Enumeration of the 1998 Nicola River Chinook Salmon Escapement

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ENUMERATION OF THE 1998 NICOLA RIVER CHINOOK SALMON ESCAPEMENT

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ABSTRACT

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The Nicola River spring - run chinook salmon stock was chosen to compare aerial escapement counting methods currently employed to estimate chinook salmon escapements to many Fraser basin tributaries, with mark - recapture type estimates. In 1998, 133 marks were in the application sample and 36 were recovered in the recovery sample of 441 chinook. Spatial and temporal biases were not detected in either sample and the Petersen estimate was deemed acceptable. The escapement estimates, derived by sex, were 668 males and 879 females. The adipose fin clipped component of the escapement was 196 chinook. The total adult escapement (Petersen estimate of 1,547 fish) was the lowest mark-recapture estimate on record. A population estimate, based on the historical expansion factor (65%) applied to the actual aerial count nearest the peak of spawning was 1,212 chinook. An expansion factor of 46% would be required for the aerial count of live and dead chinook to equal the Petersen population estimate.

Key Words: Chinook salmon, Nicola River, indicator stock, escapement, mark-recapture, aerial counts.

RÉSUMÉ

Farwell, M.K., R.E. Bailey, and J.S. Baxter. 2002. Enumeration of the 1998 Nicola River chinook salmon escapement. Can. Manuscr. Rep. Fish. Aquat. Sci. 2591: 35 p.

On a choisi le stock de saumon quinnat de montaison printanière de la rivière Nicola pour comparer les méthodes de dénombrement aérien actuellement utilisées pour estimer l'échappée de saumons quinnats dans de nombreux affluents du Fraser avec les estimations par marquage-recapture. En 1998, on a marqué 133 saumons quinnats, dont 36 ont été recapturés dans un échantillon de 441 chinooks. Aucun biais temporel ou spatial n'a été détecté dans les échantillons de marquage et de capture, et l'estimation de Petersen a été jugé acceptable. L'échappée a été estimée à 668 mâles et à 879 femelles, et comprenait 196 saumons quinnats à la nageoire adipeuse coupée. L'échappée totale (1547 poissons selon l'estimation de Petersen) constitue l'estimation de marquage-recapture la plus basse jamais observée. La taille de la population, estimée en appliquant le facteur d'extension historique de 65 % au dénombrement aérien effectué à la date qui s'approchait le plus du pic de fraie, se chiffrait à 1 212 saumons quinnats. Ainsi, il faudrait appliquer un facteur d'extension de 46 % pour que le dénombrement aérien de saumons quinnats morts et vivants corresponde à l'estimation de Petersen.

Mots cles: Saumon quinnat, rivière Nicola, marquage-recapture, stock indicateur, échappée, dénombrements aériens.

INTRODUCTION

Spawning escapements of spring-and summer-run chinook salmon (*Oncorhynchus tshawytscha)* to many tributaries of the Fraser River are estimated annually using aerial and mark-recapture census methods. In many tributary areas, aerial census methods have been preferred due to the ability to fly geographically widespread areas in a relatively short period of time, the difficulty of accessing many of the systems by land, and because water conditions are appropriate for fish counting from the air. Typically, aerial escapement estimates have been derived from two or three overflights, with the assumption that at the peak of spawning, and under ideal conditions, surveyors would observe 65% of the total run.

To date, there is little information on the repeatability of aerial counts, the influence of flight timing, and there are few comparisons of aerial counts against estimates with known statistical precision (fences or mark-recovery studies). The 1995 Nicola River comparison indicated that the best aerial count was 35% of the mark-recapture estimate (Farwell et al. 1998). The average of the two best counts in 1996 was 55% of the mark-recapture estimate (Farwell et. al 2000) and the best count in 1997 was 44% of the mark-recapture estimate (Farwell et al. 2001a). In the first three years of this study, the assumption that 65% of the spawners can be counted from the air has not been supported.

Spawning escapements to other Fraser River tributary areas have been estimated by the Petersen mark-recapture method. This estimation technique has the advantage that confidence limits about the population estimate can be determined. Mark-recapture methods have been employed to estimate chinook escapements to the Harrison River from 1984 on (Farwell et. al 1998), and to the Lower Shuswap River in 1984. The Nicola River spawning escapement was first estimated by the mark-recapture method in 1995 (Farwell et al. 1999). The presence of a mark-recapture population estimate with known precision permits assessment of the relative accuracy of the aerial estimate and its associated expansion factor.

The 1998 escapement estimation study of chinook in the Nicola River and its tributaries was designed to provide both mark-recapture and aerial enumeration estimates. The study also provided estimates of age and sex compositions of the spawning population and an estimate of the contribution of hatchery-origin salmon to the spawning escapement.

STUDY AREA

The upper Nicola River originates between the Nicola Plateau and the Douglas Plateau, approximately 70 km east of the community of Merritt. It flows in a northerly direction for 97 km, before entering Nicola Lake near the mid-point of the southeastern shoreline of the lake. The Nicola River drains Nicola Lake at a flow control structure, and flows in a southwesterly direction for 12 km before its confluence with the Coldwater River in Merritt. From this point, the Nicola River flows in a north-north-westerly direction for 20 km until its confluence with Spius Creek. Below its confluence with Spius Creek, the Nicola flows north-westerly for 52 km, entering the Thompson River at Spences Bridge (Fig. 1).

Many other smaller tributaries enter the Nicola River below Nicola Lake. Tributaries that provide spawning habitat for salmon include Clapperton and Guichon creeks. Clapperton Creek flows into the Nicola River approximately 0.5 km below the outlet of Nicola Lake, and Guichon Creek enters the Nicola River about 5 km downstream of the Nicola - Coldwater confluence. Other tributaries flowing into the Nicola below the Spius confluence include Shackan, Skuhun, and Nooaitch creeks.

The mainstem Nicola River and a major tributary, the Coldwater River, are heavily impacted by agricultural practices. Channel bank erosion and widening along with bed destabilization and siltation are common features of the Nicola drainage, often associated with the removal of riparian vegetation to increase grazing land. Other agricultural impacts include channel de-watering due to irrigation and nutrient additions from livestock.

Rood and Hamilton (1995) documented the hydrology of the Nicola basin and reported mean annual daily flows of 22.7 $m^3 \cdot sec^{-1}$, mean August flows of 15.9 $m^3 \cdot sec^{-1}$. Maximum flows, typically occur during May or June, but also may occur when heavy rain and sudden warming causes rapid snowmelt in late fall or early spring. Minimum flows often occur in late August or early September. Water temperatures range from 0°C with ice cover in mid winter to as high as 29°C when extreme heat waves are combined with low flows (Walthers and Nener 1997).

Salmonid fish species inhabiting the Nicola River other than chinook salmon include coho salmon (*O. kisutch*), pink salmon (*O gorbuscha*), steelhead and rainbow trout (*O. mykiss*), and bull trout (*Salvelinus confluentus*). Non-salmonid fish include suckers (*Catostomus* spp.), sculpins (*Cottus* spp.), and northern pikeminnow (*Ptychocheilus oregonensis*).

For the purposes of the analyses required for this study, the river and its major tributaries (Coldwater River and Spius Creek) were divided into eight sampling strata (reaches) as described in Table 1.

