

# **Estimation of the 1994 Shuswap River System Sockeye Salmon (*Oncorhynchus nerka*) Escapement**

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**by**

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## ABSTRACT

Schubert, N.D., and N.J. Vivian. 1997. Estimation of the 1994 Shuswap River system sockeye salmon (*Oncorhynchus nerka*) escapement. Can. Manuscr. Rep. Fish. Aquat. Sci. 2427: 48 p.

In 1986, the Department of Fisheries and Oceans (DFO) assumed responsibility from the International Pacific Salmon Fisheries Commission (IPSFC) for the estimation of the escapement of Fraser River sockeye salmon (*Oncorhynchus nerka*) stocks. DFO adopted the IPSFC's two-tiered system whereby large escapements (25,000+) were estimated using enumeration fences or mark-recapture studies, and small escapements (less than 25,000) were estimated using visual techniques.

The Shuswap River system supports two major sockeye salmon stocks which spawn in the lower and middle Shuswap River, and three minor stocks which spawn in Mabel Lake tributaries. The stocks exhibit a quadrennial escapement pattern, with large escapements on the 1990-1994 dominant and 1987-1991 subdominant cycles; dominant cycle escapements have exceeded 25,000 every year since 1970. The 1994 study area included all five populations. Sockeye were captured while migrating through the lower Shuswap River at a site near the lower limit of spawning; 4,085 were released with disk tags. The spawning grounds were surveyed through the period of spawning and die-off; 134,552 carcasses were recovered, of which 1,382 had disk tags. The 1994 study area escapement was estimated, using the pooled Petersen estimator, at 196,480 adult males, 203,781 adult females and 3 jacks.

The report identifies biases in the tag application and carcass recovery samples and discusses their potential impact on the population estimates. It concludes with recommendations for the improvement of study design, including improved allocation of sampling effort, resurvey procedures, and the assessment of disk tag loss and handling stress.

## RÉSUMÉ

Schubert, N.D., and N.J. Vivian. 1997. Estimation of the 1994 Shuswap River system sockeye salmon (*Oncorhynchus nerka*) escapement. Can. Manuscr. Rep. Fish. Aquat. Sci. 2427: 48 p.

En 1986, la Commission internationale des pêcheries de saumon du Pacifique chargeait le ministère des Pêches et des Océans (MPO) d'évaluer l'échappée des stocks de saumon rouge (*Oncorhynchus nerka*) du Fraser. Le MPO a adopté le système d'estimation à deux niveaux de la Commission, selon lequel les grandes échappées (25,000 et plus) ont été évaluées aux barrières de dénombrement ou par des opérations de marquage-recapture, et les petites échappées (moins de 25,000) ont été évaluées par des techniques visuelles.

Le réseau de la rivière Shuswap est fréquenté par deux grands stocks de saumons rouges qui frayent dans les cours inférieur et moyen de cette rivière, et par trois stocks de moindre importance qui frayent dans les affluents du lac Mabel. Les stocks ont un profil d'échappée quadriennal, les grandes échappées s'étant produites dans les cycles dominants de 1990-1994 et les cycles sous-dominants de 1987-1991; depuis 1970, les échappées des cycles dominants ont été supérieures à 25,000 saumons. L'aire d'étude de 1994 portait sur les cinq populations. Les saumons rouges ont été capturés au cours de leur migration dans le cours inférieur de la Shuswap, à un point situé à proximité de la limite inférieure des frayères; 4,085 saumons ont été libérés après marquage avec des disques. Les frayères ont été surveillées pendant la période de fraye et de mortalité massive. On a récupéré 134,552 carcasses, dont 1,382 portaient un disque. L'échappée de l'aire d'étude de 1994 a été évaluée, par l'estimateur de Petersen combiné, à 196,480 mâles adultes, 203,781 femelles adultes et 3 jeunes saumons précoces.

Les auteurs du rapport ont décelé des biais dans les échantillons destinés au marquage et dans les échantillons de carcasses récupérées; ils analysent l'impact que ces biais pourraient avoir sur les estimations de la population. Leurs conclusions comportent des recommandations visant l'amélioration de la conception de l'étude, notamment une meilleure allocation de l'effort d'échantillonnage, des méthodes pour répéter l'étude et l'évaluation de la perte de disques et du stress dû à la manipulation des poissons.

## INTRODUCTION

The accurate estimation of spawning escapement has long been recognized as an essential element in the management of Fraser River sockeye salmon (*Oncorhynchus nerka*) (Thompson 1939; Howard 1948). The International Pacific Salmon Fisheries Commission (IPSFC) developed a two-tiered system whereby the estimation method selected for each stock was based on the number of spawners expected to return to the spawning grounds in a given year. For stocks with large expected returns (greater than 25,000), enumeration fences and mark-recapture studies were used because they provided the statistically defensible estimates which were required to determine if system-wide precision objectives were met. For stocks with small expected returns (less than 25,000), a variety of stock-specific visual estimation methods were used (Andrew and Webb MS 1987). The IPSFC system was adopted by the Department of Fisheries and Oceans (DFO) in 1986 and remains largely in place throughout the Fraser River watershed.

The Shuswap River system supports two major sockeye salmon stocks which spawn in the lower and middle Shuswap rivers, and three minor stocks which spawn in the Mabel Lake tributaries, Noisey, Tsuius and Wap creeks (Fig. 1). The stocks exhibit a quadrennial escapement cycle, and abundance has increased substantially on all four cycles since the early 1970's. Escapements in the 1950's versus the 1990's increased from less than 15,000 to over one million on the 1990-1994 dominant cycle, from less than 300 to 16,000 on the 1987-1991 subdominant cycle, and from virtually no spawners to up to 3,000 on the two off-cycles (1988-1992 and 1989-1993) (Appendix 1).

Stream surveys have been conducted in the Shuswap River system since early in the century (Anon. 1922), and escapement estimates have been reported regularly since 1942. Escapements were estimated exclusively using visual techniques until spawner abundance began to increase in the 1960's. Subsequently, mark-recapture studies were used to estimate the escapement to the lower Shuswap River on the dominant cycle since 1970 and on the subdominant cycle in 1975 and 1979, and to the middle Shuswap River in 1986. In 1990, the lower and

middle Shuswap studies were consolidated to permit the estimation of the system-wide escapement based on the application of tags in the lower Shuswap River.

The current report provides the first published documentation of the study design, field methods, analytic techniques and results of the Shuswap sockeye escapement estimation study. Included are estimates of the 1994 adult age and length, and escapement by sex and age for the populations which spawned in the lower and middle Shuswap rivers, Noisey, Tsuius and Wap creeks. The report concludes with a discussion of the results and recommendations for the design of future studies.

## STUDY AREA

The Shuswap River originates in the Monashee Mountains of south-central British Columbia and flows northwest for almost 200 km, entering Mara Lake east of Salmon Arm (Figs. 1-3). The system consists of the upper, middle and lower Shuswap rivers, delineated by Sugar, Mabel and Mara lakes, respectively, and a number of small tributaries which combine to drain a watershed of approximately 5,000 km<sup>2</sup>.

The upper Shuswap River and Sugar Lake are inaccessible to sockeye salmon. The middle Shuswap River, which flows in a broad horseshoe from Sugar Lake to Mabel Lake (Fig. 3), is accessible in the lower 23 km up to the Wilsey Dam (114 km from Mara Lake) which obstructs further upstream passage. At the dam, the middle Shuswap River has a mean daily discharge of 50 m<sup>3</sup>s<sup>-1</sup>, (1913-1990), with mean daily maxima (165 m<sup>3</sup>s<sup>-1</sup>) and minima (17 m<sup>3</sup>s<sup>-1</sup>) occurring in June and March, respectively (Environment Canada 1991). The river is characterized by a wide, unconfined channel with a predominately gravel substrate. Numerous debris jams contribute to frequent channel shifts by scouring pools and creating new side channels (Fee and Jong MS 1984). The river was divided into three reaches (Fig. 3): Reach 1 (8.6 km in length) extends from Wilsey Dam to the Bailey Bridge; Reach 2 (6.4 km) extends from the Bailey Bridge to a pig farm located just upstream from Christian Creek; and Reach 3 (8.0 km) extends downstream to Mabel Lake. The reaches were established primarily to facilitate the data aggregations

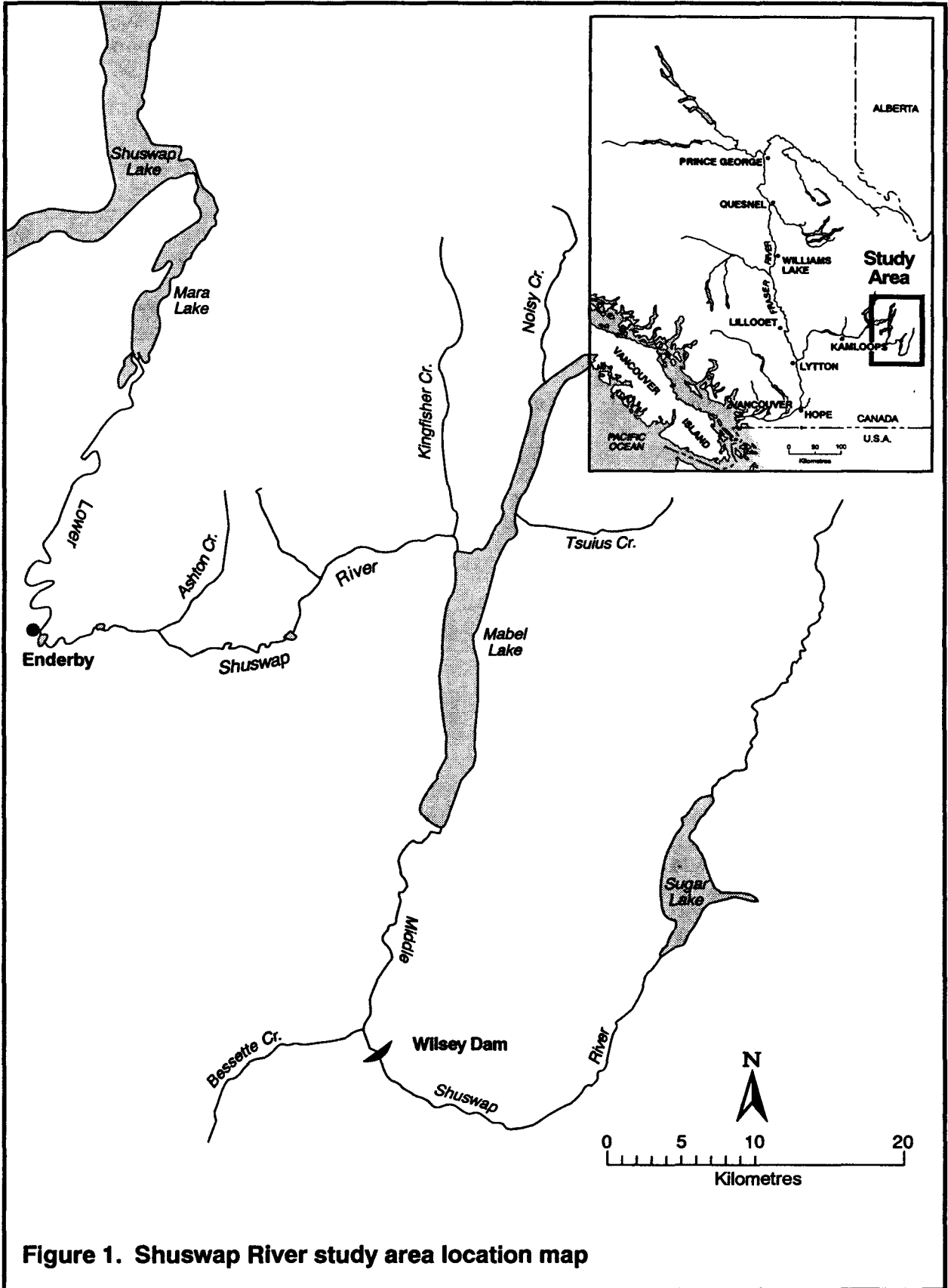
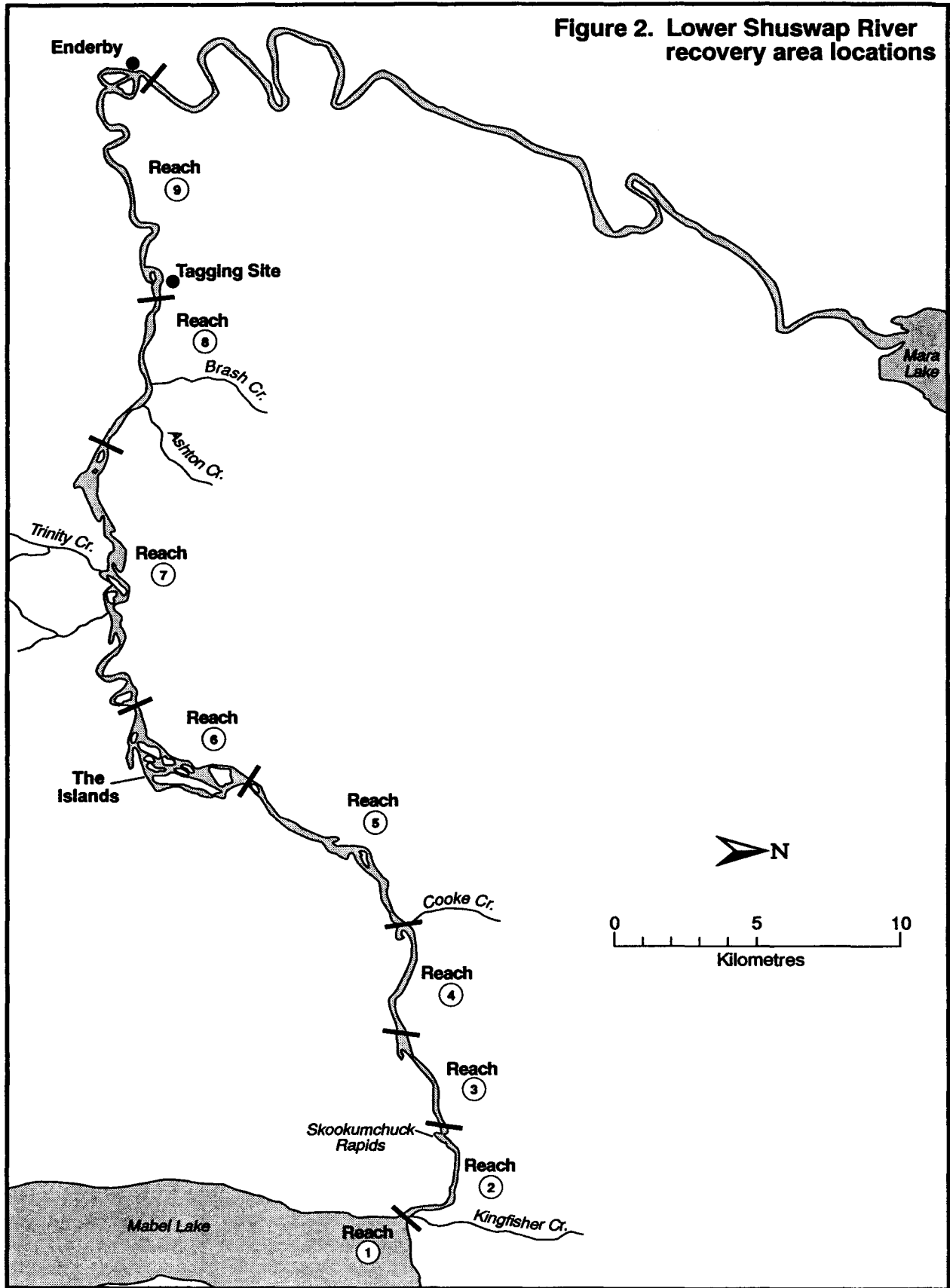


Figure 1. Shuswap River study area location map

Figure 2. Lower Shuswap River recovery area locations



required for bias testing; stream type tends to be homogeneous throughout, except in the lower 4 km where the gradient is lower and the substrate is fine sand and mud.

