recruitment from the 2013 brood year in years 2016-2019.

Introduction

A mark-recapture experiment and snorkel surveys were conducted to estimate the number of Chinook salmon (*Onchorhynchus tschawytscha*) returning to spawn at the Burman River in 2015. This was the seventh year of study. The Burman River Chinook stock is enhanced by hatchery production although a normally small population of natural spawners is present each year. The river also receives strays Chinook salmon produced at other WCVI production hatcheries. The 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 as a stock of conservation concern from over two decades.

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 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).

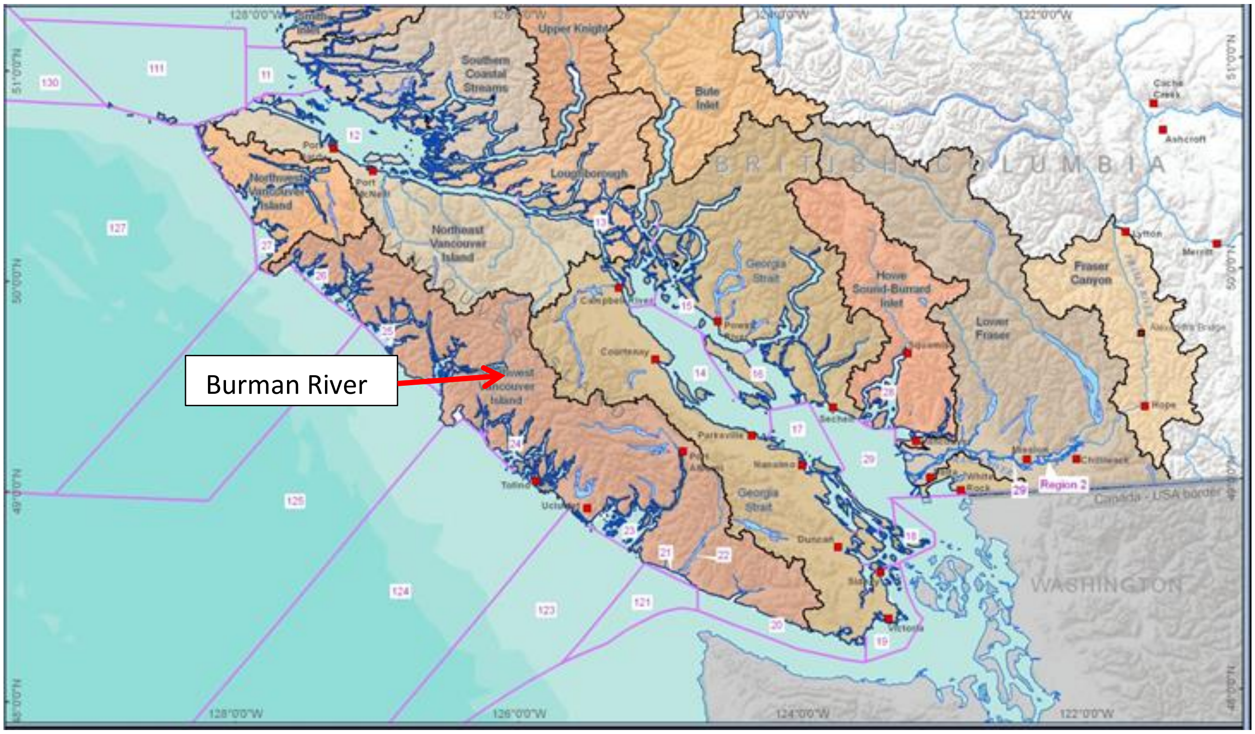

Figure 1. Location of the Burman River on Vancouver Island west coast, British Columbia.

Burman River Chinook salmon are a coastal stock with an ocean-type life-history. The 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). An ocean type life history strategy is required due to infrequent but severe droughts that occur in the region (Coulthard and Smith 2015). 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 2009-2015 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 from 2009-2015. Fish 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 or 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, 2015, and continued past October 2, 2015, when the last live Chinook salmon was captured. Three sets per day continued on four additional occasions until October 15th in an attempt to ensure marking of 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 escapement, hatchery and strays present. The Burman River is an escapement indicator stock for WCVI Natural Chinook in the Pacific Salmon Treaty. 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 can prove difficult to obtain in some years. Ten female and 10 male tagged fish removed in the hatchery broodstock collection were censored from the experiment data. An additional 87 unmarked female and 121 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 also removed from the total escapement to obtain an estimate of the Burman River origin Chinook salmon.

Snorkel surveys were conducted on 21 occasions between August 28 and November 15, 2015, and occurred every 3.6 days on average to approximate the minimum spawning survey life (S) observed in the recent past and properly define the integrals. Observers recorded a joint 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. Jacks were counted separately and were tagged with a single #3 Kurl-lock numbered sheep tag attached to an operculum to allow identification during recaptures without interference with snorkel observations for larger fish. In 2015 two snorkel crews were deliberately staggered to compare the AUC integrals produced. Rare repeat snorkel counts the same day in the past had often resulted in a lower observation by the following party.

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 from the number of effective marked fish released and recovered marked and unmarked carcasses by sex.

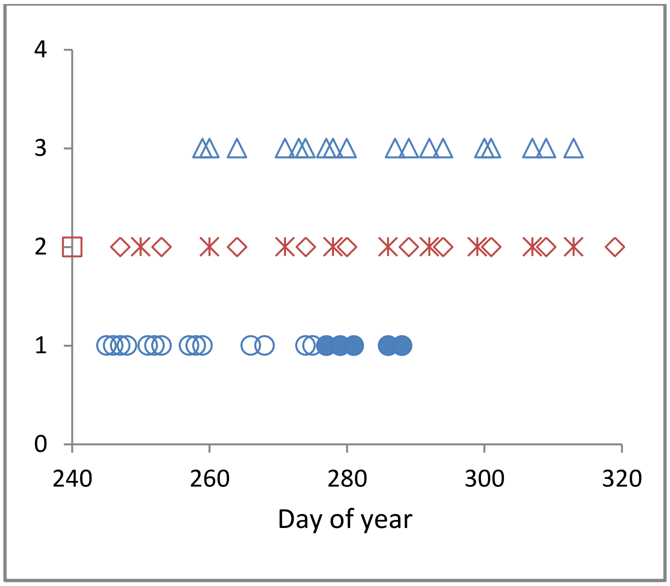

Figure 2. Shows the study designs resulting timing of live marking and recapture events with (open circles) and without Chinook salmon catches (solid circles), snorkel surveys (crew 1 diamonds, crew 2 stars), and carcass surveys (triangles) in 2015 at Burman River.

Results and Discussion

More Chinook salmon were marked in 2015 than in any year to date at Burman River. Individually numbered tags and a secondary mutilation mark were applied to 1,924 large Chinook salmon (>500 mm POH). The groups consisted of 514 females and 1,410 large males and an additional 70 jacks ($\leq$ 500 mm POH).

Among females marked 19% in three tag cohorts and 8% males in two early tag cohorts were not seen again in the live experiment. Another 70 jacks (age-2 males $\leq$500 mm POH) were marked and 46% of them in four tags groups were not seen again. Coding transients tag groups (not individual tags) not seen again retains the encounters for estimating N-hat but reduces the variability around the apparent survival parameter estimates (C. Schwarz, Simon Fraser University (SFU) per. comm. October 2015). Transients are fast migrating fish operationally defined as those with zero probability of surviving (being present) to the next occasion. Here it is due to either the release group being too small to be captured (low P), a long period between occasions or due to freshets suspending capture operations. Coding individual tag groups never seen again as losses on capture removes them from the experiment and hence variability is reduced as those animals cannot be recaptured again (C. Schwarz, SFU, per. comm., October 2015). This was not necessary in 2015.