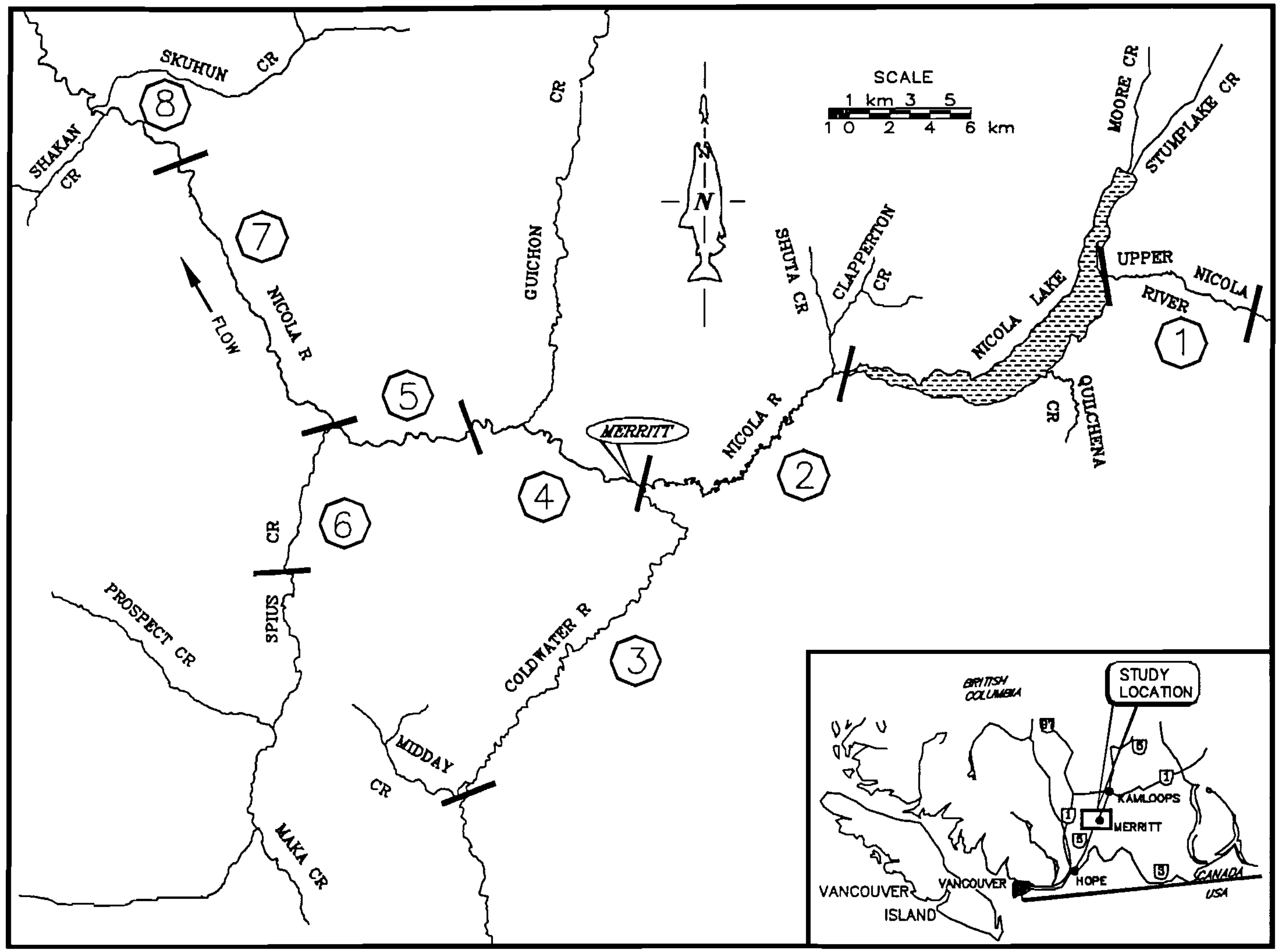

Figure 1. Study area map and stratum locations in the Nicola and Coldwater rivers and Spius Creek.

Table 1. River segments and associated stratum designations

River segment	Stratum
Upper Nicola R. (above Nicola Lake)	1
Nicola River from Nicola Lake outlet to Coldwater River confluence	2
Lower 5 km of Coldwater River	3
Nicola River from Coldwater River confluence to Gavelin Bridge	4
Nicola River from Gavelin Bridge to Spius Creek confluence	5
Spius Creek below Little Box Canyon	6
Nicola River from Spius Creek confluence to lower Dot trestle	7
Nicola River from lower Dot trestle to mouth (Spences Bridge)	8

FIELD METHODS

TAG APPLICATION

Chinook were captured by angling between 15 August and 29 August. Capture and marking was attempted in river segments known from aerial observation to be utilized by pre-spawning chinook. Strata not angled were stratum 1, a headwater area; stratum 3, a tributary of the mainstem; and stratum 5.

Anglers used single barbless hooks (Eagle Claw L183F) of sizes 1 or 2/0 baited with salmon eggs treated with borax. Chinook were landed and either processed immediately, or held for up to 15 min in 1.25 m x 0.3 m diameter vinyl flow-through holding tubes anchored instream in a manner to permit suitable water flow prior to processing. Anglers recorded the relative amount of bleeding from the area of the hook as none, slight, moderate, or heavy and also noted where the fish was hooked. The hooking location was later categorized as either critical (roof of mouth, gills, tongue, or eye) or non-critical.

For tag application, each fish was placed in a canvas cradle in shallow river water. During processing, the fork length was measured (± 1 cm) and the sex and adipose fin clip status recorded. Fish were tagged with Petersen disk tags. Sex specific operculum punches (one 0.7 cm hole in males and two in females) were applied to the left operculum as a secondary mark prior to release of the fish. The release condition of the fish, categorized as 1 (swam away rapidly), 2 (swam away slowly), or 3 (required ventilation assistance), was also recorded.

Petersen disk tags consisted of two 2.2 cm diameter laminated cellulose acetate disks (one uniquely numbered), and a 0.7 cm diameter transparent plastic buffer disk threaded through centrally punched holes onto a 7.7 cm long nickel pin. The pin was inserted through the musculature and pterygiophore bones approximately 1.5 cm below the insertion of the dorsal fin, with the disks arranged one on each side of the fish, and the buffer disk on the pin head side. Disks were held snugly against the fish by twisting the pin into a double knot.

CARCASS RECOVERY

Sampling of chinook carcasses commenced on August 29 and continued until 14 October when no further carcasses were found. Strata 2-8 were surveyed in their entirety at least once every five days during the period of the recovery; stratum 1 was not surveyed based on the lack of chinook passed over the counting fence located just upstream of the lake. Crews consisted of two to five people, and all surveys were conducted in a downstream direction.

All carcasses were recorded by date, reach, sex (confirmed by incision), tag presence and Petersen disk number, adipose fin clip (AFC) presence, post-orbital to hypural plate (POH) length (± 1 cm), and secondary mark status. Once sampled, all carcasses were cut in two and returned to the river. Heads were collected from every second AFC chinook for coded wire tag (CWT) recovery and decoding. Scale samples were taken from each secondary marked fish, each fish sampled for CWT recovery, and every tenth unmarked fish not sampled for CWT recovery. Fish were aged according to the Gilbert Rich coding system. The condition of the adipose fin clip was recorded as either complete (flush with dorsal surface), partial (nub present), or questionable (appeared to be clipped but fungus or decomposition obscured the area).

Apparent spawning success was estimated for all intact female carcasses. Success was categorized as either 0% (pre-spawning mortality), 50% (partially spent), or 100% (virtually no eggs remaining). The condition of the carcass was recorded as either fresh (gills red or mottled), moderately fresh (gills white but flesh still firm), moderately rotten (body intact but soft), or rotten (skin and bones remaining). The number of eyes in the carcass was also recorded.

AERIAL ENUMERATION

Aerial counts were performed during low level (10-30 m) flights in a Bell 206B helicopter, at speeds between 10 and 40 $km \cdot h^{-1}$, proceeding in a downstream direction. Two observers seated on the opposite side of the aircraft to the pilot, counted all chinook salmon observed, and recorded them as either live or dead by stratum. Live fish were counted in two categories: actively spawning in an area containing redds or holding away from spawning areas. Where carcasses had been cut in two by the recovery crew, only posterior sections including tails were counted as a carcass. At the end of each stratum count, the observers recorded their individual tallies, discussed their observations, and determined the best count for the stratum. Frequently, but not exclusively, the best count was the higher count of the two observers' counts. Six flight dates were scheduled. The flight days were to occur prior to, during, and after the expected peak of spawning activity.

ANALYTIC PROCEDURES

TESTS FOR SAMPLING SELECTIVITY

Period

Temporal bias was assessed in both the marking and recovery samples. Application sample bias was examined by comparing the mark incidence in the recovery sample from each application period. Recovery sample bias was examined by comparing the percentage mark occurrence in each of the recovery periods. Differences among periods were compared using the Chi-square test (Sokal and Rohlf 1981). Samples were stratified by sex prior to testing.

Location

Spatial bias in both samples was assessed, using Chi-square tests, in a manner similar to the assessment of temporal bias. Recovery bias was assessed by stratifying the application sample by stratum and comparing the proportions recovered from each stratum. Application sample bias was assessed by comparing the differences in mark incidence among recovery strata. Samples were stratified by sex prior to testing.

Fish Size

Size related bias was assessed using the Kolmogorov-Smirnov two sample test (Sokal and Rohlf 1981). Application bias was assessed by comparing POH length frequency distributions in marked and unmarked fish in the recovery sample. Recovery bias was assessed by comparing fork length frequency distributions in the recovered and not recovered portions of the tag application sample. Both samples were stratified by sex prior to performing these tests.

Fish Sex

Sex related bias was assessed using Chi-square tests. Recovery bias was assessed by stratifying the application sample into recovered and not recovered components and comparing the male and female proportions in each. Application bias was assessed by comparing the sex ratio in the marked and unmarked carcasses in the recovery sample. In addition, sex specific differences in mark recovery and tag loss were assessed.

Tagging Stress

Mark application stress was assessed by comparing the apparent spawning success data for the marked and unmarked females in the carcass recovery sample using Chi-square tests. Tag application stress was further assessed by comparing the rates of mark recovery from the three release condition categories. Angling related stress was assessed by comparing the recovery rates in fish in the four bleeding categories, between fish hooked in critical and non-critical areas, and between fish that were angled once and more than once.