The lower Shuswap River originates at the midpoint of Mabel Lake and flows west for about 40 km then north for 30 km, entering Mara Lake near Sicamous (Fig. 2). At Enderby, the lower Shuswap River has a mean daily discharge of  $88 \text{ m}^3\text{s}^{-1}$  (1911-1990), with mean daily maxima ( $288 \text{ m}^3\text{s}^{-1}$ ) and minima ( $32 \text{ m}^3\text{s}^{-1}$ ) occurring in June and March, respectively (Environment Canada 1991). The river was divided into nine reaches which were established primarily to facilitate the data aggregations required for bias testing. Three criteria were used: homogeneity of physical characteristics such as gradient, channel morphology and substrate type; the ability of the crews to survey a reach in one day and to exit the river at a point of easy access; and the existence of easily identifiable land marks to delineate the reaches.

Reach 1 (1.4 km) extends from Mabel Lake downstream to Kingfisher Creek. The river has a width of up to 200 m and is slow and deep. The substrate is predominantly small gravel and sand and the sockeye spawning density is light.

Reach 2 (2.2 km) extends from Kingfisher Creek to the bottom of Skookumchuck Rapids. The gradient is high and the river is characterized by riffles and rapids with a substrate of boulders and cobble; spawning density is light.

In reaches 3-5, the river is confined largely to a single channel with a maximum width of 100 m and few side channels. The substrate is predominantly large gravel and cobble, and the spawning density is moderate to heavy. This section includes three reaches: Reach 3 (2.9 km) extends from Skookumchuck Rapids to Delorne Creek; Reach 4 (2.8 km) extends to Cooke Creek; and Reach 5 (5.5 km) extends to the top of a highly braided section of river locally known as the *Islands*.

Reach 6 (4.3 km) consists of the *Islands*, where the total channel width increases to over 500 m and the river is a complex of islands, bars and side channels. Most of the flow and the most suitable spawning gravel is normally in a single channel (Abbott and Stewart MS 1987).

The spawning density is moderate to heavy.

Reach 7 (9.3 km) extends from the bottom of the Islands to the Ashton Creek Bridge. The gradient decreases in this reach, and the river is slow moving and deep with frequent side and back channels. The substrate is silt, sand and small gravel, and spawning density is moderate.

Reach 8 (3.6 km) extends from the Ashton Creek Bridge to the tagging site. The gradient is somewhat higher than in Reach 7 and, consequently, flows are faster, gravel bars more frequent and spawning densities are higher.

Reach 9 (7.5 km), extending from the tagging site downstream to Enderby, is a transition area between the higher gradient upstream sections and the low gradient lower river which is characterized by a broad, deep channel with a substrate of mud and sand. Reach 9 encompasses the effective lower limit of spawning; spawning density is light.

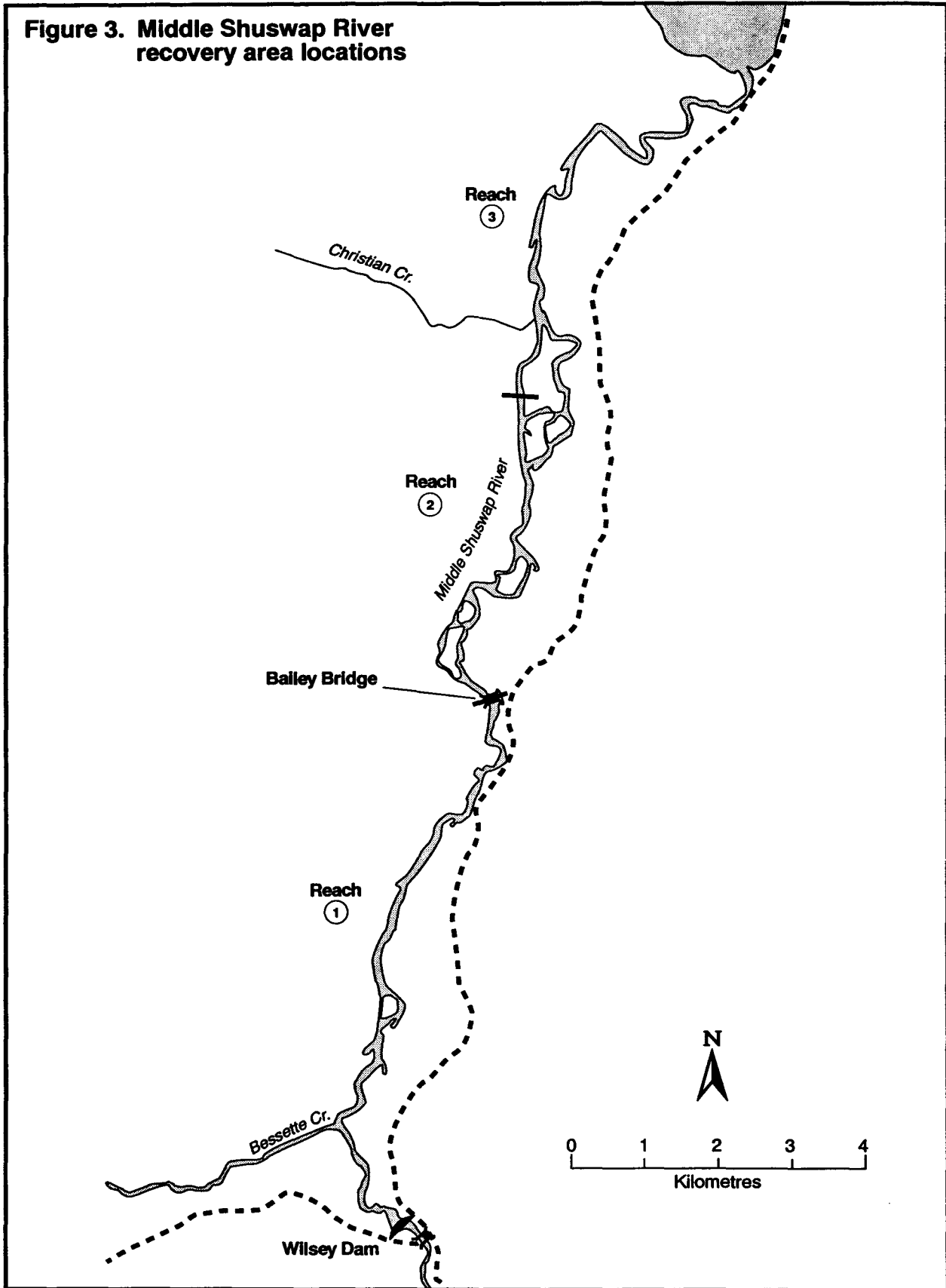
Three Mabel Lake tributaries (Fig. 1) support sockeye spawners on this cycle (Appendix 1d-f). Noisy and Wap creeks drain the north-central part of the basin and flow into the north end of the lake. Noisy creek has a length of 15.4 km, and spawning is confined to the lower reach (Anon. 1990). Wap Creek has a length of 47.7 km; spawning is concentrated in the lower 4 km and fish passage is completely obstructed by a 3 m high falls at km 29.3. Tsuius Creek flows southwest for 31.8 km, entering the east side of Mabel Lake near its midpoint. Sockeye spawning is confined to the lower 0.8 km.

## FIELD METHODS

### BRIDGE COUNTS

Migrating sockeye adults (including previously tagged fish) were counted by observers stationed on the Enderby and Ashton Creek bridges (Fig. 3). Fifteen minute counts were made as required from the Enderby Bridge, and each morning and afternoon from the Ashton Creek Bridge. The former was used to assess daily abundance trends for fish which had not yet reached the tagging site; the latter was used to assess the disk tag incidence among fish which had already passed the tagging site. Both counts were inseason tools intended to help optimize tagging effort.

**Figure 3. Middle Shuswap River  
recovery area locations**



## VISUAL SURVEYS

Visual counts were made during two helicopter flights over the lower and middle Shuswap rivers and Tsuius and Wap creeks. The first was scheduled to coincide with the peak, and the second with the peak of die-off. On each flight, two observers counted live and dead sockeye from the same side of the aircraft; individual counts were averaged. Visual counts in Noisy, Tsuius and Wap creeks were recorded during surveys conducted at the peak of spawning and also during foot surveys which were conducted on an opportunistic basis.

## TAG APPLICATION

The study objective was to apply tags to 1% of the sockeye as they migrated past the tagging site, located in the lower Shuswap River 37.5 km from Mara Lake (Fig. 3). Because an independent estimate of abundance was unavailable, application effort was standardized at three sets per day and was modified daily based on the tag incidence observed at the Ashton Creek Bridge. Tagging began early in the run and continued until the run was virtually complete. Migrating sockeye were captured using a 64 m x 7.5 m x 5 cm-mesh beach seine net which was set from a power boat in a downstream arc and withdrawn from the river to enclose a small area of water along the river bank. Captured fish were held in the net until removal for tagging.

Previously tagged sockeye were identified upon recapture and immediately processed to avoid additional stress. The tag number was recorded and the tag checked; if loose, the pin was tightened or the fish was retagged using the same tag. Those which were damaged or showed advanced stages of maturation were identified as the fish were being processed and released untagged. The remaining fish were removed from the net and placed in a wooden tagging tray (12 cm x 20 cm x 100 cm) constructed with a flexible plastic bottom and a metre stick recessed in one side; the tray was set in a stand elevated above the water surface. The tags consisted of two 15 mm diameter laminated cellulose acetate disks threaded through centrally punched holes onto a 77 mm long nickel pin. The pin was inserted with pliers through musculature and pterygiophore bones approximately 12 mm below the anterior portion of the dorsal fin insertion.

The disk tags, arranged with one on each side of the fish, were secured by twisting the pin into a double knot. One disk per pair was numbered with a unique code; no secondary marks were applied. Date of capture, disk tag number, nose-fork (NF) length ( $\pm 0.1$  cm), sex (fish with a NF length less than 50 cm were recorded as jacks) and marks (troll, gill net, lamprey or *Flexibacter columnaris* scars) were recorded for each fish released with a disk tag. Condition at release was recorded as 1 (swam away vigorously), 2 (swam away sluggishly) or 3 (required ventilation).

## SPAWNING GROUND SURVEYS

### Main Survey

All known spawning areas in the Shuswap River system were surveyed during the die-off period. The shores were surveyed on foot by two-person crews using an inflatable raft to leap-frog down the river; up to four crews were required at the peak of die-off. In the lower Shuswap River, the surveys began after die-off was first observed; survey frequency was determined by the carcass abundance observed in each reach. In the middle Shuswap River, the surveys began when staff became available near the completion of tagging; surveys were conducted every 3-6 days. The Mabel Lake tributaries were surveyed opportunistically when staff were available.

All carcasses which were retrievable along the shore or by wading into the river to waist depth were enumerated (predator kills were excluded from the survey) and thrown on the bank above the high water mark. Carcass recoveries were recorded by date, reach, sex, disk tag status, carcass condition (fresh, tainted or rotten) and female spawning success (0%, 50% or 100% spawned). If a disk tag was present, it was retrieved and the tag number was recorded before the carcass was processed.

### Resurvey

Previously processed carcasses were resurveyed through the recovery period to estimate the number of tagged carcasses which had not been correctly identified. The resurvey, conducted by an experienced technician, recorded carcasses by date, reach, sex and disk tag status.

## BIOLOGICAL SAMPLING

Biological samples were obtained following a protocol provided by the Pacific Salmon Commission. Adult carcasses were sampled for nose-hypural plate (standard) length ( $\pm 0.1$  cm), otoliths and scales (one from each preferred region, as defined by Clutter and Whitesel (1956)) for post-orbital-hypural plate (POH) length, otoliths and scales. One hundred and twenty adults of each sex were sampled at the peak of die-off in both the lower and middle Shuswap rivers. All recovered jacks were sampled for standard length and scales. Scale and otolith samples were analyzed by Pacific Salmon Commission staff.

Fifty females, killed during the peak of arrival in the lower Shuswap River, were sampled as above and the egg skeins and loose eggs were removed, placed in a cotton bag and preserved in a 10% formaldehyde solution.

## ANALYTIC PROCEDURES

### TESTS FOR SAMPLING SELECTIVITY

A bias profile was developed by evaluating five potential biases, temporal, spatial, fish size, fish sex and handling stress. Statistical tests were performed to assess whether the conditions of equal probability of capture, complete mixing, and simple random recovery sampling were violated (Seber 1982; p 434-9). Biases were treated in three ways. First, sex-related biases are common in mark-recapture studies and were addressed by stratifying the data by sex. Second, stress-related biases were treated by removing the high stress group from the application sample. Third, the severity of temporal or spatial biases was evaluated by comparing the simple or pooled Petersen estimates with those calculated using Darroch's (1961) and Schaefer's (Ricker 1975) stratified models. A stratified model was used if the confidence limits did not overlap.

#### Period

Temporal bias was assessed using chi-square tests of application and recovery data stratified by equal periods, approximately equal effort (numbers of sets or passes through the sampling area), and approximately equal numbers of sockeye tagged or recovered. Application sample bias (unequal probability of capture)

was assessed by stratifying the recovery sample as above and comparing the mark incidence among recovery strata, where mark incidence was the proportion of the fish marked with a disk tag. Recovery sample bias (nonrandom sampling in the recovery sample) was assessed by stratifying the application sample as above and comparing the proportions recovered among application strata.

#### Location

Spatial bias was similarly assessed using chi-square tests. Application sample bias was assessed by stratifying the recovery data into geographically discrete groups which allowed sufficient sample sizes in each stratum; mark incidences in each stratum were compared. Recovery bias could not be examined because the tags were applied at a single site.

#### Fish Size

Size related bias was assessed using the Kolmogorov-Smirnov two-sample test (Sokal and Rohlf 1981). Application bias could not be tested because the untagged carcasses were not sampled for length. Recovery bias was examined by partitioning the application sample into recovered and nonrecovered components and comparing the NF length-frequency distributions of each.

#### Fish Sex

Sex related bias was assessed using a chi-square test. Application bias was examined by comparing the sex ratio of the marked and unmarked spawning ground recoveries. Recovery bias was examined by partitioning the application sample into recovered and non-recovered components and comparing the sex ratio in each.

#### Stress

Potential bias resulting from handling and tagging stress was assessed in two ways. First, three tests were performed to determine whether specific tags should be excluded from the application sample: a) fish with less than five days between tag application and recovery were removed from the samples; b) the sample was partitioned into fish which required ventilation at release and those which did not. If a chi-square test showed a significant difference in the propor-

tions recovered, the high stress group was removed from the samples; and c) an identical procedure was used to evaluate fish which were recaptured in subsequent beach seine sets.

Second, two chi-square tests were performed as general indicators of a stress problem: a) percent spawning success was compared between marked and unmarked spawning ground recoveries; and b) the recovery sample was partitioned into those recovered above and below the tagging site. Disk tag incidence and the percent spawning success of tagged females was compared between each group. These tests were not used to exclude specific data from the study, but to indicate whether capture and tagging stress was a systemic problem which must be addressed in the design of future studies.