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 on September 17 and 19, 2015, were censored from the experiment as it was not possible to mark all fish released in those sets with a larger net. There were 13 sampling events with captures from Day of Year 245 or September 2, 2015 to October 2, 2015 (Day 275) after which no Chinook salmon were captured in the daily three set maximum on five more occasions (October 4, 6, 8, 13 and 15th). The intervals were 1, 1, 1, 3, 1, 1, 4, 1, 1, 6, 7, and 3 days. No jacks were caught alive at the stopover site after September 22, 2015. As in each year an attempt to sample with the robust design, and accomplished this for first three weeks until floods disrupted the planned schedule in the last week. There were 516 females marked and released and 60 (11.6%) live female were recaptured. A record number of 1,411 large males was marked and relatively few, 152 (10.7%), were recaptured due to high flows, and shorter average stopover times. The live stopover study recaptured and is informed by 8 times the number of female recaptures and 9 times the number of male recaptures than were recovered in the carcass surveys. No Chinook salmon were captured live after October 2, 2015. Seventy jacks (<500mm POH) were marked and 12 (17.4%) were recaptured alive. 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 that included both groups 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 2015.

File name	**CloseTest**	**RELEASE**	**U-Care**	**POPAN**
2015BRCN all grps with transient LOCs.inp		X		X
2015BRCN adults no jacks with transient LOCs.inp		X		X

2015BRCNFemales for CloseTest.inp	X			
2015BRCN Males for CloseTest.inp	X			
2015BRCN Jack for CloseTest.inp	X			
2015BRCN all grps no transient LOCs for UCARE Feb 6 2016.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 for the two most common causes of violations which are transient and trap dependent behaviour testing (Pradel et al. 1997). If the data fail 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 $\Phi 1/\Phi 2$ in a two-age (time-since-marking) survival model (Pradel et al. 1993, 1997, Sasso et al. 2006). Adjustments for transience and trap dependence were not required in 2015.

Fifteen carcass surveys followed the same route down the channel over the 7.5 km spawning reach from September 16 through November 5th, 2015, after which no carcasses were recovered on November 8th and sampling ceased.

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 (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 2015 due to early and higher water levels limiting access and flushing carcasses more frequently than in recent years thus reducing carcass recovery probabilities. The first freshet occurred on September 4, 2015. A total of 189 carcasses were recovered of which 161 were unmarked and 23 were acceptably marked carcasses, fewer than required to achieve the precision target in 2015. An additional seven tags picked up without a carcass were numbers identifying 6 males and a single female. Seven females (12%) were marked among 58 carcasses, the absolute minimum required for a Petersen estimate. In males > 500 mm POH, 17 of them (13%) were marked among 131 recovered carcasses. These included 6 males and 1 female that lost tags. Two unmarked jacks were recovered precluding a carcass estimate. One unmarked female collected outside the regular sample area and was also discarded from the data set.

After deducting 20 marked fish removed for hatchery broodstock, the number of marked subjects at large for a potential Petersen carcass estimate included 1,924 adults made up of 514 females and 1,411 males, and an additional 70 jacks. 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 17.5% and did not achieve the precision goal of a CV of 15% or less. 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. Only two unmarked jacks were recovered so an estimate of this type was not possible. The female Petersen estimate was nearly identical to the open population value but precision was much lower. The male estimate and its upper confidence bound were below the open values and less precise.

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	3,812	1,172.5.3	2,639 -- 6,110	31 %
Males	10,354	2,193.5	8,160 – 14,653	21 %
Females + Males	14,165	2,770.2	10,800 – 20,763	17.5%

Snorkel surveys, AUC integral and survey life

Twenty one snorkel surveys were recorded between an August 28 zero count and a final zero count estimated per Bue et al. (1998) of November 15, 2015 (Table 3) or every 3.9 days (SE= 1.7) on average, in an attempt to survey more often than the length of the average survey life (Figure 3). Failure to do so introduces error to estimates of the spawner curve integral as inflection points may be obscured.

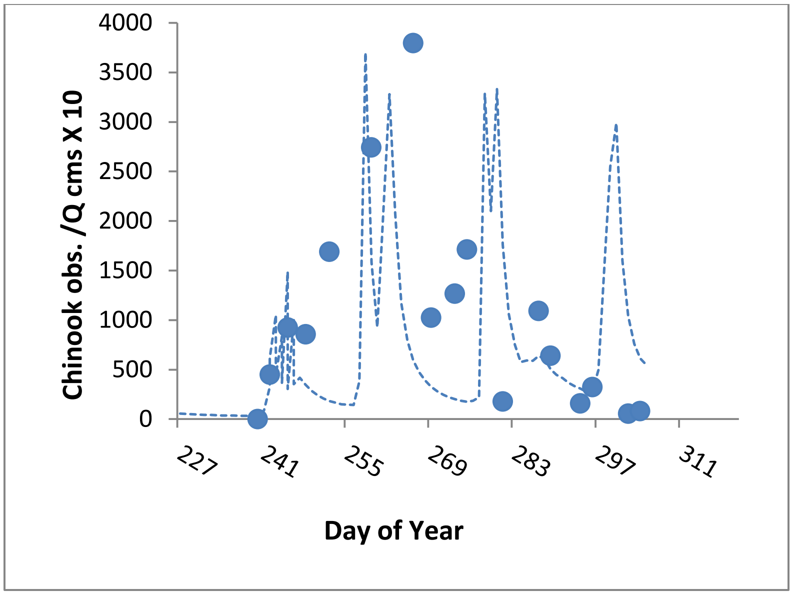

Figure 3. Periodic observations of Chinook salmon in spawning area at Burman River in 2015 and adjacent Gold River hydrograph exaggerated X 10 Q-cms

A freshet occurred on September 4, 2015. This was the earliest freshet encountered to date during the study and it occurred 4 days earlier than the former earliest freshet date of September 8 that had occurred in 2009. Two separate snorkel crews were deliberately alternated during each survey in 2015. The intension was to examine the difference between two separate crews of observers, and estimate of observer variance in the resulting AUCs integrals. The difference between the fish-day spawner curves generated by the two crews was minimal and differed by 6% if the peak observation is shared or ignored. Only one crew could observe the peak count. Earlier attempts with observers following one another, perhaps too closely, resulted in disparate observations due to alarmed fish. The 6% difference between crews making 10-11 surveys each every 7.4 days (SE=1.6) on average, over the season, is remarkably consistent given annual vagaries in flows, etc. This frequency may have been suitable in 2015 when early freshet date suggest a relatively lengthy spawning area life.

Using the migration delay index to spawning area survey life relationship developed 2009-2014 data without 2015 data suggests an $\hat{S}$ (Dunlop 2016b, Parken et al. 2003) of 14.35 days = -4.689*Ln(4 Days Delay)+20.858 in 2015. However dividing the AUC integral of 100,756 fish-days (Table 3) by the predicted 14.3 day survey life gives an unlikely estimate of 7,045 Chinook salmon, about four times the number of individuals adult animals handled and tagged. The freshet in 2015 was the earliest observed since the study began so the migration delay index of survey life was 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).