ESTIMATION OF SPAWNER POPULATION

Mark-Recapture Escapement

The adult chinook salmon population within the Nicola River study area was estimated using the Chapman modification of the Petersen estimator (Ricker 1975). In anticipation of significant sex related differences in the data and in order to facilitate comparison with past or similar studies, the escapement was calculated by sex. The escapement to the river (N_t) was the sum of the male (N_m) and female (N_f) escapements. Male escapement was estimated by:

$$N_m = \frac{(M_m + 1)(n_m + 1)}{(m_m + 1)} - 1$$

where:

M_m = number of males released with primary and secondary marks corrected for sex identification errors
m_m = number of primary and/or secondary marked male carcasses recovered; and
n_m = number of male carcasses examined for marks.

Standard error (square root of the variance) of the male escapement estimate was calculated as:

$$SE_m = \sqrt{\frac{(N_m^2)(n_m - m_m)}{(n_m + 1)(m_m + 2)}}$$

and the 95% upper and lower confidence limits on the male estimate were calculated as:

$$N_m \pm 1.96\ SE_m$$

The female spawning escapement (N_f) and its confidence limits were calculated in an analogous manner. Confidence limits around the total escapement were calculated from the square root of the summed male and female variances.

Sex Identification Correction

Identification errors occurred because sexually dimorphic traits were not fully developed at the time of marking and internal examinations were not possible until the carcass survey. Tag application data were corrected for sex identification error using the method described by Staley (1990).

Adipose Fin Clipped Escapement

The number of AFC chinook in the escapement was calculated from the AFC incidence in the carcass recovery sample. This sample was the larger of the two samples and reflected the incidence of AFC fish in the population remaining after removal of hatchery brood stock. The AFC incidence in the recovery sample was tested for differences (Chi-square test) related to clip or carcass condition. If significant differences were noted, the atypical group was removed from further analysis. AFC escapement was the product of the sex specific AFC incidence and the sex specific Petersen population estimate. Differences in AFC incidence by sex were also tested for significance. Ninety-five percent confidence limits on the AFC escapement were not calculated.

Escapement by Age Group

Escapement by age group was calculated by applying the age composition in the recovery sample to the population estimate. As sex specific Petersen estimates were calculated, age data were also stratified by sex. The significance of differences in age composition between the sexes was assessed by a Chi-square test. In addition, the age compositions in carcasses with and without AFCs were compared. If a significant difference was noted, the escapement at age was also stratified by AFC status. Ninety-five percent confidence limits on the age specific escapement were not calculated.

Coded Wire Tagged Escapement

Escapement by CWT code group was calculated by applying the sex specific CWT code composition in the carcass recovery sample to the age and sex stratified AFC escapement estimates. Age and sex grouped CWT codes were apportioned by code within the appropriate age and sex specific AFC escapement estimate. Confidence intervals on the CWT escapements were not calculated. Long-term CWT loss was calculated from the proportion of AFC carcasses recovered without a CWT in the total AFC carcass sample. Apparent CWT loss related to clip condition, carcass condition, or eye loss due to decomposition or predator activity was assessed (Chi-square test). If significant differences were noted, the atypical category within the sample was deleted from the analysis of CWT loss.

Aerial Escapement

When counting conditions were optimal, estimates of escapement were derived by summing the best reach specific counts of live and dead fish observed to obtain a best total daily count. On days when replicate flights were made the two total daily counts were averaged. The best total daily count that occurred closest to the peak of spawning was then divided by the 0.65 expansion factor to determine the size of the spawning escapement.

RESULTS

FISH CAPTURE AND MARK APPLICATION

One hundred and forty-nine individual chinook salmon were captured by angling between August 15 and August 29. Of those, one salmon died during the mark application handling process. That mortality was hooked in the gills and bleeding heavily. The remaining 148 fish were tagged and released to the river. Subsequently, 15 marked chinook were removed from the system and used for hatchery brood purposes leaving 133 chinook for inclusion in mark-recapture analyses.

Of the 133 marked chinook in the application sample, 51 were identified as male and 82 were identified as female at the time of release (Table 2, Appendix 1). In the recovery sample, 2 identification errors were noted; one male carcass was originally characterized as a female and 1 female carcass was identified as male at tag application. After application of the sex identification correction, the released application sample was comprised of 50 males and 83 females. Within the mark application sample there were 41 chinook bearing an AFC.

Table 2. Marks applied, by sex and adipose fin status, and sex identity errors in Nicola River chinook salmon, 1998.

	At mark application			Corrected for identity error	
Sex	Total	Adipose fin absent [a]	Error rate	Total	Adipose fin absent [a]
Male	51	17	1 (6.7%)	50	17
Female	82	24	1 (5.0%)	83	24
Total	133	41		133	41

a. Included in total.

Tag application was attempted in five of the eight river segments (Appendix 1). Within those 5 strata, most tags were applied in the lower section of the Nicola River mainstem (stratum 8, 29.3%) and in Spius Creek, (stratum 6, 21%). The peak day of tagging occurred August 18 when 19 tags were applied; 13 of them applied in Spius Creek (stratum 6).

Capture and Release Conditions

Of the 133 fish released with primary and secondary marks, the majority (93.2%) swam away rapidly after tag application (Table 3). None required swimming or gill ventilation assistance after mark application. There were no significant differences in either sex in percentage recovery between fish that swam away rapidly and those that swam away slowly ($p>0.05$; Chi-square test).

Table 3. Marks applied and recovered, by release condition after tag application, by sex, of Nicola River chinook salmon, 1998.

	Applied [a]		Recovered		Percent recovered	
Release condition	Male	Female	Male	Female	Male	Female
Swam rapidly	45	78	14	17	31.1%	21.8%
Swam sluggishly	5	5	1	3	20.0%	60.0%
Required assistance	0	0	0	0	-	-
Total	50	83	15	20	30.0%	24.1%

a. Corrected for sex identification errors.

Of the 133 fish released with primary and secondary marks, the majority (81.2%) were not bleeding from the angling hook location (Table 4). There were no significant differences ($p>0.05$; Chi-square test) in mark recovery rates in male (30.8%) or female (16.7%) chinook that bled at capture as compared to those that were not bleeding

(29.7% and 25.4%, respectively). Therefore, none of the bleeding fish were removed from the mark-recapture analyses.

Table 4. Marks applied and recovered, by relative amount of bleeding after being angled, by sex, of Nicola River chinook salmon, 1998.

	Applied [a]		Recovered		Percent recovered	
Bleeding condition	Male	Female	Male	Female	Male	Female
Heavy	0	0	0	0	-	-
Moderate	2	1	0	1	0.0%	100.0%
Slight	11	11	4	1	36.4%	9.1%
None	37	71	11	18	29.7%	25.4%
Total	50	83	15	20	30.0%	24.1%

a. Corrected for sex identification errors.

Of the 133 chinook released with primary and secondary marks, a small portion (10.5%) were hooked in a location which could result in a potentially critical injury (gills, tongue, roof of mouth, and eye) (Table 5). The mark-recovery rate in males (20.0%) and females (12.5%) which were hooked in critical areas was not significantly different ($p>0.05$; Chi-square test) from that of fish hooked in non-critical areas (27.1% and 23.5%, respectively). Consequently, none of the critically hooked fish were removed from the application sample.

Table 5. Marks applied and recovered, by location of angling hook, by sex, of Nicola River chinook salmon, 1998.

	Applied [a]		Recovered		Percent recovered	
Location of Hook [b]	Male	Female	Male	Female	Male	Female
Critical area	8	6	2	1	25.0%	16.7%
Non-critical area	42	77	13	19	30.9%	24.7%
Total	50	83	15	20	30.0%	24.1%

a. Corrected for sex identification errors.
b. Critical areas are roof of mouth, gills, tongue, and eye; all other areas are non-critical.

Size and Age at Release

Within the mark application sample, males averaged 698 mm fork length (range 460 to 880 mm) while females averaged 689 mm (range 465 to 960 mm). Male and female length-frequency distributions were not significantly different (p>0.05; Kolmogorov-Smirnov test). Ageing structures were not removed at the time of mark application; however, scales from marked fish in the recovery sample indicated that 80.8% were age 4, and 19.2% were age 5. All marked fish showed a yearling (sub2) freshwater age.

Recaptures

Following release, 34 marked fish were recaptured during subsequent mark application periods (Appendix 2). Six marked fish were recaptured twice and two were recaptured three times. Fifteen of the recaptures were taken for hatchery use. Of the 19 recaptured individuals released back to the river, 8 (42.1%) were recovered in the carcass recovery sample. This recovery rate was not significantly higher than that observed in fish which had not been recaptured (23.9%) (p>0.05; Chi-square test). Consequently, none of the recaptured fish were removed from the mark-recapture analyses. Elapsed time between mark application and subsequent recapture averaged 5.2 days (mode 0 days, range 0 to 24 days).

CARCASS RECOVERY

Carcass recovery was carried out daily from 29 August to 14 October. A total of 441 carcasses were examined during the recovery period of which all were suitable for inclusion in the mark-recapture study. Of the 441 carcasses, there were 36 chinook that were either primary or secondary marked and 405 unmarked fish (Table 6)(Appendices 3 and 4). Of the total carcasses there were 16 and 20 marked males and females, and 206 and 199 unmarked males and females, respectively. A total of 55 carcasses, 25 males and 30 females, bore an AFC.