### ESTIMATION OF SPAWNER POPULATION

The Shuswap River system study area consisted of the lower and middle Shuswap rivers, and Noisey, Tsuius and Wap creeks. The escapement to the study area was estimated from the mark-recapture data, with the smaller populations (middle Shuswap River and the Mabel Lake creeks) estimated from the visual data. The lower Shuswap escapement was estimated by subtracting the middle Shuswap River and Mabel Lake tributary estimates from the mark-recapture estimate.

#### Data Corrections

**Sex Identification Error:** The tag application data were corrected for sex identification error. Error occurred because the development of sexually dimorphic traits was often not advanced and internal examinations could not be made. The correction of the recovery data was unnecessary because development was complete and dead fish could be examined more carefully. Sex identification error was corrected as described by Staley (1990):

- 1) Estimated true number of adult males released with disk tags:

$$M_m = \frac{M_m^* - (M_f R_{m,f})/R_f}{1 - (R_{m,f}/R_f) - (R_{f,m}/R_m)}$$

where:

- $M_m^*$  = the field estimate of the number of adult males released with disk tags;
- $M_f$  = the total number of sockeye adults released with disk tags;
- $R_{m,f}$  = the number of adult females recovered with disk tags which were released as males;
- $R_{f,m}$  = the number of adult males recovered with disk tags which were released as females;
- $R_f$  = the number of adult females recovered with disk tags;
- $R_m$  = the number of adult males recovered with disk tags.

- 2) Estimated true number of adult females released with disk tags:

$$M_f = M_f - M_m$$

**Tag Recognition Error:** Resurvey data were used to correct the disk tag recovery totals for tags missed in the initial survey. The following was calculated by sex:

- 3) Estimated true number of tags recovered, corrected for disk tags missed on the initial survey:

$$R_{cor} = R_{is} + ((R_{rs}/C_{rs}) \cdot C_{is})$$

where:

- $R_{is}$  = the number of disk tags recovered on the initial survey;
- $R_{rs}$  = the number of disk tags recovered on the resurvey;
- $C_{rs}$  = the number of carcasses examined on the resurvey;
- $C_{is}$  = the number of carcasses examined on the initial survey.

#### Population Estimator

The escapement estimates were calculated from the mark-recapture data using: a) the simple or pooled Petersen estimator (Seber 1982; p 60); and b) the Darroch (Seber 1982; p 431-445) and Schaefer (Seber 1982; p 439) estimators for stratified populations. Total escapement was the sum of the escapement by sex:

- 4) Estimated Shuswap River system sockeye escapement:

$$N_t = N_m + N_f + N_j$$

where:

$N_m$  = the adult male escapement estimate;

$N_f$  = the adult female escapement estimate;

$N_j$  = the adult female escapement estimate.

**Pooled Petersen Estimator:** The pooled Petersen estimator was used to estimate the Shuswap River system escapement unless biases were identified which required the stratification of the data set.

- 5) Pooled Petersen estimate of the escapement of male adults:

$$N_m = \frac{(M_m + 1)(C_m + 1)}{(R_m + 1)}$$

where:

$M_m$  = the number of adult males released with disk tags;

$C_m$  = the number of adult male carcasses examined for disk tags;

$R_m$  = the number of adult males recovered with disk tags.

The female and jack escapements were calculated analogous to the above.

- 6) Variance of the pooled Petersen population estimate was calculated by sex as follows:

$V_t = V_m + V_f + V_j$   
= variance of the total escapement estimate;

$$V_m = \frac{(N_m^2)(C_m - R_m)}{(C_m + 1)(R_m + 2)}$$

= variance of the adult male escapement estimate;

$V_f$  = variance of female escapement estimate, analogous to above;

$V_j$  = variance of female escapement estimate, analogous to above.

Ninety-five percent confidence limits were calculated for the male, female, jack and total population estimates as follows:

$$N \pm 1.96 \sqrt{V}$$

**Stratified Estimators:** When spatial or temporal biases were identified, stratified estimates were calculated using Schaefer's and Darroch's estimators. The pooled Petersen was the preferred estimator because precision is generally higher; however, if the confidence intervals of the pooled and the stratified estimates did not overlap, the bias was judged to be severe and the stratified estimator was considered more appropriate. Variance estimation procedures have not been developed for the Schaefer estimator. The variance of the stratified Darroch estimator was calculated using the procedures described by Seber (1982; page 433).

#### Alternate Jack Population Estimator

If fewer than five disk tags were recovered, the jack population (where jacks were defined as fish with a NF length of less than 50 cm regardless of sex) was estimated as the product of the number recovered, an expansion factor developed from previous IPSFC studies, and the inverse of the 1994 recovery rate of adult males:

- 7) Estimate of the escapement of jacks when fewer than five disk tagged jacks were recovered:

$$N_j = \frac{C_j \cdot 1.26}{R_m/M_m}$$

where:

$C_j$  = the number of jacks recovered on the spawning grounds.

#### STOCK-SPECIFIC POPULATION ESTIMATES

Escapements to the middle Shuswap River and Noisy, Tsuius and Wap creeks were estimated from the visual counts and carcass recoveries. The stock-specific escapement was the product of the peak live count, the cumulative carcass recovery to the date of the peak live count, and an expansion factor:

Table 1. Disk tags applied, carcasses examined and marks recovered, by sex, for Shuswap River system sockeye salmon, 1994.

Sex	Disk tags applied <sup>a</sup>	Carcasses examined	Marks recovered				Total	Percent recovered
			Disk tag and secondary mark <sup>b</sup>	Secondary mark only <sup>b</sup>	Disk tag only	Resurvey adjustment		
Male	2,147 <sup>c</sup>	73,176 <sup>c</sup>	0	0	720 <sup>c</sup>	79	799	37.2%
Female	1,938	61,375	0	0	502	81	583	30.1%
Jack	0	1	0	0	0	0	0	-
Total	4,085	134,552	0	0	1,222	160	1,382	33.8%

<sup>a</sup> Corrected for sex identification errors.

<sup>c</sup> Excludes 1 male recovered within 5-days of release.

<sup>b</sup> Secondary marks were not applied in 1994.

8) Stock-specific escapement estimated from visual data:

$$N_t = (PL + CD) \cdot I$$

where:

*PL* = the maximum daily count of live spawners in the stream;

*CD* = the cumulative recovery of adult male, female and jack carcasses during stream surveys conducted prior to and including the date of the *PL* count;

*I* = an expansion factor of 1.8, developed by the IPSFC to adjust for observer efficiency (Andrew and Webb MS 1987).

If the stream-specific carcass sample was large (10% or more of the escapement estimate), then the sex-specific adult escapement was estimated from the sex ratio of the total adult carcass recovery (rather than the cumulative recovery to the date of the *PL*); the jack escapement was estimated from the jack recovery as in Equation 7. For streams with few carcass recoveries (less than 10% of the escapement), the sex and jack compositions from the mark-recapture study were used; jacks were excluded if none had been recovered in the stream.

#### FECUNDITY ESTIMATION

Mean fecundities were calculated by age as follows:

9) Estimated mean fecundity of age class *a*:

$$\bar{F}_a = \frac{\sum (f_{ai}/w_{ai})W_{ai}}{n_a}$$

where:

$f_{ai}$  = the number of eggs in a weighed subsample ( $w_i$ ) of fecundity sample *i* of age *a* females;

$w_{ai}$  = the weight, in grams, of a subsample of fecundity sample *i* of age *a* females;

$W_{ai}$  = the weight, in grams, of fecundity sample *i* of age *a* females;

$n_a$  = the number of age *a* females sampled for fecundity.

## RESULTS

### BRIDGE COUNTS

Daily counts of sockeye salmon migrating past the Ashton Creek Bridge were conducted for 15-minutes each morning and most afternoons from October 3 to 20, 1994 (Appendix 2a). The disk tag incidence averaged 1.3%, with a higher incidence in the afternoon (2.5%) than the morning (0.2%) because tagging occurred during the day. Opportunistic counts from the Enderby Bridge (Appendix 2b) did not detect disk tags.

### VISUAL SURVEYS

Two helicopter flights were conducted over the Shuswap River in 1994 (Appendix 3). On October 18, an overflight intended to coincide

Table 2. Average elapsed time between tag application and recovery and female spawning success (all recoveries), by recovery section, period and sex, in the Shuswap River system, 1994.

Location	Section	Period <sup>a</sup>	Time out between tag application and carcass recovery (days)			Female spawning success
			Male	Female	Jack	
Lower Shuswap River	Below tagging site	Early	19.6	15.9	-	90.9%
		Late	13.6	12.5	-	99.4%
		Total	17.5	13.5	-	99.1%
	Above tagging site	Early	17.3	15.6	-	95.9%
		Late	15.6	13.2	-	99.7%
		Total	16.7	14.2	-	99.1%
	Total	Early	17.4	15.6	-	95.8%
		Late	15.6	13.2	-	99.7%
		Total	16.7	14.2	-	99.1%
Middle Shuswap River	Total	Early	19.7	20.4	-	-
		Late	13.7	15.1	-	99.7%
		Total	18.0	17.9	-	99.7%
Total	-	Early	17.5	15.9	-	95.8%
		Late	15.5	13.3	-	99.7%
		Total	16.7	14.3	-	99.2%

<sup>a</sup> Time out to recovery: early = 26-Sep to 10-Oct releases; late = 11-Oct to 26-Oct releases.

Female spawning success: early = recovered to Oct 20; late = recovered after Oct 20

with the peak of spawning recorded live sockeye counts of 109,960 and 17,000 in the lower and middle Shuswap rivers, respectively. Spawner distributions were: 2% below Enderby; 10% from Enderby to the Ashton Creek Bridge (reaches 8-9); 72% between the Ashton Creek Bridge and Skookumchuck Rapids (reaches 3-7); 3% from Skookumchuck to Mabel Lake (reaches 1-2); and 13% in the middle Shuswap River. On October 23, an overflight intended to coincide with the peak of die-off recorded live sockeye counts of 65,820 and 16,010 in the lower and middle Shuswap rivers, respectively. Spawner distributions were: 15% in reaches 8-9; 63% in reaches 3-7; 2% in reaches 1-2; and 20% in the middle Shuswap River. Additional and tributary counts are reported in Appendix 6c.

#### TAG APPLICATION

Disk tags were applied to 4,086 sockeye adults from September 26 to October 26, 1994 (Appendix 4). These data were first adjusted for sex identification error. The sex of 7 (1.0%) males and 10 (2.0%) females was recorded in-

correctly at the time of tagging. When adjusted for this error, an estimated 2,148 (52.6%) males and 1,938 (47.4%) females were released with disk tags. The data were then tested to determine if specific tags should be excluded from subsequent analyses. First, fish with less than five days between tag application and recovery were removed from the application sample. This resulted in the removal of one male which was released on October 16 (Appendix 4) and recovered two days later. We note, however, that the delay between the start of tagging (September 26) and recovery (October 14) would have prevented the detection of such fish until late in the study. Second, the sample was partitioned into fish which required ventilation at release and those which did not. Twenty-four adults (0.6%) required ventilation; however, the proportion of this group which was recovered (29.2%) was not significantly different ( $P > 0.05$ ; chi-square) from the nonventilated fish (30.0%). Consequently, they were not removed from the application sample. Third, an identical procedure was used to evaluate fish which were recaptured in subsequent beach seine sets. Although the tags were

Table 3. Percent at age and mean POH length at age in lower and middle Shuswap River sockeye sampled on the spawning grounds, 1994. <sup>a</sup>

Recovery location	Sex	Percent at age					POH length (cm) at age				
		3 <sub>2</sub>	4 <sub>2</sub>	4 <sub>3</sub>	5 <sub>2</sub>	5 <sub>3</sub>	3 <sub>2</sub>	4 <sub>2</sub>	4 <sub>3</sub>	5 <sub>2</sub>	5 <sub>3</sub>
Lower Shuswap River	Male	0.0%	100.0%	0.0%	0.0%	0.0%	-	48.3	-	-	-
	Female	0.0%	100.0%	0.0%	0.0%	0.0%	-	47.0	-	-	-
	Jack	-	-	-	-	-	-	-	-	-	-
Middle Shuswap River	Male	0.0%	100.0%	0.0%	0.0%	0.0%	-	48.0	-	-	-
	Female	0.0%	100.0%	0.0%	0.0%	0.0%	-	46.6	-	-	-
	Jack	-	-	-	-	-	-	-	-	-	-

<sup>a</sup> Data are from Appendix 9; the only jack recovered in 1994 was not aged.

applied to migrating sockeye which tended to clear the tagging site quickly, 39 were recaptured and one was recaptured twice. The proportion of this group which was recovered (7.7%) was lower than for nonrecaptured fish (30.0%); however, the difference was not significant ( $P > 0.05$ ; chi-square) when the data were stratified by sex. Consequently, they were not removed from the application sample. When adjusted for males stressed by capture, the final disk tag application sample totalled 2,147 males and 1,938 females (Table 1).

The mean NF for males and females was 62.0 cm and 57.5 cm, respectively; none were sampled for age. The incidence of net, lamprey and hook marks was 15%, 6% and 1% in males, and 24%, 3% and 1% in females, respectively (Appendix 5).

## SPAWNING GROUND SURVEYS

### Main Survey

In 1994, 134,551 sockeye adults and 1 jack were recovered in the study area from October 14 to November 13, 1994 (Table 1; Appendix 6). Of the adults, 54% were male and 46% were female, and 1.0% and 0.8% had a disk tag. The only jack was untagged. Female spawning success averaged 99.2% (Table 2).

The lower Shuswap River was surveyed an average of eight times from October 14 to November 12 (Appendix 6a). Survey frequency varied between reaches and was highest (13 sur-

veys) in the main recovery areas (reaches 5-7). The lower Shuswap River accounted for 96% (129,351) of the study area carcasses; 0.91% had disk tags. The most important recovery areas were Reach 6 (30% of the total recovery), Reach 5 (27%) and Reach 7 (17%). The average time between release and recovery for disk tagged males and females was 17 days and 14 days, respectively, and was longer among those tagged earlier in the study (Table 2). Only one of the tagged fish was out for less than five days. Female spawning success averaged 99.1%, with lower success among early spawners (Table 2).

The middle Shuswap River was surveyed five times from October 22 to November 8 (Appendix 6b). Surveys were less frequent than in the lower Shuswap River because this area was more distant and staff levels did not permit more frequent surveys without compromising the tagging component of the study. The middle Shuswap River accounted for 4% (5,149) of the study area carcasses; 0.78% had disk tags. The carcasses were distributed approximately equally among the three reaches. The average time between release and recovery for disk tagged males and females was 18 days (Table 2). None of the tagged fish were out for less than five days. Female spawning success averaged 99.7% (Table 2).

The Mabel Lake tributaries were surveyed 2-5 times each from October 16 to November 13 (Appendix 6c). Less than 0.1% (38) of the study area carcasses were recovered in the tributaries; none had a disk tag.

Table 4a. Incidence of disk tags in sockeye salmon recovered on the Shuswap River system spawning grounds, by recovery period and sex, 1994. Data are stratified by equal recovery periods.