A plausible explanation is that 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. However, 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. This also lends credence to reports by snorkelers of having seen the same fish repeatedly over several weeks. The snorkel observations and a decline in population size in the stopover pool shows that the bulk of the population moved later in the season. Lesser lipid stores will remain in those dallying fish that dictates they will have a reduced spawning life that is shorter than earlier fish. Further investigation of the effects of body size, and a measure of lipid reserve depletion over the run, and integration of arrival timing with the spawning area survey life and migration delay relationship, would be useful. Hatchery production practices appear to accelerate maturation rates. Selective removals of the large fish in all fisheries may contribute: age-3 fish are less that legal size limit of 28 inches SEAK, and most Canadian sport fisheries also covet the older, larger, hence mostly female, individual trophy size fish. Some selection in these fisheries may contribute to the skewed sex ratios recently observed at Conuma River hatchery and at Burman River. It is also possible that straying of the sea-pen reared hatchery Chinook might be aggravated by the sex ratio mismatches observed at the spawning grounds (70%-80% males) and an ensuing search for mates elsewhere.

Table 3. Snorkel survey observations and resulting trapezoidal estimate of the AUC integrals using all 21 snorkel surveys of a subset of surveys selected to mimic the agency survey frequency of Chinook salmon at Burman River in 2015.

				All surveys			6-8 selected surveys		
Survey	Crew	Date	Day of year	Chinook obs.	Trapezoid area	AUC integral (fish-days)	Chinook observed (6-8	Trapezoid area	AUC integral (fish-days)
1	1	28/08/2015	240	0		66009.5	0		100756
2	2	04/09/2015	247	450	1575				
3	1	07/09/2015	250	953	2104.5		953	4765	
4	2	10/09/2015	253	558	2266.5				
5	1	15/09/2015	258	1690	5620		1690	10572	
6	2	17/09/2015	260	1643	3333				
7	1	21/09/2015	264	562	4410				
8	2	28/09/2015	271	3794	15246				
9	1	01/10/2015	274	1060	7281		3794	43872	
10	2	05/10/2015	278	1260	4640				
11	1	07/10/2015	280	1712	2972		1712	16518	
12	2	13/10/2015	286	571	6849				
13	1	16/10/2015	289	568	1708.5				
14	2	19/10/2015	292	1062	2445		1062	16644	
15	1	21/10/2015	294	640	1702				
16	2	26/10/2015	299	158	1995				
17	1	28/10/2015	301	334	492		334	6282	
18	2	03/11/2015	307	49	1149				
19	1	05/11/2015	309	39	88				
20	2	09/11/2015	313	11	100		11	2070	
21	est	15/11/2015	319	0	33		0	33	

Using an eight survey subset of the observations to mimic agency surveys that typically consist of 6-8 surveys produced an unexpanded (OE=1.0) AUC integral of 100,756 fish-days. Division by the mark-recapture estimate (below) yields an average survey life of 4.8 days. As surveys occurred on average every 3.9 day the objective of conducting visual survey more frequently than the average survey lifespan was therefore met.

The survey life of 4.8 days did not fit the pattern observed from 2009 – 2014 and appeared to be an anomaly to the recent pattern. A longer survey life was expected with a freshet on September 4.

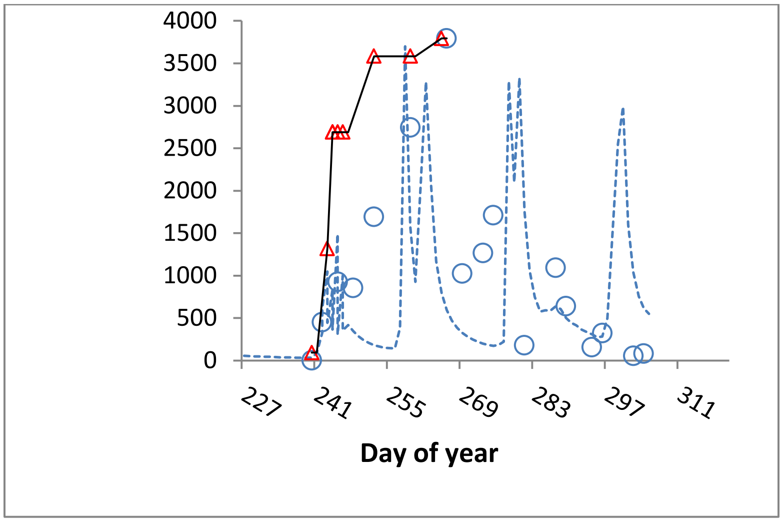

Figure 4 . Gold River mean daily discharge (Q-cms) exaggerated X 10 (dashed line), cumulative proportion arrived (triangles) at stopover site downstream from the spawning area scaled to the peak visual spawner observation, and unadjusted (OE=1.0) snorkel observations of Chinook salmon (open circles) in Burman River spawning area in 2015. Observations occurred on 17 occasions and 16 occurred under good conditions, all except for day 281. All Chinook salmon (100%) had arrived at stopover site by day 265 (September 25, 2015).

Mark-recapture estimation

Assumption testing for survival and capture *P*

There was no strong evidence of transience or trap avoidance behaviour in 2015 from testing of IEHs with U-CARE (Table 4). The trap response was suggestive of an immediate trap response pattern in the data in females although it was judged insignificant. Jack data was insufficient for valid inference about meeting the assumptions in 2015. Overall the data was robust enough to meet the assumptions to permit the use of the fully time variable starting model for both females and males.

Table 4. Testing for homogeneity of survival and capture probability assumptions of homogeneity among groups of Chinook salmon in 2015 at Burman River.

Goodness of fit test	Females			Males		
	$\chi2$	*df*	*P*	$\chi2$	*df*	*P*
Transient model {*Φ(a2-t) P(t)*}	8.68	9	0.447	11.51	22	0.967
Trap response model {*Φ(t) P(a2-t)*}	15.62	11	0.156	12.33	26	0.989
Time variable CJS model[1] {*Φ(t) P(t)*}	15.62	15	0.407	13.64	30	0.996

[1] Cormack-Jolly-Seber

The higher χ^2 values were all generated by test 2.CL caused the global test for transience among all groups to be significant but the subcomponent test 2. CL was responsible

Open population estimates

The model with the greatest AICc of 0.9997 support (Table 5) *was* {*Φ* (g) *P* (gt) *P*ENT (t)} where apparent survival was considered constant within but not among the groups, and capture probability was variable both among and within groups with time. Entry probabilities were not different between groups but varied with time.

Table 5. Table of model results for open population Jolly-Seber models from POPAN in Program MARK for Burman River Chinook salmon escapement in 2015.

Model	AICc	Delta AICc	AICc Weight	Model Likelihood	Num. Par
{*Φ* (g) *P* (gt) *P*ENT (t)}	1631.03	0	0.9997	1	32
{*Φ* (g) *P* (gt) *P*ENT (gt)}	1647.71	16.6767	0.0002	0.0002	42
{*Φ* (t) *P* (gt) *P*ENT (gt)}	1656.24	25.2034	0	0	50
{*Φ* (g) *P* (t) *P*ENT (t)}	1661.62	30.5858	0	0	21
{*Φ* (t) *P* (gt) *P*ENT (t)}	1662.82	31.7846	0	0	40
{*Φ* (gt) *P* (gt) *P*ENT (t)}	1663.73	32.6928	0	0	50
{*Φ* (gt) *P* (gt) *P*ENT (gt)}	1665.21	34.1781	0	0	60
{*Φ* (t) *P* (g) *P*ENT (gt)}	1666.6	35.5634	0	0	30
{*Φ* (t) *P* (t) *P*ENT (t)}	1671.64	40.6036	0	0	29
{*Φ* (g) *P* (g) *P*ENT (t)}	1738.20	107.1639	0	0	22

The total return of Chinook salmon of all origins, natural, Burman hatchery and strays from other WCVI regional hatcheries was 20,163 (SE=2011.8, CV=10%) and exceeded the precision criteria of the SSP and CTC for escapement estimates (Table 6). To estimate the number of spawners 87 females and 121 males must be removed from the group totals, or 208 adults from the total escapement Chinook salmon to account for hatchery brood stock removals.