Table 6. Carcass recovery and marked carcasses by sex and adipose fin status in the Nicola River, 1998.

		Primary mark			Adipose fin		
Sex	Total carcasses	Petersen disc	Secondary mark only	Total	Absent	Present	Unknown
Male	222	15	1	16	25	197	0
Female	219	20	0	20	30	189	0
Unknown	0	0	0	0	0	0	0
Total	441	35	1	36	55	386	0

Recovery efforts were concentrated in strata 2 through 8 (Appendix 4). Effort ranged from 1 to 7 survey days in strata 2 to 8. The largest number of carcasses recovered were from strata 4 (34.5%), 5 (25.2%), 2 (18.6%), and 7 (17.7%) each of which were surveyed 6 to 7 times. The lowest recoveries were in strata 6 (0.5%), 8 (1.0%) and 3 (2.7%) which were surveyed 1 to 4 times. AFC carcass distribution among reaches was not significantly different from that observed in the non-AFC carcasses ($p>0.05$; Chi-square test).

Hatchery and Miscellaneous Recoveries

Between August 17 and September 15, Spius Creek Hatchery staff removed 177 chinook (80 males and 97 females) from the watershed. Of that total, 80 chinook (37 males and 43 females) bore an AFC, of which 75 (34 males and 41 females) contained a CWT and 5 did not have a CWT present. Within the hatchery removals there were 15 Petersen disc bearing chinook used for hatchery brood stock. These fish were excluded from the mark-recapture data analyses. No other miscellaneous recoveries of marked fish were recorded.

Sex, Size, and Age

Of the recovered carcasses, 50.3% were male and 49.7% were female. Average POH lengths derived from a sample of 197 male and 203 female carcasses were 631 mm and 600 mm, respectively. There was no significant difference in the length frequency distributions of males and females ($p>0.05$; Kolmogorov-Smirnov test).

The age composition of female carcasses (0.6% age 3, 74.1% age 4, 24.7% age 5, and 0.6% age 6) was not significantly different from that of male carcasses (2.0% age 3, 74.5% age 4, and 23.5% age 5) ($p>0.05$; Chi-square test). The age composition of female AFC carcasses was significantly different from that in female carcasses which bore an adipose fin ($p< 0.05$; Chi-square); however, the difference was not significant in male carcasses. Among aged carcasses, all showed a yearling (sub2) freshwater growth pattern (Appendix 5).

SAMPLING SELECTIVITY

Period

Temporal bias in the application sample was examined by comparing mark incidences in three recovery periods, each containing approximately equal numbers of recoveries (Table 7). Pooling by recovery numbers was done to increase sample sizes and decrease the potential for invalid statistical results. Mark incidence in males averaged 7.2% (range 3.8 to 14.7%) while female mark incidence averaged 9.1%

(range 5.0 to 17.4%). Although a trend was noted, there was no statistically significantly difference among mark incidences in the three recovery periods in either of the sexes (p>0.05; Chi-square test).

Table 7. Incidence of primary or secondary marks in Nicola River chinook salmon, by recovery period and sex, 1998.

	Marked [a]			Total			Mark Incidence		
Recovery period	Male	Female	Un-known	Male	Female	Un-known	Male	Female	Un-known
Aug 29 – 24 Sep	10	12	0	68	69	0	14.7%	17.4%	-
Sep 25 – 29 Sep	3	4	0	75	70	0	4.0%	5.7%	-
Sep 30 – 14 Oct	3	4	0	79	80	0	3.8%	5.0%	-
Total	16	20	0	222	219	0	7.2%	9.1%	-

a. Includes fish bearing only a secondary mark.

Recovery bias was examined by comparing the proportions recovered from each of two mark application periods (Table 8). Data were pooled into periods of approximately equal numbers applied to increase sample sizes and decrease the potential for invalid statistical results. In males, the average percentage recovered was 30.0% (range 20.8 to 38.5%) while in females the average was 24.1% (range 19.5 to 28.6%). There was no significant difference between periods in either sex (p>0.05; Chi-square test).

Table 8. Primary marks applied and recovered in the Nicola River, by application date and sex, 1998.

	Applied [a]		Recovered		Percent recovered	
Application date	Male	Female	Male	Female	Male	Female
Aug 15 – 19	24	42	5	12	20.8%	28.6%
Aug 20 – 29	26	41	10	8	38.5%	19.5%
Total	50	83	15	20	30.0%	24.1%

a. Corrected for sex identification errors.

Location

Spatial bias in the application sample was examined by comparing the mark incidences among river sections. To increase sample size and decrease the potential for invalid statistical test results the data for geographically adjacent strata were pooled. In males, mark incidence ranged from 2.4% to 10.5% while in females the incidence of marks ranged from 7.1% to 11.1%. In both sexes the highest incidence in stratum 5 (Table 9); however, the observed distribution of marks among was not significantly different from that expected in either sex (p>0.05; Chi-square test).

Table 9. Incidence of primary or secondary marks in Nicola River chinook salmon, by recovery section and sex, 1998.

	Marked [a]			Total			Mark incidence		
Stratum	Male	Female	Un-known	Male	Female	Un-known	Male	Female	Un-known
2 & 3	2	4	0	47	47	0	4.3%	8.5%	-
4	7	7	0	76	76	0	9.2%	9.2%	-
5	6	6	0	57	54	0	10.5%	11.1%	-
6, 7 & 8	1	3	0	42	42	0	2.4%	7.1%	-
Total	16	20	0	222	219	0	7.2%	9.1%	-

a. Includes fish bearing only a secondary mark.

Spatial recovery sampling bias was assessed by examining the percentage recovery from each of the 5 mark application strata (Table 10). In males, the percentage recovered ranged from 0.0% from marks applied in stratum 4 to 50.0% for stratum 7 and 8 while in females the range was from 8.3% for marks applied in reach 2 to 34.8% for reach 8. The differences observed were not significant in either sexes (p>0.05; Chi-square test); however, small sample sizes limited the statistical validity of the data. After pooling the data for the two sexes there was no significant difference detected.

Table 10. Primary marks applied and recovered in the Nicola River, by application reach and sex, 1998.

	Applied [a]		Recovered		Percentage recovered	
Stratum	Male	Female	Male	Female	Male	Female
2	7	12	2	1	28.6%	8.3%
4	12	15	0	3	0.0%	20.0%
6	9	19	2	5	22.2%	26.3%
7	6	14	3	3	50.0%	21.4%
8	16	23	8	8	50.0%	34.8%
Total	50	83	15	20	30.0%	24.1%

a. Corrected for sex identification errors.

Fish Size

Size related bias in the application sample was examined by comparing the POH length frequency distributions of marked and unmarked carcasses. No significant differences (p>0.05; Kolmogorov-Smirnov two sample test) were detected in male or female chinook (Table 11).

Table 11. Percent marked and frequency distribution of marked chinook in the recovery sample, by sex and 100 mm increments in POH length, in the Nicola River, 1998.

POH length	Marked [a]		Total [a]		Percent marked	
interval (mm)	Male	Female	Male	Female	Male	Female
< 400	0	0	0	0	-	-
401-500	1	1	8	8	12.5%	12.5%
501-600	7	12	92	97	7.6%	12.4%
601-700	6	6	84	84	7.1%	7.1%
701-800	0	1	13	14	0.0%	7.1%
> 801	0	0	0	0	-	-
Total	14	20	197	203	7.3%	7.0%

a. Excludes carcasses not measured for length.

Recovery sample bias was examined by partitioning the application sample into recovered and not recovered components and comparing their NF length frequency distributions. There was no significant difference (p>0.05, Kolmogorov-Smirnov test) in either of the sexes (Table 12).

Table 12. Percent recovered and frequency distribution of primary marked chinook in the application and recovery samples, by sex and 100 mm increments in fork length, in the Nicola River, 1998.

Fork length	Application sample [a]		Recovery sample		Percent recovered	
interval (mm)	Male	Female	Male	Female	Male	Female
401-500	3	1	1	1	33.3%	100.0%
501-600	6	3	0	0	0.0%	0.0%
601-700	16	40	7	8	43.8%	20.0%
701-800	18	31	5	8	27.8%	25.8%
801-900	5	8	1	3	20.0%	37.5%
901-1000	2	0	1	0	50.0%	-
Total	50	83	15	20	30.0%	24.1%

a. Corrected for sex identification error.

Fish Sex

Application bias was assessed by comparing the sex ratio in the marked and unmarked carcass recoveries (Table 13). There was no significant difference detected ($p > 0.05$; Chi-square test). Similarly, recovery sample bias, assessed by comparing the sex ratio of the recovered and not recovered components of the application sample, was not detected ($p>0.05$; Chi-square test). In addition, there was no significant difference between the recovery rates of males (7.2%) and females (9.1%)($p>0.05$; Chi-square test).