Recovery period	Number of surveys <sup>a</sup>	Carcasses recovered with disk tags			Total recovery			Disk tag incidence		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
14-Oct to 20-Oct	5	204	101	0	11,442	7,105	0	1.8%	1.4%	-
21-Oct to 26-Oct	3	183	182	0	21,356	21,933	1	0.9%	0.8%	0.0%
27-Oct to 01-Nov	3	229	152	0	24,787	20,682	0	0.9%	0.7%	-
02-Nov to 07-Nov	2	73	52	0	10,300	8,145	0	0.7%	0.6%	-
08-Nov to 13-Nov	2	31	15	0	5,291	3,510	0	0.6%	0.4%	-
Chi-Square Test Result:								96.04	45.54	-
Critical Chi-Square (df = 4; $\alpha$ = 0.005):								14.86	14.86	-

<sup>a</sup> Based on recovery effort in the lower Shuswap River.

Table 4b. Incidence of disk tags in sockeye salmon recovered on the Shuswap River system spawning grounds, by recovery period and sex, 1994. Data are stratified by approximately equal recovery cycles.

Recovery period	Number of surveys <sup>a</sup>	Carcasses recovered with disk tags			Total recovery			Disk tag incidence		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
14-Oct to 18-Oct	3	127	57	0	5,632	3,351	0	2.3%	1.7%	-
19-Oct to 23-Oct	3	147	106	0	12,451	9,681	0	1.2%	1.1%	-
24-Oct to 29-Nov	4	225	211	0	26,552	27,465	1	0.8%	0.8%	0.0%
30-Oct to 05-Nov	2	168	98	0	20,204	15,303	0	0.8%	0.6%	-
06-Nov to 13-Nov	3	53	30	0	8,337	5,575	0	0.6%	0.5%	-
Chi-Square Test Result:								118.61	53.53	-
Critical Chi-Square (df = 4; $\alpha$ = 0.005):								14.86	14.86	-

<sup>a</sup> Based on recovery effort in the lower Shuswap River.

Table 4c. Incidence of disk tags in sockeye salmon recovered on the Shuswap River system spawning grounds, by recovery period and sex, 1994. Data are stratified by approximately equal numbers of total recoveries.

Recovery period	Number of surveys <sup>a</sup>	Carcasses recovered with disk tags			Total recovery			Disk tag incidence		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
14-Oct to 22-Oct	5	235	135	0	14,123	9,519	0	1.7%	1.4%	-
23-Oct to 25-Oct	2	122	122	0	15,054	15,778	0	0.8%	0.8%	-
26-Oct to 28-Oct	2	139	112	0	14,735	14,301	1	0.9%	0.8%	0.0%
29-Oct to 02-Nov	2	122	69	0	13,976	10,544	0	0.9%	0.7%	-
03-Nov to 13-Nov	4	102	64	0	15,288	11,233	0	0.7%	0.6%	-
Chi-Square Test Result:								89.45	54.89	-
Critical Chi-Square (df = 4; $\alpha$ = 0.005):								14.86	14.86	-

<sup>a</sup> Based on recovery effort in the lower Shuswap River.

Table 5. Distribution of recovered disk tagged sockeye adults on the Shuswap River system spawning grounds, by sex and tag application date, 1994.

Sex	Application date	Lower Shuswap River disk tag recoveries <sup>a</sup>								Middle Shuswap River tag recoveries <sup>b</sup>	
		Below Tagging site		Lower River		Middle River		Upper River		No.	%
		No.	%	No.	%	No.	%	No.	%		
Male	26-Sep to 30-Sep	1	6%	4	22%	9	50%	2	11%	2	11%
	01-Oct to 05-Oct	6	4%	49	31%	74	47%	21	13%	8	5%
	06-Oct to 10-Oct	6	2%	56	21%	171	63%	34	13%	5	2%
	11-Oct to 15-Oct	5	2%	56	26%	135	63%	13	6%	6	3%
	16-Oct to 20-Oct	2	4%	23	44%	27	52%	0	0%	0	0%
	21-Oct to 26-Oct	0	0%	4	80%	1	20%	0	0%	0	0%
Female	26-Sep to 30-Sep	0	0%	3	27%	3	27%	3	27%	2	18%
	01-Oct to 05-Oct	2	4%	7	14%	24	49%	13	27%	3	6%
	06-Oct to 10-Oct	6	4%	23	17%	65	47%	40	29%	5	4%
	11-Oct to 15-Oct	14	7%	52	26%	111	56%	15	8%	7	4%
	16-Oct to 20-Oct	4	5%	21	26%	52	63%	3	4%	2	2%
	21-Oct to 26-Oct	2	9%	12	55%	8	36%	0	0%	0	0%

<sup>a</sup> Lower Shuswap River section definitions:

Below tagging site: Reach 9;

Middle: reaches 5 and 6;

Lower: reaches 7 and 8;

Upper: reaches 1-4.

<sup>b</sup> Middle Shuswap River includes the Mabel Lake tributaries: Noisey, Tsuius and Wap creeks.

## Resurvey

The lower Shuswap River was resurveyed an average of twice, and the middle Shuswap River once from October 21 to November 14; 26,078 males and 20,516 females were reexamined, and 28 and 27 disk tags were recovered (Appendix 7). The incidence of missed tags by sex was not significantly different ( $P > 0.05$ ; chi-square) in the lower Shuswap (0.12%) and middle Shuswap (0.13%) rivers; therefore, the number of missed tags was estimated by sex from the pooled missed tag incidence and the number of carcasses originally processed. An estimated 78 (9.8%) and 81 (13.9%) disk tagged males and females processed during the main survey were not correctly identified as tagged fish (Table 1). When corrected for this error, a total of 799 male and 583 female disk tags were recovered, a disk tag incidence of 1.1% and 1.0%, respectively.

## BIOLOGICAL SAMPLING

Fecundities were obtained from 50 females at the tagging site on October 12; all were age 4<sub>2</sub> (Appendix 8). They had an average standard

length of 53.3 cm (range 49.4 cm to 58.6 cm) and an average fecundity of 3,853 (range 2,580 to 5,982).

The age composition of the sampled adult carcasses was entirely age 4<sub>2</sub> in both the lower and middle Shuswap rivers (Appendix 9). Males and females averaged 48.2 cm and 46.7 cm POH length, respectively. No difference was noted in the size composition of the lower and middle Shuswap populations ( $P > 0.005$ ; ANOVA) (Table 3). No jacks were sampled in 1994.

## SAMPLING SELECTIVITY

### Period

Temporal bias in the application sample was examined by comparing disk tag incidences in five recovery periods which were stratified in three ways: by equal periods; equal recovery effort; and equal numbers recovered (Table 4). Tag incidence in adults ranged from 0.4% to 2.3%, with a higher incidence early in the study. These differences were significant ( $P < 0.005$ ; chi-square) in all stratifications. This bias is

Table 6a. Proportion of the disk tag application sample recovered on the Shuswap River system spawning grounds, by application period and sex, 1994. Data are stratified by equal application periods.

Application period	Number of sets	Disk tags applied <sup>a</sup>			Carcasses recovered with disk tags			Percent recovered		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
26-Sep to 02-Oct	27	235	132	0	68	25	0	28.9%	18.9%	-
03-Oct to 08-Oct	18	660	398	0	240	102	0	36.4%	25.6%	-
09-Oct to 14-Oct	14	935	937	0	342	249	0	36.6%	26.6%	-
15-Oct to 20-Oct	7	279	368	0	65	104	0	23.3%	28.3%	-
21-Oct to 26-Oct	4	38	103	0	5	22	0	13.2%	21.4%	-
Chi-Square Test Result:								28.68	5.74	-
Critical Chi-Square (df = 4; $\alpha$ = 0.05):								9.49	9.49	-

<sup>a</sup> Corrected for sex identification error.

Table 6b. Proportion of the disk tag application sample recovered on the Shuswap River system spawning grounds, by application period and sex, 1994. Data are stratified by approximately equal application effort.

Application period	Number of sets	Disk tags applied <sup>a</sup>			Carcasses recovered with disk tags			Percent recovered		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
26-Sep to 29-Sep	14	49	20	0	13	4	0	26.5%	20.0%	-
30-Sep to 02-Oct	13	186	112	0	55	21	0	29.6%	18.8%	-
03-Oct to 07-Oct	15	557	315	0	205	79	0	36.8%	25.1%	-
08-Oct to 13-Oct	14	874	823	0	317	219	0	36.3%	26.6%	-
14-Oct to 26-Oct	14	481	668	0	130	179	0	27.0%	26.8%	-
Chi-Square Test Result:								17.13	3.95	-
Critical Chi-Square (df = 4; $\alpha$ = 0.05):								9.49	9.49	-

<sup>a</sup> Corrected for sex identification error.

Table 6c. Proportion of the disk tag application sample recovered on the Shuswap River system spawning grounds, by application period and sex, 1994. Data are stratified by approximately equal numbers of total tags applied.

Application period	Number of sets	Disk tags applied <sup>a</sup>			Carcasses recovered with disk tags			Percent recovered		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
26-Sep to 05-Oct	37	538	296	0	176	60	0	32.7%	20.3%	-
06-Oct to 09-Oct	11	509	355	0	182	88	0	35.8%	24.8%	-
10-Oct to 11-Oct	5	318	347	0	132	97	0	41.5%	28.0%	-
12-Oct to 14-Oct	6	465	469	0	160	131	0	34.4%	27.9%	-
15-Oct to 26-Oct	11	317	471	0	70	126	0	22.1%	26.8%	-
Chi-Square Test Result:								29.18	7.07	-
Critical Chi-Square (df = 4; $\alpha$ = 0.05):								9.49	9.49	-

<sup>a</sup> Corrected for sex identification error.

Table 7. Proportion of the Shuswap River system sockeye salmon spawning ground recovery sample marked with disk tags, by recovery location and sex, 1994. <sup>a</sup>

Recovery river	Recovery Section	Carcasses recovered with disk tags			Total carcasses examined			Disk tag incidence		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
Lower Shuswap	Below site	20	28	0	1,776	2,747	0	1.13%	1.02%	-
	Lower	192	118	0	19,013	12,122	0	1.01%	0.97%	-
	Middle	417	263	0	41,304	31,977	0	1.01%	0.82%	-
	Upper	70	74	0	8,400	12,012	0	0.83%	0.62%	-
Middle Shuswap	All	21	19	0	2,683	2,517	1	0.78%	0.75%	0.00%
Chi-Square Test Result:								3.85	11.15	-
Critical Chi-Square (df = 4; $\alpha$ = 0.05):								9.49	9.49	-

<sup>a</sup> See table 5 for section definitions.

Table 8. Proportion of the disk tag application sample recovered on the Shuswap River system spawning grounds, by sex and 3 cm increments of nose-fork length, 1994.

Nose-fork length (cm)	Disk tags applied <sup>a</sup>			Carcasses recovered with disk tags			Percent recovered		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
40-42.9	0	0	0	0	0	0	-	-	-
43-45.9	0	0	0	0	0	0	-	-	-
46-48.9	0	0	0	0	0	0	-	-	-
49-51.9	4	18	22	0	5	5	0.0%	27.8%	22.7%
52-54.9	18	220	238	6	49	55	33.3%	22.3%	23.1%
55-57.9	131	842	973	36	214	250	27.5%	25.4%	25.7%
58-60.9	526	759	1,285	165	216	381	31.4%	28.5%	29.6%
61-63.9	989	89	1,078	336	16	352	34.0%	18.0%	32.7%
64-66.9	447	7	454	166	2	168	37.1%	28.6%	37.0%
67-69.9	32	3	35	11	0	11	34.4%	0.0%	31.4%
Kolmogorov-Smirnov 2-sample test Dmax:							0.057 <sup>b</sup>	0.046 <sup>b</sup>	-
Kolmogorov-Smirnov 2-sample test Dcritical ( $\alpha$ = 0.05):							0.062 <sup>b</sup>	0.070 <sup>b</sup>	-

<sup>a</sup> Corrected for sex identification error.

<sup>b</sup> KS test used continuous data; see text.

Table 9. Sex composition of Shuswap River system sockeye adults in the disk tag application and spawning ground recovery samples, 1994.

Sex	Application sample, by recovery status <sup>a</sup>				Recovery sample, by mark status				
	Sample size	Recovered	Not recovered	Total	Sample size	Marked	Unmarked	Total	
Male	2,147	57.8%	49.9%	52.6%	73,176	57.8%	54.3%	54.4%	
Female	1,938	42.2%	50.1%	47.4%	61,375	42.2%	45.7%	45.6%	
Chi-Square Test Result:				22.83	Chi-Square Test Result:				6.48
Critical Chi-Square (df = 1; $\alpha$ = 0.005):				7.88	Critical Chi-Square (df = 1; $\alpha$ = 0.05):				3.84

<sup>a</sup> Corrected for sex identification error.

important because spawners from the upper system (middle Shuswap River and the upper part of the lower Shuswap River) migrated past the tagging site earlier than other spawners, i.e. these fish comprised 21% and 8% of the pre- and post-October 10 migrants, respectively (Table 5).

Recovery bias was examined by comparing the proportions recovered from five application periods which were stratified in three ways: by equal periods; equal application effort; and equal numbers applied (Table 6). The proportion of the adults recovered ranged from 13.2% to 41.5%, with a significant ( $P < 0.05$ ; chi-square) difference in males in all three stratifications; the proportion recovered was consistently lower among those tagged early and late in the study.

#### Location

Spatial bias in the application sample was examined by comparing the mark incidence in five recovery sections (Table 7). Mark incidence among adults ranged from 0.62% to 1.13%, with a lower incidence among spawners from the upper part of the system. This difference was significant ( $P < 0.05$ ; chi-square) only among the females (Table 7). Recovery bias could not be examined because the tags were applied at a single site.

#### Fish Size

Application bias could not be assessed because the length of untagged carcasses was not measured. Recovery bias was examined by partitioning the application sample into recovered and nonrecovered components and comparing the NF frequency distributions. There was no difference in either sex ( $P > 0.05$ ; Kolmogorov-Smirnov two-sample test). Similar proportions recovered were also noted when the data were stratified in 3-cm NF groups (Table 8).

#### Fish Sex

The sex ratio of the marked and unmarked spawning ground recoveries was not significantly different ( $P > 0.05$ ; Yates' chi-square) (Table 9). This indicates that the application sample was relatively unbiased with respect to sex.

The sex ratios of the recovered and nonrecovered components of the application sample

were significantly different ( $P < 0.005$ ; Yates' chi-square) (Table 9). A similar difference was noted in the proportion of males (37.2%) and females (30.1%) released with disk tags and recovered on the spawning grounds (Table 1). The recovery sample, therefore, was biased toward males.

#### Stress

Potential bias resulting from handling and tagging stress was assessed in two ways. First, three tests were performed to determine whether specific tags should be excluded from the application sample. The results of these tests were reported on Page 11; one disk tagged male which was recovered within five days of release was removed from the samples. Second, two tests were performed as general indicators of a stress problem: a) spawning success was compared between tagged (97.7%) and untagged (97.1%) females. The input data for this test of independence (number of recoveries which were 0%, 50% and 100% spawned) were collapsed into two groups because of the low number of expected recoveries in the 50% group. No significant difference ( $P < 0.05$ ; chi-square) was noted; and b) the recovery sample was partitioned into those recovered above and below the tagging site and the disk tag incidence and female spawning success were compared in each. Tag incidence below (1.06%) and above (0.90) the tagging site was not significantly different ( $P > 0.05$ ; chi-square) in either sex (Table 5), and spawning success (99.1%) was identical in each. We concluded, therefore, that handling and tagging stress was unlikely to have introduced substantial bias to this study.

#### SPAWNER POPULATION ESTIMATES

The 1994 Shuswap River system sockeye adult escapements are presented in Table 10 and are discussed below. The jack escapement estimate, calculated using Equation 7 (Page 9), was 3 fish, all of which spawned in the middle Shuswap River (Table 11).