Sex group open population estimates of abundances were 3,732 (SE=545.7, 95%CI 2,807-4,964, CV=15%) females and 16,430 (SE=1,936.4, 95%CI 13,052 - 20,684, CV=12%) males (Table 5). The age-2 'jack' male (≤ 500 mm POH) return was very low and estimated to have been 183 (SE=27.3, 95%CI 137 – 245, CV= 15%) salmon. This was the lowest escapement of jacks observed since the study began in 2009 which forebodes little recruitment from the 2013 brood year in years 2016-2019.

Table 6. Derived gross population sizes[1] from model {*Φ* (g) *P* (gt) *P*ENT (t)} for Chinook salmon at Burman River in 2015. Broodstock collected for hatchery purposes (87 females and 121 males or 208 adults were killed but 3 were discarded) have not been removed from the estimates.

Group	N*-hat	Standard Error	95% Confidence Limits Lower	Upper	CV%
Females	3,733	545.7	2,807	4,964	15%
Males	16,431	1936.4	13,052	20,684	12%
Adults	20,163	2011.8	15,859	25,647	10%
Jacks[a]	183	27.14	138	245	15%

[a] jacks were modeled separately

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 2015 escapement:

natural or wild (0.167. SE=0.026), Burman River origin hatchery (0.463, SE=0.035) and other strays predominantly from Conuma River were 0.365 (SE=0.033) (Table 6 and 7).

Combining the open population and origin estimates produced absolute component stock escapement estimates of: 3,219 (SE =805.5, CV= 25%) natural spawned Chinook salmon; 9,266 (SE =1,367.7, CV= 15%) Burman River origin hatchery fish; and stray spawners, that were predominantly from Conuma River facility sea-pen production of 7,023 (SE=1,198.1, C17%); and an estimated 390 (SE=280.3 CV= 71%) strays from other WCVI facilities (Table 9). Natural spawners had averaged 5.5% (SE=2.3%) of the return from 2009 to 2014. Interestingly, the relatively higher proportion of natural Burman River spawners in 2015 resulted from good early survival combined with a complete lack hatchery production at Burman River in 2011. Whether there the result of simply good early marine survival or related to lack of a competitive hatchery cohort is uncertain.

Table 7. Age and origin frequencies of Chinook salmon spawning at the Burman River in 2015 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 Burman**	**Conuma Early H5-2**	**Conuma Late H5-3**	**Tlupana/Sucwoa H3**	**Gold H2,5**	**Robertson 3H**	**Sum strays**	**Prop strays**
21						1					
31	2	73	75	0.37	19	3	1	1		24	0.12
41	13	3	16	0.08	13	28		1		42	0.20
51	18	19	37	0.18	5	4			1	10	0.05
61											
Total	33	95	128	0.62	37	36	1	2	1	76	0.37

Table 8. Relative abundance by age and origin estimated from thermally marked otoliths recovered from broodstock collected at Burman River in 2015.

Age	Not Marked	SE	Burman H4,2	SE	Conuma Early H5-2	SE	Conuma Late H5-3	SE	Tlupana /Sucwoa H3	SE	Gold H2,5	SE	Robertson 3H	SE
21	-	-	-	-	-	-	0.005	0.005	-	-	-	-	-	
31	0.010	0.007	0.356	0.034	0.093	0.020	0.015	0.008	0.005	0.005	0.005	0.005	-	-
41	0.063	0.017	0.015	0.008	0.063	0.017	0.137	0.024	-	-	0.005	0.005	-	-
51	0.088	0.020	0.093	0.020	0.024	0.011	0.020	0.010	-	-	-	-	0.005	0.005
61	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	0.161	0.026	0.463	0.035	0.180	0.027	0.176	0.027	0.005	0.005	0.010	0.007	0.005	0.005

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 2015. Burman River natural and hatchery fish totalled 12,485 (SE=1587.3, CV=13%) and Conuma early and late release groups totalled 7,023 (SE=1198.1, CV=17%). About 400 more strayed from other local marked stocks and Robertson Creek.

Age	Not Marked	SE	Burman H4,2	SE	Conuma Early H5-2	SE	Conuma Later H5-3	SE	Tlupana /Sucwoa H3	SE	Gold H2,5	SE	Robertson 3H	SE
21	0	-	0	-	0		98	140.2	0		0		0	
				0										
31	195	198.2	7,120	1,198.6	1,853	611.1	293	242.8	98	140.2	98	140.2	0	
41	1,268	505.5	293	242.8	1,268	505.5	2,731	741.9	0		98	140.2	0	
51	1,756	594.8	1,853	611.1	488	313.4	390	280.3	0		0		98	140.2
61	0	-	0	-	0		0		0		0		0	
				0.0										
Total > age-2	3,219	805.5	9,266	1,367.7	3,609	853.0	3,414	841.4	98	140.2	195	198.2	98	140.2

Table 10 . Chinook salmon mark-recapture arrays at Burman River stopover site in 2015. Note the few recaptures of females after occasion 7 when few were released and delayed recaptures in males at occasions 2, 7 and 8.

Occ.	R(i)	j = 2	3	4	5	6	7	8	9	10	11	Total
Group 1 Females												
1	81	3	0	3	0	1	1	0	1	0	0	9
2	27		1	1	1	0	0	0	0	1	0	4
3	76			3	3	1	0	1	3	0	1	12
4	96				3	3	3	1	2	0	0	12
5	46					1	0	0	1	0	1	3
6	58						2	2	0	0	0	4
7	26							0	0	0	0	0
8	4								0	0	0	0
9	8									0	0	0
10	23										3	3
Group 2 Males												
1	115	0	4	2	2	1	4	0	2	0	0	15
2	60		0	0	0	0	0	1	0	0	1	2
3	267			4	3	4	6	0	3	1	0	21
4	194				2	6	4	1	4	0	0	17
5	104					2	2	1	2	0	1	8
6	128						8	4	2	0	0	14
7	158							0	1	0	0	1
8	124								0	1	0	1
9	146									3	5	8
10	100										9	9

Conclusion

For the seventh 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 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 $\leq$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 sufficiently. Snorkel survey fish-day integral when divided by the open mark-recapture estimate to generate an estimate spawning area survey life 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 arrival timing with the survey life index of the preliminary spawning area residence time and migration delay relationship.

Recommendations

Future work should investigate the effect of spawner density on average detection probability perhaps using peak counts and population densities as predictor variables. 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 considerably.

Investigation of means to integrate the arrival timing of the population with the relationship between the index of migration delay and spawning survey life is required. 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. The curve has a bimodal form if there are movements to multiple freshets both before and after the bulk of spawners have arrived.