Table 13. Sex composition of Nicola River chinook salmon in mark application and carcass recovery samples, 1998.

	Application sample [a]			Recovery sample [b]		
Sex	Total [a]	Recovered [b]	Not recovered	Sample size	Marked [b]	Not marked
Male	50	44.4%	35.7%	222	44.4%	50.9%
Female	83	55.5%	64.3%	219	55.5%	49.1%
Total	133	100.0%	100.0%	441	100.0%	100.0%

a. Corrected for sex identification errors.
b. Includes fish bearing only a secondary mark.

Spawning Success

Apparent spawning success, derived from the internal examination of female spawning ground recoveries, was estimated at 95.9% (Appendix 6). The spawning success of marked females (97.4%) was not significantly different than that observed in unmarked females (95.3%) ($p<0.05$; Chi-square test).

AERIAL ENUMERATION

Six aerial enumeration flights were undertaken between September 5 and 23 (Appendix 7). The highest total count (719) occurred on September 19 when 98% of the fish were actively spawning, none were holding, and 2% were dead. Four days later 5% of the observed chinook were dead. Four days prior to September 19, 10% of the fish were holding and 1% were dead. Based on these data, the peak aerial count occurred at, or near, the peak of spawning activity.

ESTIMATION OF SPAWNER POPULATION

Mark-Recapture Escapement

The mark-recovery data used to calculate spawning population size was comprised of the number of marks released and available for recovery (corrected for sex identification errors), the number of carcasses examined within the study area, and the number of primary and secondary marks recovered within the study. Although no significant sex related biases were evident, to maintain consistency with previous year's data the data were stratified by sex. Spatial and temporal biases were not detected in data for either of the sexes (Table 14).

Table 14. Results of statistical tests for bias in the 1998 Nicola River chinook salmon escapement estimation study. [a]

Bias type	Application sample	Recovery sample
Statistical [b]	n/a	No bias
Period	No bias	No bias
Location	No bias	No bias
Fish size	No bias	No bias
Fish sex	No bias	No bias

a. No bias indicates that bias was not detected; undetected bias may be present.

b. Bias present when recoveries total 4 or less.

The 1998 spawning escapement of 1,547 Nicola River chinook salmon was calculated by summing the sex specific Petersen population estimates. Lower and upper 95% confidence limits on this estimate were 1,089 and 2,005 (Table 15). The male escapement was estimated to be 668 while the female estimate was 879. Based on the age composition of the aged portion of the recovery sample, the escapement was comprised of 1.2% age 3, 74.3% age 4, 24.3% age 5, and 0.3% age 6 chinook. (Table 16). Age composition in male and female carcasses were not significantly different (Appendix 5). Furthermore, age compositions of the AFC and adipose fin present carcasses were not significantly different.

The AFC fish in the recovery sample did not show any significant differences in CWT absence associated with loss of eyes to predators or in carcasses with partial or questionable clips (Appendix 8). The AFC incidence and CWT loss in males (10.8% and 11.5%, respectively) was not significantly different than that observed in female carcasses (14.2% and 10.0%) ($p>0.05$; G-test) (Appendix 9). Application of the sex specific AFC incidences to the sex specific escapements apportioned the total escapement into 196 AFC chinook and 1,351 chinook bearing adipose fins. Escapement by CWT code is presented in Table 17. There was a significant difference in the temporal distribution of male AFC chinook (Appendix 9) with a significantly high incidence of AFC chinook in the earliest recovery period. Females did not show a significant temporal pattern. The spatial distribution of AFCs among reaches was not significantly different from that observed in chinook bearing an adipose fin. Spatial differences may not have been detected because of small sample sizes.

The AFC fish in the Spius Hatchery brood fish were not collected randomly and therefore were excluded from the above analyses. The AFC incidence in the hatchery sample was 45.2% (46.3% in males and 44.3% in females) as compared to an average of 12.5% in the carcass recovery sample. Long term CWT loss in the hatchery sample was estimated at 6.4% (8.1% in males and 4.7% in females); less than the CWT loss (10.7%) observed in the carcass recovery sample. The composition of CWT groups in the hatchery sample was predominantly comprised of code groups 181953 (53.3%) and 181952 (29.3%); similar to the composition of those two groups in the carcass recovery CWT sample (58.0% and 28.0%, respectively).

Table 15. Escapement estimates derived from mark-recovery data for Nicola River chinook salmon, by sex, 1998.

	Sex			
	Male	Female	Unknown	Total
Carcasses sampled	222	219	0	441
Marks applied [a]	50	83	0	133
Marks recovered	16	20	0	36
Percentage recovered	32.0%	24.1%	-	27.1%
Population size	668	879	-	1,547
Lower 95% Confidence Limit	371	530	-	1,089
Upper 95% Confidence Limit	965	1,228	-	2,005
Precision	± 44.5%	± 39.7%		± 29.6%
AFC Incidence	10.8%	14.2%	-	12.5%
AFC Population size	72	124	-	196

a. Corrected for sex identification errors.

The sum of the escapement spawning in the Nicola River and taken for hatchery brood stock was 1,724 chinook. Of that total, 276 bore an AFC while of the AFC chinook, 253 contained a CWT. Total returns by CWT code group were 4 of code 181526, 3 of code 181642, 5 of code 181643, 74 of code 181952, 142 of code 181953, 3 of code 182731 and 12 of code 182732.

Table 16. Estimated spawning escapement and escapement by age and sex of Nicola River chinook salmon, 1995 to 1998.

		Age Class									95% Confidence Limits		
Sex	Year	3_1	3_2	4_1	4_2	5_1	5_2	5_3	6_2	Total	Lower	Upper	% Precision
Male	1995	228	0	222	3,536	0	420	0	32	4,438	3,560	5,317	20%
	1996	63	2	112	6,790	2	602	0	0	7,573	6,498	8,647	14%
	1997	21	21	21	3,887	0	516	24	0	4,489	3,762	5,215	16%
	1998	0	9	0	493	0	165	0	0	668	371	965	44%
Female	1995	398	1	377	4,912	0	500	0	0	6,187	5,125	7,247	17%
	1996	6	0	207	9,295	0	696	0	0	10,204	8,740	11,669	14%
	1997	15	0	0	4,844	0	264	0	0	5,123	4,358	5,889	15%
	1998	0	2	0	632	0	239	0	6	879	530	1,228	40%
Total	1995	626	1	599	8,448	0	920	0	32	10,626	9,247	12,002	13%
	1996	69	2	319	16,086	2	1,299	0	0	17,777	15,961	19,594	10%
	1997	36	21	21	8,731	0	779	24	0	9,612	8,557	10,668	11%
	1998	0	12	0	1,125	0	404	0	6	1,547	1,089	2,005	30%

Table 17. Estimated escapement by sex, age, and CWT group of chinook salmon spawning in the Nicola River, 1998.

		Male	Female	Total [a]
Age Class	3	13	5	18
	4	498	650	1,148
	5	157	218	375
	6	0	5	5
CWT Code	181526	0	4	4
	181642	3	0	3
	181952	12	40	52
	181953	42	60	102
	182731	6	4	10
	182732	3	4	7
	Not present	6	12	18
	Total	72	124	196

a. Sum of sex-specific data.

Aerial Escapement

The largest aerial count (719) was recorded on September 19 and, based on the small numbers of carcasses and holding fish, occurred close to the peak of spawning activity. Expansion of the total aerial count by the standard 65% expansion factor, resulted in an estimate of 1,102 spawning chinook. This estimate is 29% lower than the mark-recapture estimate and is within the 95% confidence limits about the mark-recapture estimate.

Due to the protracted nature of the spawning, and the small run size in 1998, we were also able to count vacated redds during overflights. On the September 19th flight, we counted 50 vacated redds, with no carcasses in the vicinity of those redds. Each redd was assumed to represent an additional 2.2 spawners (110 in total), which were added on to the estimate of 1,102, resulting in a total overflight escapement estimate of 1,212 chinook.

DISCUSSION

The estimation of population size for spring and summer run chinook salmon present in the tributaries of the Fraser and Thompson rivers has traditionally been done using visual counts from helicopter overflights. Initially, only one flight per year was undertaken on each tributary, however, the current program attempts to estimate escapement on two or three separate days, near the peak of spawning for each system. The overflight program was initiated in the early 1970's and expanded to provide two or three flights per spawning system in 1989.

Visual estimates tend to be inaccurate and frequently underestimate population size (Tschaplinski and Hyatt 1991). The accuracy of aerial counts are influenced by the physical conditions at the time of counting. Light penetration, turbidity, fish behaviour and weather all influence fish visibility (Bevan 1961). Other factors influencing aerial estimates include the experience of the pilot and observers, flight scheduling and frequency of counts (Bevan 1961; Neilson and Geen 1981). To increase accuracy, flights occurred when observation conditions were the best available. Also, we used experienced enumerators and a helicopter pilot with prior experience in low level fish enumeration. We have no evidence that the 1998 observations were hampered by weather or observer conditions.