#### Petersen Estimator

The pooled Petersen estimate was calculated for the Shuswap River system study area from the data presented in Table 1. Escapement was estimated for adult males and females only;

Table 10. Escapement estimates and 95% confidence limits, by age and sex, for Shuswap River system sockeye adults, 1994. The symbol \* indicated the final study area escapement estimates.

Stratification type	Estimator	Sex	Escapement at age <sup>a</sup>					Total	95% confidence limits on total escapement	
			3 <sub>2</sub>	4 <sub>2</sub>	4 <sub>3</sub>	5 <sub>2</sub>	5 <sub>3</sub>		Lower	Upper
Pooled	Petersen	Male	0	196,480	0	0	0	196,480 *	182,948	210,013
		Female	0	203,781	0	0	0	203,781 *	187,346	220,216
		Total	0	400,261	0	0	0	400,261 *	378,972	421,550
Spatial <sup>b</sup>	Schaefer	Male	-	-	-	-	-	196,632	-	-
		Female	-	-	-	-	-	204,022	-	-
	Darroch	Male	-	-	-	-	-	196,016	185,342	206,690
		Female	-	-	-	-	-	200,926	187,547	214,305
Temporal <sup>c</sup>	Schaefer	Male	-	-	-	-	-	198,482	-	-
		Female	-	-	-	-	-	203,217	-	-
	Darroch	Male	-	-	-	-	-	219,828	163,803	275,853
		Female	-	-	-	-	-	254,164	-144,616	652,944

<sup>a</sup> Does not include 50 males and 53 females which were killed for fecundity and other samples.

<sup>b</sup> Used a 1x4 matrix: lower Shuswap application; lower Shuswap (lower, middle and upper) and middle Shuswap recovery.

<sup>c</sup> Used a 4x4 matrix: 26-Sep to 09 Oct, 10-11 Oct, 12-14 Oct, 15-26 Oct application; 14-25 Oct, 26-28 Oct, 29 Oct to 02 Nov, 03-13 Nov recovery.

Table 11. Estimated escapement of adult males, females and jacks to the lower and middle Shuswap rivers and Mabel Lake tributaries, 1994.

Stock	Peak live	Cumulative dead	Adult escapement			Jacks
			Males	Females	Total	
Lower Shuswap River	n/a	n/a	179,650	188,011	367,661	0
Middle Shuswap River	17,000	670	16,441	15,365	31,806	3
Noisey Creek	0	0	0	0	0	0
Tsuius Creek	94	0	83	86	169	0
Wap Creek	346	1	307	318	625	0
Total <sup>a</sup>	-	-	196,480	203,781	400,261	3

<sup>a</sup> Does not include 50 males and 53 females which were killed for fecundity and other samples.

jack (NF length of less than 50 cm) abundance did not meet the minimum requirement for a mark-recapture estimate.

The 1994 study area sockeye adult escapement was estimated at 400,261 with 95% confidence limits of  $\pm 21,289$  (5.3%) (Table 10). The escapement of males and females was 196,480  $\pm 13,532$  (6.9%) and 203,781  $\pm 16,435$  (8.1%), respectively. Age-specific escapement by sex (Table 10) was calculated from the data in Appendix 9. Because there was no difference in age composition between the two stocks, escapement by age was calculated from the pooled sample data. All of the adults were age 4<sub>2</sub>.

### Stratified Estimators

Because both temporal and, potentially, spatial biases were identified in the sampling data, stratified estimates were calculated using the Schaefer and Darroch estimators (Table 10). Spatially, the data were stratified into one application and four recovery locations. Temporally, the data were initially stratified into five application periods, each with an approximately equal number of tags applied (Table 6c), and five recovery periods, each with an approximately equal number of carcasses recovered (Table 4c); however, the two initial application and recovery strata were collapsed into single strata to increase the number of recoveries per cell.

The stratified estimates of the male and female escapements ranged from -0.2% to +11.9% and -1.4% to +24.7% of the Petersen estimates, respectively. Both of the temporally stratified Darroch estimates fell outside the 95% confidence limits of the pooled Petersens, although the respective confidence intervals overlapped. The Darroch estimates for both sexes were higher and had considerably poorer precision than the Petersen estimates. This was especially true for the female estimate, which may have reflected a low recovery of only six disk tags in one cell; however, when that stratum was collapsed, the estimator failed to converge. We also recalculated the Darroch estimate from a 3x3 matrix; however, in view of the 95% confidence range of over six million, the point estimate was relatively uninformative. These results suggest that the temporal biases in both the application and recovery samples were serious and that the Petersen estimator may have a negative bias and may

overstate the precision of the estimate. Because the confidence limits of the Darroch and Petersen estimates overlapped and the Petersen estimates fell within the confidence limits of the Darroch estimates, however, the pooled Petersen was accepted as the most appropriate population estimator.

### Stock-Specific Estimates

Sockeye escapements to the middle Shuswap River and Noisey, Tsuius and Wap creeks were estimated from the peak live and cumulative dead data using Equation 8. Because the number of carcasses recovered in the middle Shuswap River (Appendix 6b) exceeded 10% of the escapement estimate (Table 11) (see Page 10), those data were used to estimate the sex-specific adult escapement. The number of carcasses recovered in each of the Mabel Lake tributaries (Appendix 6c), however, was less than 10% of the escapement estimate. For these stocks, the sex ratio from the mark-recapture estimates was used to estimate the escapement by sex.

## DISCUSSION

### MARK-RECAPTURE ASSUMPTIONS

The Petersen mark-recapture technique is based on the principle that, by tagging a random sample of fish, permitting them to redistribute through the population, and by obtaining a second random sample of tagged and untagged individuals, the number of fish in the population can be estimated with known precision. Even a very precise estimate, however, can be inaccurate. The accuracy of an escapement estimate depends on how well the assumptions underlying the technique have been addressed. These assumptions have been described in various forms by Ricker (1975), Otis *et al.* (1978), Eames *et al.* (1981) and Seber (1982) and are restated below in the context of the current study.

### Population Closure

A closed population is one where the number of animals does not change during the study. In spawning salmon populations, this implies that there is neither recruitment nor immigration, and that death and emigration affect tagged and untagged fish equally. Functionally, closure also

implies that all components of the population will be vulnerable to either capture or recapture. The Shuswap study was designed to address the closure assumption through temporal and spatial design elements which ensured that the study encompassed virtually the entire period of immigration, spawning and die-off in all of the terminal spawning areas. These efforts attempted to ensure that all fish would be vulnerable to application or recovery, although survey effort was not consistent across all spatial and temporal strata. Based on the temporal pattern of migration observed at the tagging sites and the bridges and the distribution of spawners in the system, we concluded that the closure assumption was adequately addressed in the current study.

### **Identification of Tag Status**

The failure to correctly identify the tag status of a carcass is a common error in mark-recapture studies. It generally results from surveyor inexperience, fatigue, or from assigning a higher priority to the speed of carcass processing than to the thoroughness of carcass examination. The latter especially applies to major stocks such as the Shuswap where the number of carcasses processed each day can be large (greater than 2,500 carcasses per person). If uncorrected, this type of error results in an underestimate of the proportion of tags in the population and an overestimate of escapement. In the current study, the proportion of the tags missed by the initial survey was evaluated by resurveying about one-third of the carcasses in previously surveyed areas; the estimated proportion of the tags missed was 11.6% or 160 tags. Because this proportion was large relative to other 1994 studies (Schubert 1997), three procedural changes are recommended to reduce the missed tag rate in future studies: staff training should reemphasize the importance of carefully examining each carcass; the crew chief, through more frequent resurveys, should provide immediate feedback and retraining to staff who are missing tags; and the crew size should be increased during the peak recovery period, thereby reducing the daily number of carcasses processed by each individual. Further, the relationship between the daily number of carcasses processed by an individual and the missed tag rate should be investigated and, if appropriate, a maximum daily carcass processing level should be established.

We have four concerns with the resurvey conducted in 1994. First, the resurveys were un-systematic, i.e. they were less frequent than the initial surveys and did not representatively sample all spatial and temporal components of the run. For example, the middle Shuswap River was resurveyed only once while parts of the lower Shuswap River were resurveyed up to four times, and the proportion of the carcasses which were resurveyed progressively increased from less than 20% early in the study to almost 60% late in the study. Unsystematic resurveys could introduce error in the population estimate if the missed tag rate was not uniform, e.g. if the proportion of tags missed was related to the daily number of fish processed, to surveyor fatigue, or to the physical characteristics of the survey area. While stratification is an option, it was not considered in the current study because sample size was inadequate in several spatial and temporal strata. This issue should be addressed in future studies by a more frequent and representative resurvey. Second, carcasses fish could be injected into the population between the initial survey and the resurvey in two ways: a) by rising and falling river levels between the two surveys; and b) animals could drag ashore carcasses which later could not be identified as predator kills. Such carcass introductions would result in an overestimate of the proportion of tags in the population and an underestimate of the escapement. This type of error was unlikely in the current study because flows were stable and predator activity was generally minor; however, the potential error is significant and should be addressed in future studies. Tag introductions could be controlled by reducing the elapsed time between the two surveys; it could be eliminated by applying an unambiguous mark (e.g. abdominal incision or chopping the fish in two) to processed carcasses. Third, as with the sex identification error correction, there is no variance estimator for the resurvey sampling stage. Consequently, the precision of the population estimate was overstated. This should be addressed in the analytic design of future studies. Fourth, to minimize estimator variance, simulation studies are required to determine the optimal allocation of effort between the initial and resurvey sampling stages.

### **Tag Loss**

The undetected loss of tags between tag application and recovery would result in an under-

estimate of the proportion of the population with tags and an overestimate of escapement. Tag loss can result from poorly applied tags, released fish becoming entangled in the net, or from aggressive behaviour among males. It can be easily evaluated (although with an incremental labour cost) by applying a secondary tag, or a mark such as an opercular punch or fin clip, in addition to the primary tag. Tag loss in the current study could not be assessed because secondary marks were not used. A 1989 tag loss study reported, however, an average 3.5% (range 0% to 9.7%) loss of disk tags in seven Fraser river sockeye stocks (DFO, unpublished). Studies of Fraser River chinook (Schubert *et al.* 1994a) and coho (Schubert *et al.* 1994b) also reported levels of tag loss which varied annually within the same range. If tag loss in the current study was similar to that reported in the 1989 studies, the 1994 escapement would have been overestimated by approximately 17,000 sockeye (range 0 to 41,000). Clearly, tag loss could introduce a bias in the population estimate and its assessment should be an integral part of all future mark-recapture studies. We note, however, that a positive bias of the same relative magnitude would also have occurred in past years because tag loss was not evaluated by any previous mark-recapture study in the Shuswap River system.

### Tagging Effects

Tagging can influence subsequent catchability if, for example, a tagged fish becomes more vulnerable to capture in a fishery, to identification during carcass recovery surveys or to predators. This type of tagging effect had little impact on the current study because: there were no net fisheries upstream from the tagging site; the capture net was the only net used in the river, and few previously tagged fish were recaptured; the technicians were trained to recover carcasses independent of their tag status; and, although there was no indication that predators differentially removed tagged fish, predator recoveries were excluded from the sample.

The capture, holding and tagging of fish can subject sockeye to physiological stress (Ricker 1975). Two potentially serious tagging effects are: a) behavioral changes which violate the assumption of constant and equal probability of capture and recapture; and b) acute or short-term mortality, which violates the closure as-

sumption and causes an underestimate of the proportion of tags in the population and an overestimate of escapement. The impact of low level or subacute stress may be trivial, or it may be manifested in subtle behavioral changes which influence subsequent catchability but which do not affect the ability of the fish to spawn successfully. If the stress is particularly severe, some individuals may die within a few days of release, and others may drift downstream and die outside the study area. The potential impact on the current study of a spectrum of subacute to severe acute stresses is discussed below.

There are a number of stress-related tagging effects which are of potential concern in the current study. First, stress could impair the ability of an affected fish to swim in stronger currents. In a subacute case, the ability of a stressed fish to hold position in faster currents could be impaired, forcing it to spawn in slower flowing water along the river periphery. This would increase the probability that the fish would wash ashore and could result in a higher recovery rate among the stressed group, a violation of the equal probability of recapture assumption. In a more severe case, the ability of the fish to move beyond the tagging site could be impaired, resulting in a higher probability of recovery downstream. In an extreme case, such fish could be flushed from the study area, a violation of the closure assumption. Second, stress may impair the ability of a fish to spawn successfully, resulting in a measurable reduction in spawning success. Lower spawning success among disk tagged fish could indicate a subacute stress, while lower success below the tagging site could indicate a more severe, acute stress. By itself, differential spawning success does not violate the basic mark-recapture assumptions; however, it does demonstrate behavioural differences which could violate the assumptions in a way which would be undetectable using current study techniques. Such differential spawning success should be treated as an indicator that the study stock may be highly susceptible to stress; low stress study techniques should be considered. Third, the time span between release and death could be shorter among stressed fish. Shorter time spans among tagged fish in general could indicate a subacute stress which would violate the assumption of random mixing. The detection of such a stress, however, requires an independent estimate of the time between release and death for

untagged fish; such an assessment was unavailable in the current study. In contrast, acute stresses should be detectable because behaviour was assessed immediately after release.

In the current study, we attempted to minimize handling stress by ensuring that the capture and tagging processes were as stress-free as possible. This was done by selecting a tagging site proximal to the main spawning areas, where fast water would not stress the fish being held for tagging, and by minimizing the holding and handling time. These conditions were intended to minimize stress induced mortality while at the same time permit the complete mixing of tagged and untagged fish. Our tests (described earlier) detected no difference in recovery rates or time out to recovery between fish which were obviously stressed at release and the other releases (Table 12). Spawning success was lower among the tagged recoveries; however, the difference was small (0.6%) and was not statistically significant. We note, however, that we were unable to assess the relative time spans between release and death among tagged and untagged fish because the bridge counts were not sufficiently structured to estimate the latter. Such a difference would constitute a violation of the assumption of random mixing of tagged and untagged fish which would be undetectable using our current techniques. We detected no difference in either spawning success and disk tag incidence between fish recovered upstream and downstream from the tagging site. Although only one fish which was recovered less than five days after release, we note that the delay of 18 days between the start of tagging and recovery impaired our ability to evaluate stress in 1994. Despite the latter, however, we concluded that there was little evidence in support bias resulting from subacute or acute stress in 1994.

Both subacute and acute stresses could differentially impact specific components of the study population. The 1994 Shuswap study was designed to estimate the escapement of two significant stocks, those spawning in the lower and middle Shuswap rivers. Such system-wide tagging programs can be more susceptible to the delayed mortality which can result from capture and tagging stress because one component of the population, in this case the middle Shuswap River stock, must travel a considerably greater distance after tagging and may be less fit to do

so. Stress, therefore, may play a more prominent role in determining the subsequent catchability of this component of the population than among the lower Shuswap spawners which have a comparatively shorter distance to travel to the spawning grounds. This type of stress effect may have occurred in studies of two lower Fraser River sockeye stocks. In a study of Birkenhead River sockeye, Schaefer (1951) attributed to tagging stress a progressive reduction in tag ratios along a 160 km migratory pathway between the tagging site and the spawning grounds. Howard (1948), in an early study of Cultus Lake sockeye, also reported a considerably higher tag incidence in carcasses recovered immediately above the Sweltzer Creek tagging site. In a review of a number of tagging studies, Simpson (1984) concluded that the level of stress-induced mortality increased with distance between the tagging site and the spawning grounds. In the current study, the disk tag incidence above the tagging site was lower than below the site; however, the difference was not significant and was less than that reported by Howard (1948). Tag incidences were also lower among fish which migrated 20-80 km beyond the tagging site (Table 7); however, we were unable to determine whether this reflected a stress-induced reduction in the survival of the tagged fish or a violation of the assumption of equal probability of capture. Both could introduce substantial biases into the population estimate, although the effect of the latter would be mediated by the lower probable recovery rate in the middle Shuswap River (discussed later).