A very large escapement is expected in 2016 so additional tag applications and attendant sampling efforts will need to be considered in the program budget to maintain respectable marking rates for the live mark-recapture program. Consideration will be given to abandoning Petersen estimates entirely to reallocate some carcass surveys funds to use them more effectively in live recapture experiment.

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Appendix 1.

Table A1. Summary of daily live encounters with Chinook salmon at Burman River in 2015 used for the open population estimation and assumption testing. Unmarked fish were marked on the day indicated and released alive and subsequently available for recapture. Large Chinook were not encountered after October 2, and jacks were not caught in the stopover pool 10 days earlier after September 22 in 2015, near the mean annual freshet date.

		Females live			Males live			Jacks live		
Day	Date	Unmarked (M)	Recaptures (R)	Daily total (C)	Unmarked (M)	Recaptures (R)	Daily total (C)	Unmarked (M)	Recaptures (R)	Daily total (C)
245	02/09/2015	2	0	2	2	0	2	1	0	1
246	03/09/2015	1	0	1	6	0	6	0	0	0
247	04/09/2015	78	0	78	106	0	106	3	0	3
249	05/09/2015	24	5	29	60	13	73	5	0	5
251	08/09/2015	76	2	78	265	14	279	17	1	18
252	09/09/2015	88	10	98	187	15	202	12	2	14
253	10/09/2015	40	7	47	99	6	105	6	2	8
257	14/09/2015	58	7	65	113	15	128	8	1	9
258	15/09/2015	29	7	36	134	26	160	10	3	13
259	16/09/2015	50	4	54	118	7	125	2	1	3
265	22/09/2015	32	11	43	132	34	166	6	2	8
272	29/09/2015	21	2	23	95	5	100	0	0	0
275	02/10/2015	17	5	22	94	17	111	0	0	0
277	04/10/2015	0	0	0	0	0	0	0	0	0
279	06/10/2015	0	0	0	0	0	0	0	0	0
281	08/10/2015	0	0	0	0	0	0	0	0	0
284	11/10/2015	0	0	0	0	0	0	0	0	0
286	13/10/2015	0	0	0	0	0	0	0	0	0
	Grand Total	516	60	576	1411	152	1563	70	12	82

APPENDICES

2015 BRCN Adults Burman River Chinook without jacks Feb 8 2016

Estimates of Derived Parameters
Gross Birth + Immigration Estimates of {Phi (g) P (gt) Pent (t)}

				95% Confidence Interval	
Grp.	Occ.	B*-hat	Standard Error	Lower	Upper
----	----	--------------	--------------	--------------	--------------
1	1	1137.11	875.114	298.7081	4328.705
1	2	1418.412	644.7173	606.6133	3316.597
1	3	2.28E-04	0.00803	1.22E-06	0.042653
1	4	3.97E-131	2.72E-130	8.41E-133	1.88E-129
1	5	2.23E-11	0	2.23E-11	2.23E-11
1	6	1.19E-12	1.07E-08	2.79E-16	5.11E-09
1	7	829.5384	281.6701	434.1634	1584.965
1	8	6.96E-07	0	6.96E-07	6.96E-07
1	9	265.7749	123.2661	111.8888	631.308
1	10	9.73E-08	1.47E-04	5.37E-11	1.76E-04
2	1	4898.037	3857.084	1255.303	19111.54
2	2	6344.672	2643.888	2896.001	13900.16
2	3	9.82E-04	0.034596	5.25E-06	0.183749
2	4	1.71E-130	1.17E-129	3.62E-132	8.09E-129
2	5	1.02E-10	0	1.02E-10	1.02E-10
2	6	5.15E-12	4.61E-08	1.20E-15	2.20E-08
2	7	3573.19	1115.144	1965.852	6494.734
2	8	3.27E-06	0	3.27E-06	3.27E-06
2	9	1268.476	542.5641	568.0326	2832.638
2	10	4.35E-07	6.60E-04	2.40E-10	7.88E-04

Net Birth + Immigration Estimates of {Phi (g) P (gt) Pent (t)}

				95% Confidence Interval	
Grp.	Occ.	B-hat	Standard Error	Lower	Upper
----	----	--------------	--------------	--------------	--------------
1	1	1076.176	829.3048	282.3056	4102.484
1	2	1206.104	538.4548	522.9936	2781.463
1	3	2.16E-04	0.0076	1.15E-06	0.040367
1	4	3.76E-131	2.57E-130	7.96E-133	1.78E-129
1	5	1.80E-11	0	1.80E-11	1.80E-11
1	6	1.13E-12	1.01E-08	2.64E-16	4.84E-09
1	7	785.086	267.4439	410.0786	1503.029
1	8	5.08E-07	0	5.08E-07	5.08E-07
1	9	184.6798	85.73171	77.69327	438.9907

```
         1     10     8.27E-08        1.25E-04      4.57E-11      1.50E-04
         2      1     4542.755        3575.184      1164.996      17713.91
         2      2      5091.21        2103.479      2338.273      11085.29
         2      3     9.11E-04        0.032087      4.87E-06      0.170421
         2      4   1.59E-130       1.09E-129     3.36E-132     7.50E-129
         2      5     7.60E-11               0      7.60E-11      7.60E-11
         2      6     4.77E-12        4.27E-08      1.12E-15      2.04E-08
         2      7     3314.007         1035.38      1822.129      6027.367
         2      8     2.14E-06               0      2.14E-06      2.14E-06
         2      9     779.5707        329.7312      351.9885      1726.564
         2     10     3.49E-07        5.29E-04      1.93E-10      6.32E-04
```

```
Population Estimates of {Phi (g) P (gt) Pent (t)}
                                    95% Confidence Interval
                                     Standard
Grp.       Occ.   N-hat              Error         Lower         Upper
----       ----   --------------     --------------  --------------  --------------
         1      1       82.014        561.4879      1.736476      3873.532
         1      2      1149.56        671.1823      397.6567      3323.187
         1      3     2029.624         301.804      1518.908      2712.062
         1      4     1816.058        286.1968          1336      2468.614
         1      5     1624.965        279.5787      1162.671      2271.072
         1      6     1041.599        273.7964      627.5883      1728.725
         1      7     925.7336        270.0691         528.7      1620.924
         1      8     1606.252        401.4627      991.4642      2602.257
         1      9     800.7177          327.06      370.7787      1729.196
         1     10      538.591        246.4517      229.1463      1265.917
         1     11     385.8348        210.2728      142.0091      1048.303
         2      1     346.1977        2373.081      7.321196      16370.66
         2      2     4839.974        2957.233      1604.752      14597.49
         2      3     8153.884        1052.407      6338.011      10490.02
         2      4     7000.309        909.9357      5431.688      9021.933
         2      5     6009.935        808.6662      4622.189      7814.331
         2      6     3264.977        589.9976      2297.709      4639.438
         2      7     2803.062        551.5699      1913.038      4107.163
         2      8     5720.504        1131.825      3896.114       8399.18
         2      9     2290.603        639.5299      1338.868      3918.878
         2     10     1567.012        419.3374      935.8599      2623.817
         2     11      991.585        314.1565      540.8388      1817.993
     Gross Population Estimates of {Phi (g) P (gt) Pent (t)}
                                    95% Confidence Interval
                                     Standard
Grp.       Occ.   N*-hat             Error         Lower         Upper
----       ----   --------------     --------------  --------------  --------------
Females         0     3732.849        545.6719      2807.151       4963.81
Males           0     16430.57         1936.39      13052.09      20683.56
```