Salmon are counted most easily when dispersed into shallow spawning grounds at the peak of spawning (Cousens et al. 1982). Therefore, it is important to schedule flights to coincide with the peak of spawning. In 1998, we scheduled six aerial counts over the expected duration of spawning. During the first four flights holding fish were observed while on the fifth flight all live fish were actively spawning. On the sixth flight all live fish were actively spawning; however, the number of carcasses increased. We conclude that the 1998 peak count coincided with the peak of spawning activity, however, due to the extended low flows and warmer water, the spawning activity was more protracted in 1998 than observed in previous years.

All previous Nicola River studies have noted lower than expected percentage of the spawning population that was enumerated in the best available aerial counts. In 1995, 35% of the mark recovery estimate was aerially counted, apparently a result of abnormally turbid waters during the enumeration flights. In 1996 there were no notable negative influences on visual observation and the aerial count was 55% of the mark-recovery derived population estimate. In 1997, the visual counts were not negatively affected by observation conditions and the aerial count at the peak of spawning was 44% of the mark-recovery population estimate. In the present study, the best aerial count was 46% of the mark-recovery estimate. These four years of data show a range of 32% and 55% and an average of 44%. This is notably lower than the 65% presently used and we recommend that future aerial estimates use the average as an expansion factor.

In 1998, we also expanded the estimated escapement to incorporate vacated redds observed during the peak count flight. This was feasible due to the low density of fish and the protracted spawning run. Ordinarily at the peak of spawning, there are very few empty redds, and virtually none that are clearly not associated with nearby carcasses.

The mark-recovery method will produce an accurate estimate of the actual population size if the capture and tagging process do not significantly influence subsequent fish behaviour (Ricker 1975). We assessed this possible source of bias by comparing the recovery rates from fish that were categorized by apparently different amounts of stress at the time of release back into the population. No impact from capture stress was detected and we conclude that any stress-related bias in the mark-recovery estimate was small.

A second important aspect to producing an accurate population estimate from the mark-recovery method is that the mark application and carcass recovery samples should be representative of the population (Ricker 1975). It is preferable for both samples to be taken in a random manner; however, if only one of the samples is random, the results are not seriously biased (Robson 1969). In the present study we assessed the representativeness of the sampling process by looking for bias in the temporal, spatial, fish size and sex composition patterns of the two samples. No significant impacts were observed and we conclude that these potential sources of bias did not significantly impact the mark-recovery population estimate. Further, no significant biases were noted in length frequency distributions or sex compositions in the two samples. We conclude that the mark-recovery estimate was relatively unbiased.

Although we conclude that the mark-recovery population estimate was accurate, we are concerned about the imprecision about the estimate (±30%). Previous studies have shown precision levels of between 10 and 13% (Table 16). We suggest that the relatively large imprecision in 1998 was an artifact of the small sample sizes in both the application and recovery samples.

POPULATION SIZE

The population size estimated by the mark-recovery data was 1,547 chinook while the estimates derived from the aerial enumeration data nearest the peak was 1,212. This is the lowest population estimate in the four years since the start of the mark-recovery study (Table 16). The low visual observations are also the lowest on record since 1971, when the current time series of visual escapement data began.

The low escapements in 1998 are attributed to an extended period of low water and high instream temperatures inhibiting returns to the Nicola from the Thompson River, and also leading to mortality enroute to the spawning grounds. Up to 100 chinook per hour were observed either dead or moribund, floating downstream in the Thompson River at Spences Bridge for several days in August 1998, during the period of mark application. At the same time, there was a school of chinook, estimated visually to be over 1,000 animals holding off the mouth of the Nicola, presumably waiting for increased flows and cooler temperatures, prior to entering the Nicola to spawn. The fate of these fish is unknown, as none remained visible by the last flight.

SUMMARY

1. In an attempt to improve upon the available information, the population of Nicola River chinook salmon was assessed by a mark-recovery programme. The results of this assessment were compared with the results of the traditional aerial escapement enumeration programme.

2. Primary and secondary marks were applied to chinook following their capture by angling. During the period 15 to 29 August, 149 individual chinook were captured and 133 were marked, released, and remained available for inclusion in the study.

3. After correction for sex identification errors, the application sample was comprised of 50 males and 83 females. The males averaged 698 mm fork length while females averaged 689 mm. Age composition of marked fish in the recovery sample was 80.8% age 4, and 19.2% age 5. All marked fish showed a yearling freshwater growth pattern.

4. Carcass recovery occurred from 29 August to 14 October. The recovery sample was comprised of 441 chinook, of which 36 bore primary or secondary marks.

5. The recovery sample was comprised of 222 males and 219 females. Average size of the males was 631 mm POH length while females averaged 600 mm. Age composition of female chinook was 0.6% age 3, 74.1% age 4, 24.7% age 5, and 0.6% age 6. Male chinook were comprised of 2.0% age 3, 74.5% age 4, and 23.5% age 5. All carcasses exhibited a yearling freshwater age.

6. Sampling selectivity related to temporal and spatial patterns, fish size, and sex was assessed in both mark and recovery samples. To facilitate comparison with other reports, the data were stratified by sex.

7. Six aerial chinook enumeration flights were done between 5 and 23 September. The total count on the flight nearest the peak of spawning was 719 chinook (98% live and all actively spawning).

8. Spawning population size estimated from the mark-recovery data was 1,547 chinook (668 male and 879 female). Within that population there were 196 AFC fish. The population size estimate derived from the September 19 peak aerial enumeration was 1,212 chinook.

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APPENDICES

Appendix 1. Daily mark application, by sex, reach, and adipose fin status, to Nicola River chinook, 1998.

		Total Marks Applied [c]			AFC Chinook [a]		
Date	Stratum	Male	Female	Total	Male	Female	Total
15-Aug	8	5	9	14	1	1	2
16-Aug	4	1	0	1	0	0	0
"	7	0	1	1	0	0	0
"	8	2	3	5	0	1	1
17-Aug	4	3 [b]	4	7	2	1	3
"	8	4	4	8	2	1	3
18-Aug	4	0	2	2	0	1	1
"	6	5	8	13	0	4	4
"	7	1	3	4	1	1	2
19-Aug	2	3	6	9	0	3	3
"	6	0	2	2	0	0	0
20-Aug	6	1	0	1	0	0	0
"	8	2	0	2	0	0	0
21-Aug	6	1	6	7	0	1	1
"	7	0	1	1	0	1	1
"	8	1	3	4	1	2	3
22-Aug	2	2	5	7	0	2	2
"	4	1	0	1	1	0	1
25-Aug	4	2	2	4	0	0	0
"	6	2	0	2	0	0	0
"	7	1	5	6	0	2	2
"	8	3	3	6	3	1	4
26-Aug	4	0	1	1	0	0	0
"	7	1	1	2	0	0	0
27-Aug	2	2	1	3	2	0	2
"	4	3	4	7	3	0	3
"	7	1	0	1	0	0	0
28-Aug	4	2	2	4	0	0	0
"	7	0	1	1	0	0	0
29-Aug	6	0	3	3	0	1	1
"	7	2	2	4	1	1	2
Total	2	7	12	19	2	5	7
	4	12	15	27	6	2	8
	6	9	19	28	0	6	6
	7	6	14	20	2	5	7
	8	17	22	39	7	6	13
Grand total		51	82	133	17	24	41

a. Adipose absent chinook are included in total marks applied.
b. Excludes one mortalitity at time of tag application.
c. Excludes 15 fish recaptured and taken for hatchery brood (see Appendix 2).

Appendix 2. Recaptures of previously marked chinook salmon, by application and recovery dates and locations, and sex, in the Nicola River, 1998.