In summary, none of our tests demonstrated a serious concern with stress-induced tagging effects in the 1994 Shuswap study. We were unable to discount the possibility that subacute and acute stresses did not bias the population estimate, however, and we recommend several design changes to permit such an assessment in the future: a) to permit the assessment of the relative importance of tagging effects and sampling selectivity, tag application should be made temporally more consistent, and the lower and middle Shuswap rivers should be surveyed with equal frequency; b) to evaluate the Shuswap stock's susceptibility to stress and the potential impact of sub-acute stress on the study results, high and low stress tag application techniques should be developed; and c) to permit a more thorough assessment of acute tagging effects, surveys of the river above and below the tagging

Table 12. Bias profile for the 1994 Shuswap River system sockeye escapement estimation study. <sup>a</sup>

Sample	Bias type	Test of	Between	Test result
Application	Temporal	Tag incidence:	Equal recovery periods	Bias to early period, both sexes
			Equal recovery effort	Bias to early period, both sexes
			Equal numbers of recoveries	Bias to early period, both sexes
	Spatial	Tag incidence:	Five recovery areas	No bias
			Lower/mid LSR vs upper LSR/MSR	Bias to lower river in females
	Fish sex	Sex ratio:	Marked/unmarked recoveries	Bias to males
	Stress	Recovery rate: Recovery of a tag within 5-days of rel:	Ventilated/nonventilated releases	No bias
			-	Removed 1 tag
			Live recaptured/not recaptured	No bias
			Tagged/untagged recoveries	No bias
			Above and below tagging site	No bias
			Above and below tagging site	No bias
	Recovery	Statistical <sup>b</sup>	Minimum recovery of 5 tags:	-
Temporal		Recovery rate:	Equal application periods	Middle period bias in males
			Equal application effort	Middle period bias in males
			Equal numbers applied	Middle period bias in males
Fish size	Size-frequency distrib:	Recovered/nonrecovered tags	No bias	
Fish sex	Sex ratio:	Recovered/nonrecovered tags	Bias to males	

<sup>a</sup> A "no bias" test result indicates that bias was not detected; undetected bias may be present.

<sup>b</sup> See Ricker (1975; page 79).

site should begin immediately after the start of tagging.

### Sampling Selectivity

The assumption of equal probability of capture and simple random sampling is violated in virtually all mark-recapture studies and is generally considered to be an unattainable ideal (Otis *et al.* 1978). This condition can be relaxed to some extent, however, without introducing bias in the population estimate. Junge (1963) showed that selectivity can exist in both samples without introducing a bias in the population estimate if the sources of selectivity are independent, and if the selectivity in the recovery sample is independent of tag status. When nonrepresentative sam-

pling occurs, it can be at least partially addressed by using a stratified population estimator.

The design of the current study attempted to address this assumption by making both tag application and recovery as representative as possible. The tag incidence was monitored through observations at the Ashton Creek Bridge and by using a gear (beach seine net) known to minimize selectivity. There were deficiencies in the study design, however, which compromised the representativeness of both the application and recovery samples.

We could not definitively test sample representativeness because the true population parameters were not known. Instead, we constructed a bias profile by examining the samples for five

potential biases, temporal, spatial, fish size, fish sex and stress, as indicators of weaknesses in the study design (Table 12). Four biases were detected in the application and recovery samples: a) a temporal application bias toward early migrants in both sexes; b) a spatial application bias which resulted in lower disk tag incidences among spawners in the upper portion of the study area; c) a temporal recovery bias which resulted in lower recovery rates in early and late male spawners; d) and a recovery bias towards males in general. The latter bias was easily treated by stratifying the data set by sex and calculating independent population estimates. The other biases are potentially more serious and are discussed below in greater detail.

The temporal biases likely reflected staff levels which were adequate to conduct the application or recovery surveys individually, but which did not permit a consistent level of effort during the period of concurrent surveys. Two effects were noted. First, capture effort declined late in the study, from an average of 3.7 sets per day in the first ten days of the study to only 0.9 sets per day in the last 11 days (Appendix 4). This may have resulted in the observed disk tag incidence among late spawners of about half that of the earlier spawners, with a greater impact among females due to their later arrival on the spawning grounds. We note, however, that this observation could also be explained by a stress induced reduction in the stream life of disk tagged fish. Second, the low recovery rate in early and late spawners reflected two deficiencies in the implementation of the study design. There was a delay between the start of tagging and the start of the recovery survey of 18 days in the lower Shuswap River and 26 days in the middle Shuswap River. Because the average time out to recovery was 17-18 days, this delay would reduce the recovery rate among fish tagged early in the study because at least some of the tags applied at the start of the study would have been unavailable for recovery. The low recovery rate late in the study reflected a decline in survey effort between October and November from about three to two per week. Future studies must address these issues by ensuring that: a) the recovery surveys in both the lower and middle Shuswap rivers begin shortly after the start of tagging; and b) staff levels are sufficient to permit spatially and temporally consistent effort in both the application and recovery surveys.

The female spatial bias in the application sample resulted from a disk tag incidence in the upper river areas which was 0.1-0.2% lower than in the lower river. This was unexpected because these fish apparently migrated past the tagging site early in the study (Table 5) when application effort was high. This may reflect a higher vulnerability to capture among lower river fish resulting from a closer proximity of the tagging site to their spawning area; undetected tagging stress which impaired the ability of tagged fish to move further upstream; or a lower vulnerability to capture of the earlier, upper river fish resulting, perhaps, from a more active migration which would result in a shorter time in the capture area relative to lower river fish. We reiterate the recommendation, therefore, that future studies evaluate the susceptibility of this stock to stress. We further recommend that future studies consider establishing a second tagging site in the upper part of the lower Shuswap River or in the middle Shuswap River to differentially capture spawners from those areas.

The study data were spatially and temporally stratified to address the above assumption violations. We note that the variations among the stratified and pooled estimates tended to be small and that the stratified estimates were generally within the 95% confidence intervals of the pooled Petersen estimate. The only exception, the temporally stratified Darroch estimator, was considered uninformative because of estimator instability and unacceptably high variance among stratifications. We concluded, therefore, that the assumption violations may not have been particularly severe and were unlikely to have introduced substantial bias into the population estimate.

While there is no indication that the three biases discussed above introduced a serious bias into the population estimate, we are concerned that a combination of biases acting in concert with the unique attributes of the two major study area stocks had the potential to do so. Middle Shuswap spawners were tagged at a lower rate than most river spawners, a possible reflection of stress-induced mortality or differential vulnerability to capture in the river resulting from either their earlier migration or some other factor. A combination of low vulnerability of middle Shuswap fish to tag application, and the lower probable recovery rate which resulted from the late survey start and lower effort, could bias the

Table 13. Population estimation error, at simulated middle Shuswap River population mark incidences ranging from 0.25% to 1.0%, middle Shuswap River recovery rates ranging from 5% to 20%, and a total population size of 400,000 spawners, for two cases: middle Shuswap escapements of 30,000 and 60,000.

Simulated lower Shuswap statistics		Simulated middle Shuswap statistics		% bias when true population sizes are:	
Mark incidence	Recovery rate	Mark incidence	Recovery rate	Lower = 370,000 Middle = 30,000	Lower = 340,000 Middle = 60,000
1.00%	30.0%	1.00%	25.0%	0.0%	0.0%
1.00%	30.0%	1.00%	20.0%	0.0%	0.0%
1.00%	30.0%	1.00%	15.0%	0.0%	0.0%
1.00%	30.0%	1.00%	10.0%	0.0%	0.0%
1.00%	30.0%	0.75%	25.0%	-0.3%	-0.6%
1.00%	30.0%	0.75%	20.0%	-0.6%	-1.1%
1.00%	30.0%	0.75%	15.0%	-0.9%	-1.8%
1.00%	30.0%	0.75%	10.0%	-1.2%	-2.4%
1.00%	30.0%	0.50%	25.0%	-0.6%	-1.2%
1.00%	30.0%	0.50%	20.0%	-1.2%	-2.4%
1.00%	30.0%	0.50%	15.0%	-1.8%	-3.6%
1.00%	30.0%	0.50%	10.0%	-2.5%	-4.9%
1.00%	30.0%	0.25%	25.0%	-0.9%	-1.8%
1.00%	30.0%	0.25%	20.0%	-1.9%	-3.6%
1.00%	30.0%	0.25%	15.0%	-2.8%	-5.5%
1.00%	30.0%	0.25%	10.0%	-3.7%	-7.4%

system-wide escapement estimate. To determine the probable direction and magnitude of this bias, we simulated the lower and middle Shuswap rivers under different scenarios of middle Shuswap application and recovery bias and lower and middle Shuswap population sizes. The results of the simulation of two relative stock sizes, where the lower Shuswap statistics were set at approximately the observed levels (1.00% tag incidence; 30% recovery rate) and the middle Shuswap statistics were varied within the maximum probable range (0.25%-1.00% tag incidence; 10%-25% recovery rate), are presented in Table 13. Two general conclusions can be drawn from the simulations: a) this combination of sampling biases would result in an underestimate of the system-wide escapement; and b) a large bias would occur only if sampling selectivity was extreme and the middle Shuswap population was large, i.e. one-third or more of the study area population. The latter was unlikely because our aerial observations indicated that the middle Shuswap comprises less than 15% of the total population. We recommend two study design

changes, however, which will permit the assessment of this potential bias in future studies: a) application effort should be adjusted to increase the tag incidence among middle Shuswap River spawners; b) the frequency of the lower and middle Shuswap surveys should be approximately equal and the middle Shuswap surveys should commence earlier.

### RECOMMENDATIONS

1. The resurvey of carcass recovery areas is an important component of a mark-recapture study because, for a number of reasons, errors can be made in the identification of disk tags during the initial survey. The following changes are recommended to improve the resurvey component of this study:
  - Staff training must emphasize the importance of thoroughly examining each carcass for a disk tag;
  - Crew chiefs should resurvey the recovery areas more frequently, and provide immedi-

- ate feedback and retraining to crew members who miss disk tags;
- The relationship between the daily number of carcasses processed by an individual and the proportion of the disk tags which were missed should be investigated and, if appropriate, a maximum daily carcass processing level should be established. This will permit the adjustment of the crew size during the peak period of carcass recovery to ensure that the daily number of carcasses processed per individual remains below that limit;
  - The resurvey should be made spatially and temporally more representative;
  - The frequency of resurveys should be increased to avoid inter-survey periods of high water which could inject new carcasses into the resurvey area;
  - Predator activity should be documented to determine the need to apply an unambiguous mark (abdominal incision or cutting the carcass in two) to all processed carcasses;
  - The variance of the resurvey sampling stage should be incorporated into the variance of the population estimator;
  - Simulation studies are required to determine the optimum allocation of effort between the initial and resurvey sampling stages.
2. Secondary tags or marks should be applied to sockeye released with disk tags to permit the assessment of disk tag loss. In 1998 (the next year when abundance will be sufficient for a mark-recapture study), we recommend that all disk tagged fish receive a sex-specific opercular punch as a secondary mark. Implicit in this recommendation is the need for improved staff training and feedback discussed under Recommendation No. 1; improved training and clear standards for what constitutes a properly applied tag would also reduce actual tag loss.
3. The sub-acute and acute stresses which may result from the capture, handling and tagging of sockeye adults were identified as a potential concern in 1994. Three study design changes are recommended to assess the role of stress in the Shuswap study and to remove the potentially confounding influence of stress effects from the evaluation of sampling selectivity:
- To evaluate the Shuswap stock's susceptibility to stress and the potential impact of sub-acute stress on the study results, low stress tag application techniques should be developed for comparison with current procedures;
  - To permit a more thorough assessment of acute tagging effects, surveys of the river below and above the tagging site should begin immediately after the start of tagging;
  - Consistent techniques should be developed to estimate spawning success in disk tagged versus untagged females.
4. Three study design changes are recommended to assess the sampling selectivity issues identified in the 1994 study:
- The recovery surveys in both the lower and middle Shuswap rivers should begin shortly after the start of tagging, and their frequency should be similar;
  - Staff levels should be increased, or the study area subsampled, to permit spatially and temporally consistent effort in both the application and recovery surveys;
  - Consideration should be given to adjusting the application procedures, perhaps through establishing a second tagging site, to increase the tag incidence among spawners in the middle Shuswap River and the upper part of the lower Shuswap River.
5. The daily 15-minute counts of migrating sockeye conducted from the lower river bridges did not provide information useful to the assessment of the Shuswap system stocks. The counting procedures should be restructured to provide useful estimates of daily abundance, or cancelled to permit the reallocation of staff to the application or recovery surveys.
6. Analytic methods should be developed to permit incorporating the variance of the sex identification error correction into the variance of the population estimator.

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**Appendices**

Appendix 1a. Sockeye jack and adult escapement by sex, percent spawning success and the number of females which spawned effectively in the Shuswap River system, 1938-1994.

Year	Escapement				Percent spawning success	Effective females
	Total	Jacks	Males	Females		
1938	0	0	0	0	-	0
1939	0	0	0	0	-	0
1940	0	0	0	0	-	0
1941	0	0	0	0	-	0
1942	2,000	0	956	1,044	91.2%	952
1943	0	0	0	0	-	0
1944	0	0	0	0	-	0
1945	0	0	0	0	-	0
1946	1,237	0	618	619	100.0%	619
1947	0	0	0	0	-	0
1948	0	0	0	0	-	0
1949	13	0	6	7	100.0%	7
1950	12,050	0	4,201	7,849	99.1%	7,779
1951	0	0	0	0	-	0
1952	0	0	0	0	-	0
1953	0	0	0	0	-	0
1954	17,523	0	6,312	11,211	98.0%	10,986
1955	23	0	11	12	100.0%	12
1956	5	0	0	0	-	0
1957	490	488	1	1	100.0%	1
1958	9,886	21	4,058	5,807	97.7%	5,675
1959	281	0	94	187	100.0%	187
1960	0	0	0	0	-	0
1961	342	310	16	16	93.8%	15
1962	31,662	181	13,222	18,259	98.7%	18,020
1963	2,014	0	988	1,026	99.2%	1,018
1964	0	0	0	0	-	0
1965	583	291	117	175	98.3%	172
1966	26,501	214	11,923	14,364	100.0%	14,364
1967	6,009	0	3,004	3,005	98.7%	2,966
1968	0	0	0	0	-	0
1969	1,703	704	444	555	93.3%	518
1970	33,633	275	16,419	16,939	99.8%	16,903
1971	6,401	0	2,558	3,843	100.0%	3,843
1972	290	251	19	20	100.0%	20
1973	7,452	4,658	812	1,982	99.2%	1,966
1974	89,460	462	37,592	51,406	99.7%	51,252
1975	11,879	31	5,636	6,212	98.6%	6,124
1976	400	370	11	19	100.0%	19
1977	14,695	8,336	2,738	3,621	98.2%	3,555
1978	198,057	33	101,315	96,709	99.1%	95,819
1979	10,670	44	4,853	5,773	97.8%	5,644
1980	81	63	13	5	100.0%	5
1981	7,358	3,283	2,275	1,800	99.4%	1,789
1982	554,227	30	269,881	284,316	99.6%	283,067
1983	7,335	0	3,020	4,315	-	4,315
1984	79	4	33	42	-	42
1985	3,303	2,306	427	570	100.0%	570

Continued

Appendix 1a. Sockeye jack and adult escapement by sex, percent spawning success and the number of females which spawned effectively in the Shuswap River system, 1938-1994, continued.