2015 BRCN Adult Burman River Chinook Real Parameters without jacks Feb 8 2016

Real Function Parameters of {Phi (g) P (gt) Pent (t)}

			95% Confidence Interval	
Parameter	Estimate	Standard Error	Lower	Upper
1:Phi	0.894776	0.028596	0.824216	0.939105
2:Phi	0.858524	0.01892	0.817242	0.891717
3:p	0.9877	6.761201	7.92E-303	1
4:p	0.023492	0.014443	0.006955	0.076326
5:p	0.037416	0.006973	0.025908	0.053754
6:p	0.052811	0.009823	0.036555	0.075727
7:p	0.028272	0.006357	0.01815	0.043787
8:p	0.062253	0.017916	0.035101	0.108055
9:p	0.03663	0.01229	0.01885	0.069983
10:p	0.03111	0.0089	0.017683	0.054171
11:p	0.047468	0.020811	0.019817	0.109395
12:p	0.04283	0.021565	0.015708	0.111481
13:p	0.057188	0.033505	0.017627	0.170152
14:p	0.332175	2.277168	9.10E-10	1
15:p	0.012394	0.007735	0.003624	0.041507
16:p	0.032743	0.004661	0.024742	0.043219
17:p	0.027711	0.0041	0.020713	0.036984
18:p	0.017302	0.002871	0.012488	0.023927
19:p	0.039173	0.007839	0.026391	0.05778
20:p	0.056304	0.01188	0.037066	0.084648
21:p	0.021662	0.004695	0.01414	0.033053
22:p	0.063776	0.018543	0.035738	0.111274
23:p	0.063887	0.018183	0.036245	0.110198
24:p	0.111057	0.036628	0.056938	0.205412
25:pent	0.322782	0.238777	0.053052	0.802176
26:pent	0.361752	0.170119	0.117959	0.70607
27:pent	6.47E-08	2.28E-06	7.11E-38	1
28:pent	1.13E-134	7.70E-134	-1.40E-133	1.62E-133
29:pent	5.40E-15	0	5.40E-15	5.40E-15
30:pent	3.39E-16	3.03E-12	-5.95E-12	5.95E-12
31:pent	0.235475	0.066088	0.130429	0.387428
32:pent	1.52E-10	0	1.52E-10	1.52E-10
33:pent	0.055392	0.024831	0.02261	0.129408
34:pent	2.48E-11	3.76E-08	-7.37E-08	7.37E-08
35:N Females	3334.06	497.2642	2515.137	4487.608
36:N Males	14073.74	1814.556	10986.62	18156.02

Appendix 2. IEH files for 2015 analyses of Burman River Chinook in CloseTest, RELEASE, U-CARE, and Program MARK.

2015BRCN adults no jacks with transient LOCs.inp

2015BRCN all grps with transient LOCs.inp

2015BRCN Jacks for CloseTest.inp

2015BRCN Males for CloseTest.inp

2015BRCNFemales for CloseTest.inp

Appendix 3. U-CARE Results

- Global TEST, number of groups =3
- df =55
- Quadratic Chi2 =31.1378
- ->P-level=0.99608
- N(0,1) statistic for transient(>0) =1.6913
- ->P-level, two-sided test =0.090784
- ->P-level, one-sided test for transience =0.045392
- N(0,1) signed statistic for trap-dependence =0.70295
- ->P-level, two-sided test =0.48208
-
-
- TEST3.SR, group =1 Females
- component df z LOR S.E.LOR chi2 G2
- 2 0 0.00 0.00 0.00 0.00 0.00
- 3 0 0.00 0.00 0.00 0.00 0.00
- 4 1 0.00 -0.43 1.60 0.00 0.00
- 5 1 1.41 2.82 1.66 1.99 1.99
- 6 1 0.00 0.45 0.96 0.00 0.00
- 7 1 0.85 1.24 1.12 0.71 0.71
- 8 1 2.06 2.55 1.02 4.23 4.23
- 9 0 0.00 0.00 0.00 0.00 0.00
- 10 0 0.00 0.00 0.00 0.00 0.00
- 11 0 0.00 0.00 0.00 0.00 0.00
- 12 1 0.00 0.62 1.73 0.00 0.00
- component df low nrs P(chi2) P(Cochran) P(G2)
- 2 0 0.00 0.00 0.00 0.00
- 3 0 0.00 0.00 0.00 0.00
- 4 1 1.00 1.00 1.00 1.00
- 5 1 2.00 0.16 0.17 0.16
- 6 1 1.00 1.00 1.00 1.00
- 7 1 1.00 0.40 0.47 0.40
- 8 1 1.00 0.04 0.02 0.04
- 9 0 0.00 0.00 0.00 0.00
- 10 0 0.00 0.00 0.00 0.00

- 11 0 0.00 0.00 0.00 0.00
- 12 1 2.00 1.00 1.00 1.00
- ===
- N(0,1) statistic for transient(>0) =1.7614
- P-level, two-sided test =0.078166
- P-level, one-sided test for transience =0.039083
- Log-Odds-Ratio (LOR) =2.9623
- N(0,1) standardized LOR statistic for transience (>0) =2.1364
- P-level, two-sided test =0.03265
- P-level, one-sided test for transience =0.016325
- Overall test df =6
- Quadratic Chi2 =6.9406
- P-level =0.32638
- G2 =6.9406
- P-level =0.32638
- **
- TEST3.SR, group =2 Large Males
- component df z LOR S.E.LOR chi2 G2
- 2 0 0.00 0.00 0.00 0.00 0.00
- 3 0 0.00 0.00 0.00 0.00 0.00
- 4 0 0.00 0.00 0.00 0.00 0.00
- 5 1 1.08 1.63 1.00 1.16 1.16
- 6 1 0.79 1.05 0.96 0.63 0.63
- 7 1 0.00 -0.35 1.50 0.00 0.00
- 8 1 0.00 -0.09 0.91 0.00 0.00
- 9 1 0.00 0.60 1.65 0.00 0.00
- 10 1 0.00 1.64 1.68 0.00 0.00
- 11 1 0.58 0.62 0.94 0.33 0.33
- 12 1 0.00 -0.19 1.52 0.00 0.00
- component df low nrs P(chi2) P(Cochran) P(G2)
- 2 0 0.00 0.00 0.00 0.00
- 3 0 0.00 0.00 0.00 0.00
- 4 0 0.00 0.00 0.00 0.00
- 5 1 1.00 0.28 0.36 0.28
- 6 1 1.00 0.43 1.00 0.43
- 7 1 1.00 1.00 0.46 1.00
- 8 1 1.00 1.00 1.00 1.00
- 9 1 2.00 1.00 1.00 1.00
- 10 1 2.00 1.00 1.00 1.00
- 11 1 1.00 0.56 1.00 0.56

- 12 1 1.00 1.00 1.00 1.00
- ===
- N(0,1) statistic for transient(>0) =0.86639
- P-level, two-sided test =0.38628
- P-level, one-sided test for transience =0.19314
- Log-Odds-Ratio (LOR) =1.7326
- N(0,1) standardized LOR statistic for transience (>0) =1.3232
- P-level, two-sided test =0.18578
- P-level, one-sided test for transience =0.092892
- Overall test df =8
- Quadratic Chi2 =2.1275
- P-level =0.97685
- G2 =2.1275
- P-level =0.97685
- **