Primary Tag		Application				Recapture			
Series	Number	Date	Stratum	Sex	Release condition [c]	Date	Stratum	Result [a]	Days out
G	015001	15-Aug	8	F	1	27-Aug	7	Br	12
G	015004	15-Aug	8	F	1	25-Aug	7	R	10
G	015006	15-Aug	8	M	1	17-Aug	7	R	2
G	015007	15-Aug	8	F	1	21-Aug	7	R	6
G	015012	18-Aug	8	M	1	01-Sep	6	Br	14
G	015013	18-Aug	7	F	1	25-Aug	7	R	7
G	"	18-Aug	7	F	1	28-Aug	7	R	10
G	015014	18-Aug	7	F	1	18-Aug	7	R	0
G	"	18-Aug	7	F	1	19-Aug	7	R	1
G	015015	18-Aug	7	M	1	19-Aug	7	R	1
G	"	18-Aug	7	M	1	21-Aug	7	R	3
G	"	18-Aug	7	M	1	11-Sep	7	Br	24
G	015017	18-Aug	7	M	2	25-Aug	7	R	7
G	015020	18-Aug	6	M	1	21-Aug	7	R	3
G	015024	18-Aug	6	M	1	18-Aug	7	R	0
G	015025	18-Aug	6	F	1	21-Aug	7	R	3
G	015029	18-Aug	6	M	1	18-Aug	7	R	0
G	"	18-Aug	6	M	1	21-Aug	7	R	3
G	"	18-Aug	6	M	1	27-Aug	7	Br	9
G	015031	19-Aug	7	F	1	27-Aug	7	Br	8
G	015033	19-Aug	6	M	1	21-Aug	7	R	2
G	"	19-Aug	6	M	1	27-Aug	7	Br	8
G	015035	19-Aug	7	F	1	27-Aug	7	Br	8
G	015036	19-Aug	8	F	1	21-Aug	7	R	2
G	"	19-Aug	8	F	1	25-Aug	7	Br	6
G	015037	19-Aug	8	F	1	21-Aug	7	R	2
G	"	19-Aug	8	F	1	27-Aug	7	Br	8
G	015039	21-Aug	6	M	1	27-Aug	7	Br	6
G	015040	21-Aug	6	F	1	25-Aug	7	R	4
G	015047	21-Aug	6	M	1	31-Aug	7	Br	10
G	015049	21-Aug	8	M	1	21-Aug	7	R	0
G	015050	21-Aug	8	F	1	25-Aug	7	R	4
G	015053	25-Aug	6	M	1	25-Aug	7	R	0
G	015055	25-Aug	8	F	1	25-Aug	7	R	0
G	"	25-Aug	8	F	1	25-Aug	7	R	0
G	015056	25-Aug	8	M	1	02-Sep	6	Br	8
G	015061	26-Aug	4	M	1	01-Sep	6	Br	6
G	015103	15-Aug	8	F	1	17-Aug	4	R	2
G	015109	16-Aug	8	F	1	20-Aug	4	R	4
G	015120	17-Aug	8	F	1	18-Aug	7	R	1
G	015148	23-Aug	7	F	1	10-Sep	7	Br	18
G	015156	25-Aug	7	M	1	25-Aug	4	R	0
G	015158	25-Aug	7	F	1	27-Aug	4	R	2
G	015175	29-Aug	6	F	1	02-Sep	6	Br	4

a. Recapture result codes: R - returned to the river; Br - taken for hatchery brood stock.

b. Adipose fin missing.

c. Release condition codes: 1 -swam away vigorously; 2 - swam away slowly.

Appendix 3. Mark recoveries, by application and recovery date and location, size, sex, adipose fin status, and age, of chinook salmon recovered in the Nicola River, 1998.

Application						Recovery					
Date	Reach	Fork length (mm)	Sex	Adipose fin	Tag Number	Date	Reach	POH length (mm)	Sex	Age	Days out
15-Aug	8	670	M [a]	P	G15002	24-Sep	4	580	F	4_2	40
15-Aug	8	720	F	P	G15003	22-Sep	5	585	F	4_2	38
15-Aug	8	785	F	P	G15100	25-Sep	2	670	F	5_2	41
15-Aug	8	630	F	P	G15103	30-Sep	4	540	F	4_2	46
16-Aug	7	740	F	P	G15008	17-Sep	7	630	F	5_2	32
16-Aug	8	800	F	P	G15108	30-Sep	4	660	F	-	45
16-Aug	8	850	M	P	G15110	30-Sep	4	690	M	5_2	45
17-Aug	8	675	M	A	G15010	28-Sep	7	590	M	4_2	42
17-Aug	4	880	F	P	G15115	24-Sep	4	715	F	-	38
17-Aug	8	770	F [a]	P	G15120	26-Sep	5	630	M	-	40
17-Aug	8	655	M	P	G15122	22-Sep	5	540	M	4_2	36
17-Aug	8	670	F	P	G15123	26-Sep	5	535	F	4_2	40
18-Aug	7	680	F	P	G15014	16-Sep	5	570	F	4_2	29
18-Aug	6	640	F	P	G15025	23-Sep	7	510	F	4_2	36
18-Aug	6	700	F	A	G15026	23-Sep	7	540	F	4_2	36
18-Aug	4	670	F	A	G15125	25-Sep	2	550	F	4_2	38
19-Aug	2	635	M	P	G15129	30-Sep	4	530	M	4_2	42
20-Aug	8	750	M	P	G15137	24-Sep	4	605	M	-	35
20-Aug	8	860	M	P	G15138	21-Sep	4	665	M	-	32
21-Aug	6	730	F	P	G15041	01-Oct	5	590	F	5_2	41
21-Aug	6	680 [b]	M	P	G15044	22-Sep	5	680 [b]	M	-	32
21-Aug	6	690	F	P	G15046	24-Sep	4	590	F	4_2	34
21-Aug	7	700	F	A	G15048	21-Sep	4	610	F	4_2	31
21-Aug	8	580	M	A	G15049	08-Oct	5	-	M	-	48
21-Aug	8	630	F	A	G15050	22-Sep	5	540	F	4_2	32
21-Aug	8	700	F	A	G15051	29-Sep	2	600	F	-	39
22-Aug	2	690	F	P	G15143	12-Oct	2	555	F	4_2	51
22-Aug	2	670	M	P	G15146	18-Sep	2	525	M	4_2	27
25-Aug	6	630	M	P	G15053	21-Sep	4	530	M	-	27
25-Aug	8	570	M	A	G15153	21-Sep	4	435	M	5_2	27
25-Aug	7	815	M	P	G15156	21-Sep	4	-	M	-	27
26-Aug	7	730	M	P	G15160	25-Sep	2	600	M	4_2	30
26-Aug	4	720	F	P	G15161	21-Sep	4	610	F	4_2	26
29-Aug	6	550	F	P	G15178	22-Sep	5	460	F	4_2	24
29-Aug	7	695	M	A	G15181	22-Sep	5	560	M	4_2	24
-	-	-	-	-	Tag lost	22-Sep	5	590	M	4_2	-

Percent sex identification error: Males: 6.7% — Females: 5.0%

Mean days out: 36
Maximum: 51
Minimum: 24

Length regressions:

Males: $POH = 0.759NF + 37.69$ $r^2 = 0.92$
$NF = 1.207POHL + 13.65$

Females: $POH = 0.796NF + 24.78$ $r^2 = 0.89$
$NF = 1.123POHL + 46.11$

[a] Sex identification error.
[b] Excluded from length regressions.

Appendix 4. Daily chinook salmon carcass recoveries, by reach, mark status, and sex, in the Nicola River, 1998.

		Unmarked		1° and 2° Marked		2° Mark Only		Total		Adipose Fin Absent [a]	
Date	Stratum	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
29-Aug	2	1	1	0	0	0	0	1	1	0	0
14-Sep	4	0	0	0	0	0	0	0	0	0	0
15-Sep	3	1	1	0	0	0	0	1	1	0	0
"	4	2	2	0	0	0	0	2	2	0	0
16-Sep	2	1	0	0	0	0	0	1	0	0	0
"	5	0	0	0	1	0	0	0	1	0	0
17-Sep	7	1	1	0	1	0	0	1	2	0	0
18-Sep	2	5	5	1	0	0	0	6	5	0	1
21-Sep	4	8	8	4	2	0	0	12	10	5	1
22-Sep	5	11	11	3	3	1	0	15	14	4	2
23-Sep	7	4	4	0	2	0	0	4	6	2	1
24-Sep	4	24	24	1	3	0	0	25	27	2	3
25-Sep	2	11	10	1	2	0	0	12	12	2	3
"	3	2	2	0	0	0	0	2	2	0	1
26-Sep	5	20	17	1	1	0	0	21	18	2	2
"	7	14	14	0	0	0	0	14	14	0	0
28-Sep	6	1	1	0	0	0	0	1	1	0	0
"	7	9	7	1	0	0	0	10	7	2	2
29-Sep	2	14	14	0	1	0	0	14	15	2	5
"	3	1	1	0	0	0	0	1	1	0	0
30-Sep	4	30	30	2	2	0	0	32	32	2	2
01-Oct	5	20	20	0	1	0	0	20	21	0	4
02-Oct	7	9	9	0	0	0	0	9	9	1	1
04-Oct	8	2	2	0	0	0	0	2	2	0	1
05-Oct	2	7	7	0	0	0	0	7	7	0	1
"	3	2	2	0	0	0	0	2	2	0	0
06-Oct	4	2	2	0	0	0	0	2	2	0	0
07-Oct	5	0	0	0	0	0	0	0	0	1	0
08-Oct	5	0	0	1	0	0	0	1	0	0	0
09-Oct	7	1	1	0	0	0	0	1	1	0	0
12-Oct	2	0	0	0	1	0	0	0	1	0	0
13-Oct	4	3	3	0	0	0	0	3	3	0	0
14-Oct	5	0	0	0	0	0	0	0	0	0	0
Total	2	39	37	2	4	0	0	41	41	4	10
	3	6	6	0	0	0	0	6	6	0	1
	4	69	69	7	7	0	0	76	76	9	6
	5	51	48	5	6	1	0	57	54	7	8
	6	1	1	0	0	0	0	1	1	0	0
	7	38	36	1	3	0	0	39	39	5	4
	8	2	2	0	0	0	0	2	2	0	1
Grand total		206	199	15	20	1	0	222	219	25	30

a. Included in total carcasses.