Year	Escapement				Percent spawning success	Effective females
	Total	Jacks	Males	Females		
1986	682,228	125	390,116	291,987	99.6%	290,894
1987	11,130	0	6,080	5,050	100.0%	5,050
1988	194	0	97	97	100.0%	97
1989	3,017	2,529	163	325	100.0%	325
1990	1,081,738	83	624,614	457,041	99.9%	456,439
1991	16,259	0	8,035	8,224	100.0%	8,220
1992	535	115	173	247	100.0%	247
1993	2,783	2,038	305	440	95.9%	422
1994	400,264	3	196,480	203,781	99.1%	201,951

Appendix 1b. Annual date of sockeye salmon arrival and peak spawning, jack and adult escapement by sex, percent spawning success and the number of females which had spawned effectively in the lower Shuswap River, 1938-1994.

Year	Arrival	Period of peak spawning	Escapement				Percent spawning success	Effective females
			Total	Jacks	Males	Females		
1938	-	-	0	0	0	0	-	0
1939	-	-	0	0	0	0	-	0
1940	-	-	0	0	0	0	-	0
1941	-	-	0	0	0	0	-	0
1942	-	-	2,000	0	956	1,044	91.2%	952
1943	-	-	0	0	0	0	-	0
1944	-	-	0	0	0	0	-	0
1945	-	-	0	0	0	0	-	0
1946	Oct 01	Oct 15-Oct 20	1,237	0	618	619	100.0%	619
1947	-	-	0	0	0	0	-	0
1948	-	-	0	0	0	0	-	0
1949	-	-	13	0	6	7	100.0%	7
1950	Oct 10	Oct 16-Oct 20	12,000	0	4,176	7,824	99.1%	7,754
1951	-	-	0	0	0	0	-	0
1952	-	-	0	0	0	0	-	0
1953	-	-	0	0	0	0	-	0
1954	Oct 05	Oct 15-Oct 21	17,462	0	6,290	11,172	98.0%	10,948
1955	-	Oct 15-Oct 18	23	0	11	12	100.0%	12
1956	Oct 12	-	5	5	0	0	-	0
1957	Oct 01	-	490	488	1	1	100.0%	1
1958	Oct 13	Nov 03-Nov 05	9,387	20	3,853	5,514	97.7%	5,389
1959	-	-	281	0	94	187	99.8%	187
1960	-	-	0	0	0	0	-	0
1961	-	Oct 21-Oct 23	342	310	16	16	95.1%	15
1962	-	Oct 21-Oct 26	31,205	178	13,031	17,996	98.7%	17,757
1963	-	-	2,014	0	988	1,026	99.2%	1,018
1964	-	-	0	0	0	0	-	0
1965	Early Oct	Oct 15-Oct 20	583	291	117	175	98.5%	172
1966	-	Oct 13-Oct 16	24,629	214	10,987	13,428	100.0%	13,428
1967	Oct 01	Oct 18-Oct 21	5,951	0	2,975	2,976	98.1%	2,937
1968	-	-	0	0	0	0	-	0
1969	Sep 25	Oct 14-Oct 17	1,703	704	444	555	93.3%	518
1970	Oct 01	Oct 17-Oct 20	29,074 <sup>a</sup>	275	14,175	14,624	99.8%	14,593
1971	Oct 10	Oct 20-Oct 24	6,117	0	2,416	3,701	100.0%	3,701
1972	Oct 01	Oct 18-Oct 20	290	251	19	20	100.0%	20
1973	Oct 01	Oct 15-Oct 18	7,452	4,658	812	1,982	99.2%	1,966
1974	Sep 29	Oct 12-Oct 15	86,396 <sup>a</sup>	446	36,305	49,645	99.7%	49,496
1975	-	Oct 10-Oct 15	11,652 <sup>a</sup>	30	5,528	6,094	98.6%	6,006
1976	Oct 01	Oct 18-Oct 20	400	370	11	19	100.0%	19
1977	Sep 25	Oct 10-Oct 15	14,695	8,336	2,738	3,621	98.2%	3,555
1978	Oct 01	Oct 19-Oct 20	187,167 <sup>a</sup>	33	96,346	90,788	99.0%	89,898
1979	-	Oct 13-Oct 15	10,092 <sup>a</sup>	44	4,598	5,450	97.6%	5,321
1980	-	Oct 19-Oct 22	81	63	13	5	100.0%	5
1981	-	Oct 27-Nov 01	7,358	3,283	2,275	1,800	99.4%	1,789
1982	-	Oct 19-Oct 25	513,925 <sup>a</sup>	28	250,256	263,641	99.6%	262,578
1983	-	Oct 13-Oct 18	7,308	0	3,009	4,299	100.0%	4,299
1984	-	Oct 19-Oct 22	79	4	33	42	100.0%	42
1985	-	Oct 17-Oct 21	3,123	2,306	350	467	100.0%	467

<sup>a</sup> Mark-recapture study.

Continued

Appendix 1b. Annual date of sockeye salmon arrival and peak spawning, jack and adult escapement by sex, percent spawning success and the number of females which had spawned effectively in the lower Shuswap River, 1938-1994, continued.

Year	Arrival	Period of peak spawning	Escapement			Percent spawning success	Effective females	
			Total	Jacks	Males			Females
1986	Sep 25	Oct 16-Oct 20	600,495 <sup>a</sup>	125	338,023	262,347	99.7%	261,606
1987	n/a	Oct 22-Oct 27	10,343	0	5,650	4,693	100.0%	4,693
1988	Oct 05	Oct 18-Oct 20	194	0	97	97	100.0%	97
1989	Early Oct	Oct 18-Oct 23	3,017	2,529	163	325	100.0%	325
1990	Late Sep	Oct 15-Oct 21	983,554 <sup>a</sup>	73	578,770	404,711	99.9%	404,156
1991	Early Oct	Oct 20-Oct 28	15,678	0	7,742	7,936	99.9%	7,932
1992	Mid Sep	Oct 03-Oct 10	355	115	83	157	100%	157
1993	Late Sep	Oct 18-Oct 22	2,736	1,991	305	440	95.9%	422
1994	-	Oct 17-Oct 20	368,869 <sup>a</sup>	0	180,274	188,595	99.1%	186,898

<sup>a</sup> Mark-recapture study.

Appendix 1c. Annual date of sockeye salmon arrival and peak spawning, jack and adult escapement by sex, percent spawning success and the number of females which spawned effectively in the middle Shuswap River, 1938-1994.

Year	Arrival	Period of peak spawning	Escapement				Percent spawning success	Effective females
			Total	Jacks	Males	Females		
1938	-	-	0	0	0	0	-	0
1939	-	-	0	0	0	0	-	0
1940	-	-	0	0	0	0	-	0
1941	-	-	0	0	0	0	-	0
1942	-	-	0	0	0	0	-	0
1943	-	-	0	0	0	0	-	0
1944	-	-	0	0	0	0	-	0
1945	-	-	0	0	0	0	-	0
1946	-	-	0	0	0	0	-	0
1947	-	-	0	0	0	0	-	0
1948	-	-	0	0	0	0	-	0
1949	-	-	0	0	0	0	-	0
1950	-	Oct 16-Oct 20	50	0	25	25	99.1%	25
1951	-	-	0	0	0	0	-	0
1952	-	-	0	0	0	0	-	0
1953	-	-	0	0	0	0	-	0
1954	Early Oct	Oct 13-Oct 22	61	0	22	39	98.0%	38
1955	-	-	0	0	0	0	-	0
1956	-	-	0	0	0	0	-	0
1957	-	-	0	0	0	0	-	0
1958	Oct 16	Oct 28-Nov 03	499	1	205	293	97.7%	286
1959	-	-	0	0	0	0	-	0
1960	-	-	0	0	0	0	-	0
1961	-	-	0	0	0	0	-	0
1962	-	Oct 22-Oct 27	457	3	191	263	100.0%	263
1963	-	-	0	0	0	0	-	0
1964	-	-	0	0	0	0	-	0
1965	-	-	0	0	0	0	-	0
1966	-	-	1,872	0	936	936	100.0%	936
1967	Oct 10	Oct 18-Oct 22	58	0	29	29	98.7%	29
1968	-	-	0	0	0	0	-	0
1969	-	-	0	0	0	0	-	0
1970	Oct 05	Oct 19-Oct 22	4,559	0	2,244	2,315	99.8%	2,310
1971	Oct 14	Oct 24-Oct 26	284	0	142	142	100.0%	142
1972	-	-	0	0	0	0	-	0
1973	-	-	0	0	0	0	-	0
1974	-	Oct 18-Oct 22	3,064	16	1,287	1,761	99.7%	1,756
1975	-	Oct 26-Oct 28	227	1	108	118	100.0%	118
1976	-	-	0	0	0	0	-	0
1977	-	-	0	0	0	0	-	0
1978	-	Oct 19-Oct 20	10,890	0	4,969	5,921	100.0%	5,921
1979	-	Oct 17-Oct 20	578	0	255	323	100.0%	323
1980	-	-	0	0	0	0	-	0
1981	-	-	0	0	0	0	-	0
1982	-	-	40,302	2	19,625	20,675	99.1%	20,489
1983	-	Late Oct	27	0	11	16	100.0%	16
1984	-	-	0	0	0	0	-	0
1985	-	Early Nov	180	0	77	103	100.0%	103

Continued

Appendix 1c. Annual date of sockeye salmon arrival and peak spawning, jack and adult escapement by sex, percent spawning success and the number of females which spawned effectively in the middle Shuswap River, 1938-1994, continued.

Year	Arrival	Period of peak spawning	Escapement			Percent spawning success	Effective females	
			Total	Jacks	Males			Females
1986	Early Oct	Oct 16-Oct 20	80,529 <sup>a</sup>	0	51,415	29,114	99.0%	28,822
1987	n/a	Oct 22-Oct 27	787	0	430	357	100.0%	357
1988	-	-	0	0	0	0	-	0
1989	-	-	0	0	0	0	-	0
1990	Late Sep	Oct 13-Oct 19	96,451	10	44,821	51,620	99.9%	51,574
1991	Early Oct	Oct 20-Oct 28	581	0	293	288	100.0%	288
1992	-	Early Oct	180	0	90	90	100.0%	90
1993	-	Oct 18-Oct 22	47	47	0	0	-	0
1994	-	Oct 17-Oct 22	30,603	3	15,817	14,783	99.7%	14,739

<sup>a</sup>. Mark-recapture study.

Appendix 1d. Annual date of sockeye salmon arrival and peak spawning, jack and adult escapement by sex, percent spawning success and the number of females which spawned effectively in the Noisey Creek, 1938-1994.

Year	Arrival	Period of peak spawning	Escapement				Percent spawning success	Effective females
			Total	Jacks	Males	Females		
1978	-	-	0	0	0	0	-	0
1979	-	-	0	0	0	0	-	0
1980	-	-	0	0	0	0	-	0
1981	-	-	0	0	0	0	-	0
1982	-	-	0	0	0	0	-	0
1983	-	-	0	0	0	0	-	0
1984	-	-	0	0	0	0	-	0
1985	-	-	0	0	0	0	-	0
1986	Early Oct	Oct 21-Oct 25	122	0	69	53	99.7%	53
1987	-	-	0	0	0	0	-	0
1988	-	-	0	0	0	0	-	0
1989	-	-	0	0	0	0	-	0
1990	-	-	0	0	0	0	-	0
1991	-	-	0	0	0	0	-	0
1992	-	-	0	0	0	0	-	0
1993	-	-	0	0	0	0	-	0
1994	-	-	0	0	0	0	-	0

Appendix 1e. Annual date of sockeye salmon arrival and peak spawning, jack and adult escapement by sex, percent spawning success and the number of females which spawned effectively in the Tsuius Creek, 1938-1994.

Year	Arrival	Period of peak spawning	Escapement				Percent spawning success	Effective females
			Total	Jacks	Males	Females		
1978	-	-	0	0	0	0	-	0
1979	-	-	0	0	0	0	-	0
1980	-	-	0	0	0	0	-	0
1981	-	-	0	0	0	0	-	6
1982	-	-	0	0	0	0	-	0
1983	-	-	0	0	0	0	-	0
1984	-	-	0	0	0	0	-	0
1985	-	-	0	0	0	0	-	0
1986	Mid Oct	Late Oct	13	0	7	6	99.7%	6
1987	-	-	0	0	0	0	-	0
1988	-	-	0	0	0	0	-	0
1989	-	-	0	0	0	0	-	0
1990	-	-	0	0	0	0	-	0
1991	-	-	0	0	0	0	-	0
1992	-	-	0	0	0	0	-	0
1993	-	-	0	0	0	0	-	0
1994	-	-	169	0	83	86	99.2%	85

Appendix 1f. Annual date of sockeye salmon arrival and peak spawning, jack and adult escapement by sex, percent spawning success and the number of females which spawned effectively in the Wap Creek, 1938-1994.

Year	Arrival	Period of peak spawning	Escapement			Percent spawning success	Effective females	
			Total	Jacks	Males			Females
1978	-	-	0	0	0	0	-	0
1979	-	-	0	0	0	0	-	0
1980	-	-	0	0	0	0	-	0
1981	-	-	0	0	0	0	-	0
1982	-	-	0	0	0	0	-	0
1983	-	-	0	0	0	0	-	0
1984	-	-	0	0	0	0	-	0
1985	-	-	0	0	0	0	-	0
1986	Mid Oct	Oct 21-Oct 25	1,069	0	602	467	99.7%	466
1987	-	-	0	0	0	0	-	0
1988	-	-	0	0	0	0	-	0
1989	-	-	0	0	0	0	-	0
1990	Early Oct	Oct 13-Oct 23	1,733	0	1,023	710	99.9%	709
1991	-	-	0	0	0	0	-	0
1992	-	-	0	0	0	0	-	0
1993	-	-	0	0	0	0	-	0
1994	-	-	623	0	306	317	99%	314

Appendix 2a. Daily sockeye counts, by 15-minute periods, in the lower Shuswap River at the Ashton Creek (Trinity Valley Road) Bridge, 1994.

Date	Morning Count No. 1			Morning Count No. 2			Afternoon Count No. 1			Afternoon Count No. 2		
	Start Time	No tag	Tag	Start Time	No tag	Tag	Start Time	No tag	Tag	Start Time	No tag	Tag
3-Oct	0800	22	0	0845	10	0	1600	24	0	-	-	-
4-Oct	0815	79	1	-	-	-	1615	163	11	-	-	-
5-Oct	0815	131	1	-	-	-	-	-	-	-	-	-
6-Oct	0735	173	0	-	-	-	1615	246	4	-	-	-
7-Oct	0750	222	0	-	-	-	-	-	-	-	-	-
8-Oct	0800	335	2	-	-	-	1615	287	9	-	-	-
9-Oct	0815	328	0	-	-	-	1615	324	6	-	-	-
10-Oct	-	-	-	-	-	-	1615	426	0	-	-	-
11-Oct	0830	281	0	-	-	-	1530	210	12	1600	276	11
12-Oct	-	-	-	-	-	-	1615	309	3	-	-	-
13-Oct	0830	292	1	-	-	-	-	-	-	-	-	-
14-Oct	0915	507	0	-	-	-	1545	251	8	-	-	-
15-Oct	0800	326	1	-	-	-	-	-	-	-	-	-
16-Oct	0800	226	0	-	-	-	-	-	-	-	-	-
17-Oct	-	-	-	-	-	-	-	-	-	-	-	-
18-Oct	0800	82	0	-	-	-	-	-	-	-	-	-
19-Oct	-	-	-	-	-	-	-	-	-	-	-	-
20-Oct	0800	67	0	-	-	-	-	-	-	-	-	-

Appendix 2b. Daily sockeye counts, by 15-minute periods, in the lower Shuswap River at the Enderby Bridge, 1994.