- TEST3.SR, group =3 Jacks < 500 mm POH
- component df z LOR S.E.LOR chi2 G2
- 2 0 0.00 0.00 0.00 0.00 0.00
- 3 0 0.00 0.00 0.00 0.00 0.00
- 4 0 0.00 0.00 0.00 0.00 0.00
- 5 0 0.00 0.00 0.00 0.00 0.00
- 6 1 0.00 0.34 1.78 0.00 0.00
- 7 0 0.00 0.00 0.00 0.00 0.00
- 8 1 0.00 -0.14 1.79 0.00 0.00
- 9 0 0.00 0.00 0.00 0.00 0.00
- 10 0 0.00 0.00 0.00 0.00 0.00
- 11 0 0.00 0.00 0.00 0.00 0.00
- 12 0 0.00 0.00 0.00 0.00 0.00
- component df low nrs P(chi2) P(Cochran) P(G2)
- 2 0 0.00 0.00 0.00 0.00
- 3 0 0.00 0.00 0.00 0.00
- 4 0 0.00 0.00 0.00 0.00
- 5 0 0.00 0.00 0.00 0.00
- 6 1 3.00 1.00 1.00 1.00
- 7 0 0.00 0.00 0.00 0.00
- 8 1 3.00 1.00 1.00 1.00
- 9 0 0.00 0.00 0.00 0.00
- 10 0 0.00 0.00 0.00 0.00

- 11 0 0.00 0.00 0.00 0.00
- 12 0 0.00 0.00 0.00 0.00
- ==
- N(0,1) statistic for transient(>0) =0
- P-level, two-sided test =1
- P-level, one-sided test for transience =0.5
- Log-Odds-Ratio (LOR) =0.13673
- N(0,1) standardized LOR statistic for transience (>0) =0.076542
- P-level, two-sided test =0.93899
- P-level, one-sided test for transience =0.46949
- Overall test df =2
- Quadratic Chi2 =0
- P-level =1
- G2 =0
- P-level =1
- ***

- TEST3.SM, group =1 Females
- component df chi2 G2
- 2 0 0.00 0.00
- 3 0 0.00 0.00
- 4 0 0.00 0.00
- 5 1 0.00 0.00
- 6 1 0.00 0.00
- 7 1 0.00 0.00
- 8 1 0.00 0.00
- 9 0 0.00 0.00
- 10 0 0.00 0.00
- 11 0 0.00 0.00
- component df low nrs P(chi2) P(G2)
- 2 0 0.00 0.00 0.00
- 3 0 0.00 0.00 0.00
- 4 0 0.00 0.00 0.00
- 5 1 2.00 1.00 1.00
- 6 1 2.00 1.00 1.00
- 7 1 4.00 1.00 1.00
- 8 1 4.00 1.00 1.00
- 9 0 0.00 0.00 0.00
- 10 0 0.00 0.00 0.00

```
• 11 0 0.00 0.00 0.00
• ============================================
• Overall test df =4
• Quadratic Chi2 =0
• P-level =1
• G2 =0
• P-level =1
• ********************************************
•
•
• TEST3.SM, group =2  Males
• component df chi2 G2
• 2 0 0.00 0.00
• 3 0 0.00 0.00
• 4 0 0.00 0.00
• 5 1 0.00 0.00
• 6 1 0.52 0.52
• 7 0 0.00 0.00
• 8 1 0.00 0.00
• 9 0 0.00 0.00
• 10 0 0.00 0.00
• 11 1 0.79 0.79
• component df low nrs P(chi2) P(G2)
• 2 0 0.00 0.00 0.00
• 3 0 0.00 0.00 0.00
• 4 0 0.00 0.00 0.00
• 5 1 2.00 1.00 1.00
• 6 1 2.00 0.47 0.47
• 7 0 0.00 0.00 0.00
• 8 1 2.00 1.00 1.00
• 9 0 0.00 0.00 0.00
• 10 0 0.00 0.00 0.00
• 11 1 2.00 0.38 0.38
• ============================================
• Overall test df =4
• Quadratic Chi2 =1.3076
• P-level =0.86008
• G2 =1.3076
• P-level =0.86008
• ********************************************
```

- TEST3.SM, group =3 Jacks
- component df chi2 G2
- 2 0 0.00 0.00
- 3 0 0.00 0.00
- 4 0 0.00 0.00
- 5 0 0.00 0.00
- 6 0 0.00 0.00
- 7 0 0.00 0.00
- 8 0 0.00 0.00
- 9 0 0.00 0.00
- 10 0 0.00 0.00
- 11 0 0.00 0.00
- component df low nrs P(chi2) P(G2)
- 2 0 0.00 0.00 0.00
- 3 0 0.00 0.00 0.00
- 4 0 0.00 0.00 0.00
- 5 0 0.00 0.00 0.00
- 6 0 0.00 0.00 0.00
- 7 0 0.00 0.00 0.00
- 8 0 0.00 0.00 0.00
- 9 0 0.00 0.00 0.00
- 10 0 0.00 0.00 0.00
- 11 0 0.00 0.00 0.00
- **

Capture

- TEST2.CT, group =1 Females
- component df z LOR S.E.LOR chi2 G2
- 2 0 0.00 0.00 0.00 0.00 0.00
- 3 0 0.00 0.00 0.00 0.00 0.00
- 4 1 -0.84 -1.72 1.76 0.71 0.71
- 5 1 0.94 0.80 0.89 0.87 0.87
- 6 1 0.20 0.15 0.84 0.04 0.04
- 7 1 0.00 -0.46 1.15 0.00 0.00
- 8 1 -0.60 -1.02 1.05 0.36 0.36
- 9 0 0.00 0.00 0.00 0.00 0.00

- 10 0 0.00 0.00 0.00 0.00 0.00
- 11 0 0.00 0.00 0.00 0.00 0.00
- component df low nrs P(chi2) P(Cochran) P(G2)
- 2 0 0.00 0.00 0.00 0.00
- 3 0 0.00 0.00 0.00 0.00
- 4 1 2.00 0.40 0.41 0.40
- 5 1 0.00 0.35 0.64 0.35
- 6 1 0.00 0.84 1.00 0.84
- 7 1 1.00 1.00 1.00 1.00
- 8 1 1.00 0.55 0.54 0.55
- 9 0 0.00 0.00 0.00 0.00
- 10 0 0.00 0.00 0.00 0.00
- 11 0 0.00 0.00 0.00 0.00
- ===
- N(0,1) signed statistic for trap-dependence =-0.13437
- trap-happiness0
- P-level, two-sided test =0.89311
- logit(p*)-logit(p) =-0.44976
- N(0,1) standardized LOR statistic for trap-dependence =-0.84819
- trap-happiness0
- P-level, two-sided test =0.39633
- Overall test df =5
- Quadratic Chi2 =1.9839
- P-level =0.85137
- G2 =1.9813
- P-level =0.85173
- **
- TEST2.CT, group =2
- component df z LOR S.E.LOR chi2 G2
- 2 0 0.00 0.00 0.00 0.00 0.00
- 3 0 0.00 0.00 0.00 0.00 0.00
- 4 1 0.00 0.67 1.65 0.00 0.00
- 5 1 -0.27 -0.17 0.88 0.07 0.08
- 6 1 0.55 0.37 0.83 0.30 0.31
- 7 1 0.23 0.08 0.82 0.05 0.05
- 8 1 -0.54 -0.33 0.62 0.29 0.30
- 9 1 0.00 0.31 1.69 0.00 0.00
- 10 1 1.22 2.52 1.74 1.49 1.49
- 11 1 0.00 0.45 1.13 0.00 0.00
- component df low nrs P(chi2) P(Cochran) P(G2)