Appendix 5. Percentage at age and mean length at age, by adipose fin status and sex, of chinook carcasses recovered in the Nicola River, 1998.

		Female			Male		
Adipose fin status	Age	Sample size	Percent	Mean POH length (mm)	Sample size	Percent	Mean POH length (mm)
Absent a	3 1	0	0.0%	-	0	0.0%	-
	3 2	1	3.8%	450	2	8.7%	433
	4 1	0	0.0%	-	0	0.0%	-
	4 2	24	92.3%	584	19	82.6%	595
	5 2	1	3.8%	660	2	8.7%	538
	6 2	0	0.0%	-	0	0.0%	-
	5 3	0	0.0%	-	0	0.0%	-
	Total Sub 1	0	0.0%	-	0	0.0%	-
	Sub 2	26	100.0%	582	23	100.0%	557
	Sub 3	0	0.0%	-	0	0.0%	-
	Total c	30	-	577	25	-	575
Present a	3 1	0	0.0%	-	0	0.0%	-
	4 1	0	0.0%	-	0	0.0%	-
	3 2	0	0.0%	-	1	0.8%	370
	4 2	98	70.5%	576	95	73.1%	615
	5 2	40	28.8%	655	34	26.2%	707
	6 2	1	0.7%	670	0	0.0%	-
	5 3	0	0.0%	-	0	0.0%	-
	Total Sub 1	0	0.0%	-	0	0.0%	-
	Sub 2	139	100.0%	599	130	100.0%	639
	Sub 3	0	0.0%	-	0	0.0%	-
	Total c	175	-	604	173	-	640
Total b	3 1	0	0.0%	-	0	0.0%	-
	4 1	0	0.0%	-	0	0.0%	-
	3 2	1	0.6%	450	3	2.0%	412
	4 2	123	74.1%	578	114	74.5%	612
	5 2	41	24.7%	655	36	23.5%	697
	6 2	1	0.6%	670	0	0.0%	-
	5 3	0	0.0%	-	0	0.0%	-
	Total Sub 1	0	0.0%	-	0	0.0%	-
	Sub 2	166	100.0%	597	153	100.0%	630
	Sub 3	0	0.0%	-	0	0.0%	-
	Total c	206	-	600	198	-	631

a. Excludes unreadable scale samples.
b. Includes fish of unknown adipose status.
c. Includes all aged carcasses.

Appendix 6. Spawning success, by mark status, in female chinook salmon carcasses recovered in the Nicola River, 1998.

		Percent spawned			
Mark status		0%	50%	100%	Weighted mean
Marked (1° or 2°)	Number	0	1	18	
	Percent	0.0%	5.3%	94.7%	97.4%
Unmarked	Number	7	3	171	
	Percent	3.9%	1.7%	94.5%	95.3%
Total	Number	7	4	189	
	Percent	3.5%	2.0%	94.5%	95.5%

Appendix 7. Number of live and dead chinook observed during aerial enumeration flights over the Nicola River, 1998

		Reach																Total		
		1		2		3		4		5		6		7		8				
Flight Date		Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Total
09/05/1998	Observer 1	-	-	3	2	9	0	15	0	0	1	18	0	69	1	2	0	116	4	120
	Observer 2	-	-	3	2	8	0	15	0	0	1	18	0	66	1	2	0	112	4	116
	Best Estimate	-	-	3	2	9	0	15	0	0	1	18	0	69	1	2	0	116	4	120
	% Dead		-		40%		0%		0%		100%		0%		1%		0%		3%	Dead
																			89%	Holding
09/09/1998	Observer 1	-	-	3	0	6	0	16	0	16	0	18	0	99	0	0	0	158	0	158
	Observer 2	-	-	3	0	6	0	17	0	21	0	18	0	104	0	0	0	169	0	169
	Best Estimate	-	-	3	0	6	0	17	0	21	0	18	0	104	0	0	0	169	0	169
	% Dead		-		0%		0%		0%		0%		0%		0%		-		0%	Dead
																			70%	Holding
09/12/1998	Observer 1	-	-	44	1	6	0	66	0	51	0	9	2	44	0	6	0	226	3	229
	Observer 2	-	-	46	1	6	0	67	0	51	0	9	2	44	0	6	0	229	3	232
	Best Estimate	-	-	46	1	6	0	67	0	51	0	9	2	44	0	6	0	229	3	232
	% Dead		-		2%		0%		0%		0%		18%		0%		0%		1%	Dead
																			15%	Holding
09/15/1998	Observer 1	-	-	124	0	3	0	178	0	103	2	10	0	97	3	29	0	544	5	549
	Observer 2	-	-	126	0	3	0	179	0	110	2	10	0	94	3	29	0	551	5	556
	Best Estimate	-	-	126	0	3	0	179	0	110	2	10	0	97	3	29	0	554	5	559
	% Dead		-		0%		0%		0%		2%		0%		3%		0%		1%	Dead
																			10%	Holding
09/19/1998	Observer 1	-	-	136	2	2	0	279	4	161	7	2	0	89	2	22	0	691	15	706
	Observer 2	-	-	137	2	2	0	288	4	163	5	2	0	90	2	22	0	704	13	717
	Best Estimate	-	-	137	2	2	0	288	4	163	7	2	0	90	2	22	0	704	15	719
	% Dead		-		1%		0%		1%		4%		0%		2%		0%		2%	Dead
																			0%	Holding
09/23/1998	Observer 1	-	-	87	3	1	0	204	13	145	8	0	1	99	5	23	0	559	30	589
	Observer 2	-	-	88	3	1	0	204	13	145	8	0	1	99	5	23	0	560	30	590
	Best Estimate	-	-	88	3	1	0	204	13	145	8	0	1	99	5	23	0	560	30	590
	% Dead		-		3%		0%		6%		5%		100%		5%		0%		5%	Dead
																			0%	Holding

Appendix 8. Incidence of CWT absence, by carcass condition, eye status, and adipose fin clip condition, in AFC chinook carcasses recovered in the Nicola River, 1998.

Observation	Condition	Number	CWT absent	Percentage loss
Carcass condition	Fresh	12	0	0.0%
	Moderately fresh	20	1	5.0%
	Moderately rotten	14	2	14.3%
	Rotten	9	3	33.3%
Eyes present	None	4	1	25.0%
	One	5	0	0.0%
	Two	46	5	10.9%
Adipose fin clip	Complete	37	6	16.2%
	Partial	16	0	0.0%
	Questionable	0	0	-

Appendix 9. AFC and CWT sampling of chinook salmon from broodstock and carcasses recovered in the Nicola River, 1998.

			Male	Female	Unknown sex	Total
Broodstock						
Sample size			80	97	0	177
Number with AFCs			37	43	0	80
AFC carcass without a head			0	0	0	0
CWT lost during processing			0	0	0	0
AFC carcass without a CWT			3	2	0	5
CWTs recovered from AFC carcasses:						
Code	Brood	Release site				
181643	1993	Nicola River	2	3	0	5
181952	1994	Nicola River	10	12	0	22
181953	1994	Nicola River	14	26	0	40
182731	1995	Nicola River	3	0	0	3
182732	1995	Nicola River	5	0	0	5
Total			34	41	0	75
AFC incidence (%)			46.3%	44.3%	-	45.2%
CWT loss (%)			8.1%	4.7%	-	6.4%
Carcass Recovery Sample						
Sample size			222	219	0	441
Number with AFCs			24	31	0	55
AFC carcass without a head			0	0	0	0
CWT lost during processing			0	0	0	0
AFC carcass without a CWT			2	3	0	5
CWTs recovered from AFC carcasses:						
Code	Brood	Release site				
181642	1993	Nicola River	1	0	0	1
181526	1994	Coldwater River	0	1	0	1
181952	1994	Nicola River	4	10	0	14
181953	1994	Nicola River	14	15	0	29
182731	1995	Nicola River	2	1	0	3
182732	1995	Nicola River	1	1	0	2
Total			22	28	0	50
AFC incidence (%)			10.8%	14.2%	-	12.5%
CWT loss (%)			11.5%	10.0%	-	10.7%
Spatial pattern in AFC incidence		Stratum				
		1	-	-	-	-
		2	15.4%	4.9%	-	9.0%
		3	0.0%	16.7%	-	8.3%
		4	8.3%	2.6%	-	5.6%
		5	5.9%	7.4%	-	6.7%
		6	0.0%	0.0%	-	0.0%
		7	8.7%	10.3%	-	9.4%
		8	-	50.0%	-	50.0%
Temporal pattern in AFC incidence		Period				
		Aug 29 - Sep 24	19.1%	11.6%	-	15.3%
		Sep 25 - Sep 29	10.7%	18.6%	-	14.5%
		Sep 30 - Oct 14	5.1%	11.3%	-	8.2%