- 2 0 0.00 0.00 0.00 0.00
- 3 0 0.00 0.00 0.00 0.00
- 4 1 2.00 1.00 1.00 1.00
- 5 1 0.00 0.79 1.00 0.78
- 6 1 0.00 0.58 0.67 0.58
- 7 1 0.00 0.82 1.00 0.82
- 8 1 0.00 0.59 0.75 0.59
- 9 1 2.00 1.00 1.00 1.00
- 10 1 2.00 0.22 0.25 0.22
- 11 1 1.00 1.00 1.00 1.00
- ==
- N(0,1) signed statistic for trap-dependence =0.41628
- trap-happiness0
- P-level, two-sided test =0.6772
- logit(p*)-logit(p) =0.48928
- N(0,1) standardized LOR statistic for trap-dependence =1.1125
- trap-happiness0
- P-level, two-sided test =0.26594
- Overall test df =8
- Quadratic Chi2 =2.2087
- P-level =0.97394
- G2 =2.2215
- P-level =0.97346
- **
- TEST2.CT, group =3
- component df z LOR S.E.LOR chi2 G2
- 2 0 0.00 0.00 0.00 0.00 0.00
- 3 0 0.00 0.00 0.00 0.00 0.00
- 4 0 0.00 0.00 0.00 0.00 0.00
- 5 1 0.97 2.71 2.25 0.94 0.94
- 6 1 0.97 3.22 2.19 0.94 0.94
- 7 0 0.00 0.00 0.00 0.00 0.00
- 8 1 0.00 1.10 2.00 0.00 0.00
- 9 0 0.00 0.00 0.00 0.00 0.00
- 10 0 0.00 0.00 0.00 0.00 0.00
- 11 0 0.00 0.00 0.00 0.00 0.00
- component df low nrs P(chi2) P(Cochran) P(G2)
- 2 0 0.00 0.00 0.00 0.00
- 3 0 0.00 0.00 0.00 0.00
- 4 0 0.00 0.00 0.00 0.00

- 5 1 4.00 0.33 0.33 0.33
- 6 1 4.00 0.33 0.32 0.33
- 7 0 0.00 0.00 0.00 0.00
- 8 1 4.00 1.00 1.00 1.00
- 9 0 0.00 0.00 0.00 0.00
- 10 0 0.00 0.00 0.00 0.00
- 11 0 0.00 0.00 0.00 0.00
- ==
- N(0,1) signed statistic for trap-dependence =1.1171
- trap-happiness0
- P-level, two-sided test =0.26396
- logit(p*)-logit(p) =2.3418
- N(0,1) standardized LOR statistic for trap-dependence =1.8867
- trap-happiness0
- P-level, two-sided test =0.059206
- Overall test df =3
- Quadratic Chi2 =1.8718
- P-level =0.59943
- G2 =1.8718
- P-level =0.59943
- **

- TEST2.CL, group= Females.
- component df chi2 G2
- 2 0 0.00 0.00
- 3 0 0.00 0.00
- 4 1 0.00 0.00
- 5 1 0.31 0.31
- 6 1 2.55 2.61
- 7 1 0.45 0.45
- 8 1 3.38 3.38
- 9 0 0.00 0.00
- 10 0 0.00 0.00
- component df low nrs P(chi2) P(G2)
- 2 0 0.00 0.00 0.00
- 3 0 0.00 0.00 0.00
- 4 1 2.00 1.00 1.00
- 5 1 0.00 0.58 0.58
- 6 1 0.00 0.11 0.11

- 7 1 2.00 0.50 0.50
- 8 1 2.00 0.07 0.07
- 9 0 0.00 0.00 0.00
- 10 0 0.00 0.00 0.00
- ==
- Overall test df=5
- Quadratic Chi2=6.7019
- P-level=0.24377
- G2=6.7615
- P-level=0.23899
- ***
-
-
- TEST2.CL, group=2 Large Males
- component df chi2 G2
- 2 0 0.00 0.00
- 3 1 0.32 0.32
- 4 1 0.48 0.48
- 5 2 0.75 0.75
- 6 2 1.75 1.75
- 7 1 0.67 0.69
- 8 1 4.02 4.02
- 9 1 0.00 0.00
- 10 1 0.00 0.00
- component df low nrs P(chi2) P(G2)
- 2 0 0.00 0.00 0.00
- 3 1 2.00 0.57 0.57
- 4 1 2.00 0.49 0.49
- 5 2 0.00 0.69 0.69
- 6 2 0.00 0.42 0.42
- 7 1 0.00 0.41 0.41
- 8 1 1.00 0.05 0.05
- 9 1 2.00 1.00 1.00
- 10 1 4.00 1.00 1.00
- ==
- Overall test df=10
- Quadratic Chi2=7.9958
- P-level=0.62925
- G2=8.0135
- P-level=0.62752

- **
- TEST2.CL, group=3 Jacks . sparce data
- component df chi2 G2
- 2 0 0.00 0.00
- 3 0 0.00 0.00
- 4 0 0.00 0.00
- 5 0 0.00 0.00
- 6 0 0.00 0.00
- 7 0 0.00 0.00
- 8 0 0.00 0.00
- 9 0 0.00 0.00
- 10 0 0.00 0.00
- component df low nrs P(chi2) P(G2)
- 2 0 0.00 0.00 0.00
- 3 0 0.00 0.00 0.00
- 4 0 0.00 0.00 0.00
- 5 0 0.00 0.00 0.00
- 6 0 0.00 0.00 0.00
- 7 0 0.00 0.00 0.00
- 8 0 0.00 0.00 0.00
- 9 0 0.00 0.00 0.00
- 10 0 0.00 0.00 0.00
- **

Appendix 45 POPAN Derived estimates

Gross Birth+Immigration Estimates of {Phi (*) P(*) Pent (t)}

				95% Confidence Interval	
Grp.	Occ.	B*-hat	Standard Error	Lower	Upper
Jacks	1	52.67447	12.2709	33.56735	82.6577
	2	42.98799	10.2764	27.08206	68.23583
	3	62.99206	15.27034	39.43439	100.6228
	4	23.82086	10.10762	10.7303	52.88138

Net Birth + Immigration Estimates of {Phi (*) P (*) Pent (t)}

Grp.	Occ.	B-hat	Standard Error	95% Confidence Interval Lower	Upper
Jacks	1	20.00	3.721041	13.93172	28.71146
	2	18.00	3.607683	12.19952	26.55842
	3	20.00	3.721041	13.93172	28.71146
	4	6.000001	2.3337	2.875146	12.52111

Population Estimates of {Phi (*) P (*) Pent (t)}

Grp.	Occ.	N-hat	Standard Error	95% Confidence Interval Lower	Upper
Jacks	1	1.000003	0.992278	0.197368	5.066709
	2	20.09134	3.714806	14.0263	28.77893
	3	20.47509	3.574757	14.57892	28.75584
	4	21.02815	3.690916	14.94601	29.58537
	5	6.43041	2.340015	3.221522	12.8356

Gross Population Estimates of {Phi (*) P (*) Pent (t)}

Grp.	N*-hat	Standard Error	95% Confidence Interval Lower	Upper
Jacks	183	27.14	138	245