Date	Morning Count No. 1			Morning Count No. 2			Afternoon Count No. 1			Afternoon Count No. 2		
	Start Time	No tag	Tag	Start Time	No tag	Tag	Start Time	No tag	Tag	Start Time	No tag	Tag
7-Oct	-	-	-	-	-	-	1230	507	0	-	-	-
8-Oct	-	-	-	-	-	-	-	-	-	-	-	-
9-Oct	1045	306	0	-	-	-	-	-	-	-	-	-
10-Oct	-	-	-	-	-	-	1230	138	0	1245	1,054	0
11-Oct	-	-	-	-	-	-	-	-	-	-	-	-
12-Oct	-	-	-	-	-	-	-	-	-	-	-	-
13-Oct	-	-	-	-	-	-	1500	319	0	-	-	-

Appendix 3. Live sockeye counts, by reach, from helicopter flights of the lower and middle Shuswap rivers, 1994. <sup>a</sup>

Date	Location	Section	Reach	Observer No. 1		Observer No. 2 Live	Mean live count
				Live	Dead		
18-Oct	Lower Shuswap River	Mara Lake to Enderby	9	2,650	n/r	-	2,650
		Enderby to the Ashton Cr. Bridge	8,9	16,400	n/r	9,200	12,800
		Ashton Cr. Bridge to Cook Creek	5,6,7	76,300	n/r	52,700	64,500
		Cook Creek to Skookumchuck Rapids	3,4	25,100	n/r	28,000	26,550
		Skookumchuck Rapids to Mabel Lake	1,2	2,610	n/r	4,310	3,460
		Total	-	123,060	n/r	94,210	109,960
18-Oct	Middle Shuswap River	Mabel Lake to the Bailey Bridge	2,3	13,700	390	5,280	9,490
		Bailey Bridge to Wilsey Dam	1	8,320	280	6,700	7,510
		Total	-	22,020	670	11,980	17,000
	Wap Creek	Total	-	351	1	341	346
23-Oct	Lower Shuswap River	Enderby to the Ashton Cr. Bridge	8,9	12,450	n/r	-	12,450
		Ashton Cr. Br. to Skookumchuck Rapids	5,6,7	51,600	n/r	-	51,600
		Skookumchuck Rapids to Mabel Lake	1,2	1,770	n/r	-	1,770
		Total	-	65,820	n/r	0	65,820
23-Oct	Middle Shuswap River	Mabel Lake to the Bailey Bridge	2,3	11,210	n/r	7,590	9,400
		Bailey Bridge to Wilsey Dam	1	8,070	n/r	5,150	6,610
		Total	-	19,280	n/r	12,740	16,010
	Tsuius Creek	Total	-	101	n/r	87	94

<sup>a</sup> October 18 was the estimated date of peak spawning; October 23 was the estimated date of peak die-off.

Appendix 4. Daily application of disk tags, by location and sex (field estimate and correction for sex identification error), to sockeye salmon in the lower Shuswap River, 1994. <sup>a</sup>

Date	Reach	Number of sets	Original field estimate of sex composition			Corrected for sex identification error			Recaptures		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Total
26-Sep	8	1	1	0	0	1	0	0	0	0	0
27-Sep	8	3	4	2	0	4	2	0	0	0	0
28-Sep	8	7	37	16	0	37	16	0	0	0	0
29-Sep	8	3	7	2	0	7	2	0	0	0	0
30-Sep	8	5	32	30	0	32	30	0	0	0	2 <sup>c</sup>
1-Oct	8	5	65	32	0	64	33	0	0	0	5 <sup>c</sup>
2-Oct	8	3	91	48	0	90	49	0	0	0	18 <sup>c</sup>
3-Oct	8	4	54	16	0	53	17	0	0	0	1 <sup>c</sup>
4-Oct	8	3	138	79	0	137	80	0	0	0	0
5-Oct	8	3	114	66	0	113	67	0	1	0	1
6-Oct	8	2	97	46	0	96	47	0	0	0	0
7-Oct	8	3	159	103	0	158	104	0	1	0	1
8-Oct	8	3	104	82	0	103	83	0	0	0	0
9-Oct	8	3	153	120	0	152	121	0	0	1	1
10-Oct	8	3	203	197	0	201	199	0	0	0	0
11-Oct	8	2	118	147	0	117	148	0	0	0	0
12-Oct	8	1	163	102	0	162	103	0	3	0	3
13-Oct	8	2	140	167	0	139	168	0	0	0	0
14-Oct	8	3	166	196	0	164	198	0	0	0	0
15-Oct	8	1	71	63	0	70	64	0	0	0	0
16-Oct	8	2	70 <sup>b</sup>	86	0	69	87	0	0	0	0
17-Oct	8	1	57	66	0	56	67	0	1	1	2
18-Oct	8	1	51	70	0	51	70	0	1	0	1
19-Oct	8	1	22	43	0	22	43	0	0	0	0
20-Oct	8	1	11	37	0	11	37	0	1	0	1
21-Oct	8	1	19	56	0	19	56	0	1	0	1
22-Oct	8	0	0	0	0	0	0	0	0	0	0
23-Oct	8	1	7	26	0	7	26	0	1	0	1
24-Oct	8	0	0	0	0	0	0	0	0	0	0
25-Oct	8	1	6	20	0	6	20	0	1	1	2
26-Oct	8	1	6	1	0	6	1	0	0	0	0
Total	-	70	2,166	1,919	0	2,147	1,938	0	11	3	40

<sup>a</sup> See Methods for sex identification error correction procedure.

<sup>b</sup> One disk tag excluded because elapsed time between release and recovery was less than five days.

<sup>c</sup> Sex and tag number were not recorded.

Appendix 5a. Incidence of net, lamprey and hook marks and of *Flexibacter columnaris* lesions among adult male sockeye examined at tag application in the lower Shuswap River, 1994. <sup>a</sup>

Date	Number of adult males examined	Net marks		Lamprey marks		Hook marks		<i>F. columnaris</i> <sup>b</sup>	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent
26-Sep	1	0	0.0%	1	100.0%	0	0.0%	0	0.0%
27-Sep	4	0	0.0%	0	0.0%	0	0.0%	0	0.0%
28-Sep	37	5	13.5%	4	10.8%	0	0.0%	0	0.0%
29-Sep	7	1	14.3%	0	0.0%	1	14.3%	0	0.0%
30-Sep	32	5	15.6%	3	9.4%	1	3.1%	0	0.0%
1-Oct	65	2	3.1%	3	4.6%	0	0.0%	0	0.0%
2-Oct	91	11	12.1%	13	14.3%	4	4.4%	0	0.0%
3-Oct	54	10	18.5%	8	14.8%	0	0.0%	0	0.0%
4-Oct	138	19	13.8%	16	11.6%	2	1.4%	0	0.0%
5-Oct	114	15	13.2%	19	16.7%	2	1.8%	0	0.0%
6-Oct	97	10	10.3%	4	4.1%	0	0.0%	0	0.0%
7-Oct	159	27	17.0%	7	4.4%	0	0.0%	0	0.0%
8-Oct	104	22	21.2%	6	5.8%	2	1.9%	0	0.0%
9-Oct	153	28	18.3%	8	5.2%	4	2.6%	0	0.0%
10-Oct	203	30	14.8%	11	5.4%	0	0.0%	0	0.0%
11-Oct	118	20	16.9%	4	3.4%	2	1.7%	0	0.0%
12-Oct	163	28	17.2%	0	0.0%	1	0.6%	0	0.0%
13-Oct	140	18	12.9%	3	2.1%	4	2.9%	0	0.0%
14-Oct	166	31	18.7%	5	3.0%	1	0.6%	0	0.0%
15-Oct	71	19	26.8%	6	8.5%	2	2.8%	0	0.0%
16-Oct	70	6	8.6%	1	1.4%	0	0.0%	0	0.0%
17-Oct	57	5	8.8%	3	5.3%	1	1.8%	0	0.0%
18-Oct	51	9	17.6%	0	0.0%	2	3.9%	0	0.0%
19-Oct	22	0	0.0%	0	0.0%	0	0.0%	0	0.0%
20-Oct	11	3	27.3%	0	0.0%	0	0.0%	0	0.0%
21-Oct	19	1	5.3%	0	0.0%	0	0.0%	0	0.0%
22-Oct	0	0	-	0	-	0	-	0	-
23-Oct	7	1	14.3%	0	0.0%	0	0.0%	0	0.0%
24-Oct	0	0	-	0	-	0	-	0	-
25-Oct	6	1	16.7%	0	0.0%	0	0.0%	0	0.0%
26-Oct	6	1	16.7%	0	0.0%	0	0.0%	0	0.0%
Total	2,166	328	15.1%	125	5.8%	29	1.3%	0	0.0%

<sup>a</sup>. Not corrected for sex identification error.

<sup>b</sup>. *F. columnaris* incidence was not recorded in 1994.

Appendix 5b. Incidence of net, lamprey and hook marks and of *Flexibacter columnaris* lesions among adult female sockeye examined at tag application in the lower Shuswap River, 1994. <sup>a</sup>

Date	Number of females examined	Net marks		Lamprey marks		Hook marks		<i>F. columnaris</i> <sup>b</sup>	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent
26-Sep	0	0	-	0	-	0	-	0	-
27-Sep	2	0	0.0%	0	0.0%	0	0.0%	0	0.0%
28-Sep	16	2	12.5%	1	6.3%	0	0.0%	0	0.0%
29-Sep	2	0	0.0%	1	50.0%	0	0.0%	0	0.0%
30-Sep	30	6	20.0%	0	0.0%	0	0.0%	0	0.0%
1-Oct	32	6	18.8%	1	3.1%	0	0.0%	0	0.0%
2-Oct	48	14	29.2%	0	0.0%	0	0.0%	0	0.0%
3-Oct	16	3	18.8%	0	0.0%	0	0.0%	0	0.0%
4-Oct	79	23	29.1%	5	6.3%	0	0.0%	0	0.0%
5-Oct	66	21	31.8%	8	12.1%	1	1.5%	0	0.0%
6-Oct	46	12	26.1%	1	2.2%	0	0.0%	0	0.0%
7-Oct	103	23	22.3%	5	4.9%	0	0.0%	0	0.0%
8-Oct	82	24	29.3%	1	1.2%	0	0.0%	0	0.0%
9-Oct	120	32	26.7%	0	0.0%	1	0.8%	0	0.0%
10-Oct	197	46	23.4%	2	1.0%	2	1.0%	0	0.0%
11-Oct	147	29	19.7%	0	0.0%	0	0.0%	0	0.0%
12-Oct	102	26	25.5%	3	2.9%	0	0.0%	0	0.0%
13-Oct	167	35	21.0%	5	3.0%	2	1.2%	0	0.0%
14-Oct	196	52	26.5%	4	2.0%	1	0.5%	0	0.0%
15-Oct	63	21	33.3%	3	4.8%	1	1.6%	0	0.0%
16-Oct	86	19	22.1%	2	2.3%	0	0.0%	0	0.0%
17-Oct	66	13	19.7%	0	0.0%	0	0.0%	0	0.0%
18-Oct	70	21	30.0%	2	2.9%	1	1.4%	0	0.0%
19-Oct	43	6	14.0%	0	0.0%	2	4.7%	0	0.0%
20-Oct	37	4	10.8%	1	2.7%	0	0.0%	0	0.0%
21-Oct	56	8	14.3%	4	7.1%	1	1.8%	0	0.0%
22-Oct	0	0	-	0	-	0	-	0	-
23-Oct	26	6	23.1%	0	0.0%	0	0.0%	0	0.0%
24-Oct	0	0	-	0	-	0	-	0	-
25-Oct	20	1	5.0%	0	0.0%	0	0.0%	0	0.0%
26-Oct	1	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total	1,919	453	23.6%	49	2.6%	12	0.6%	0	0.0%

<sup>a</sup> Not corrected for sex identification error.

<sup>b</sup> *F. columnaris* incidence was not recorded in 1994.

Appendix 6a. Daily sockeye carcass recoveries, by location, mark status and sex, in the lower Shuswap River, 1994.

Date	Reach	Number of surveys	Disk tag present			Untagged			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
14-Oct	3	-	1	1	0	29	25	0	30	26	0
	4	-	3	3	0	169	101	0	172	104	0
	5	-	6	5	0	149	79	0	155	84	0
15-Oct	3	-	2	2	0	61	51	0	63	53	0
	4	-	4	4	0	141	81	0	145	85	0
	5	-	10	3	0	346	144	0	356	147	0
	6	-	21	5	0	837	564	0	858	569	0
17-Oct	8	-	4	0	0	107	56	0	111	56	0
	1	-	2	3	0	38	62	0	40	65	0
	3	-	5	2	0	288	223	0	293	225	0
	4	-	3	3	0	477	285	0	480	288	0
18-Oct	5	-	17	6	0	754	374	0	771	380	0
	6	-	20	9	0	1,368	748	0	1,388	757	0
	7	-	17	6	0	493	225	0	510	231	0
	8	-	6	4	0	152	201	0	158	205	0
19-Oct	9	-	6	1 <sup>a</sup>	0	96	75	0	102	76	0
	3	-	7	4	0	242	311	0	249	315	0
	4	-	9	2	0	582	399	0	591	401	0
20-Oct	5	-	23	10	0	1,384	686	0	1,407	696	0
	1	-	0	0	0	60	76	0	60	76	0
	5	-	3	7	0	421	273	0	424	280	0
	6	-	25	17	0	2,353	1,624	0	2,378	1,641	0
21-Oct	7	-	10	4	0	691	341	0	701	345	0
	3	-	2	2	0	311	527	0	313	529	0
	4	-	4	12	0	766	745	0	770	757	0
	5	-	5	2	0	416	227	0	421	229	0
	8	-	7	3	0	225	280	0	232	283	0
23-Oct	9	-	2	9	0	179	214	0	181	223	0
	5	-	39	28	0	3,921	3,485	0	3,960	3,513	0
24-Oct	5	-	5	3	0	1,014	832	0	1,019	835	0
	6	-	49	51	0	5,928	4,917	0	5,977	4,968	0
25-Oct	7	-	3	6	0	505	326	0	508	332	0
	3	-	10	13	0	858	2,414	0	868	2,427	0
	4	-	7	10	0	1,606	2,211	0	1,613	2,221	0
	5	-	1	0	0	294	292	0	295	292	0
	8	-	8	11	0	801	1,178	0	809	1,189	0
26-Oct	5	-	25	21	0	2,880	3,098	0	2,905	3,119	0
	6	-	47	37	0	4,656	4,219	0	4,703	4,256	0
27-Oct	7	-	7	9	0	918	751	0	925	760	0
	9	-	6	11	0	721	1,273	0	727	1,284	0
	1	-	0	0	0	156	449	0	156	449	0
	2	-	0	0	0	90	176	0	90	176	0
28-Oct	3	-	4	1	0	251	586	0	255	587	0
	4	-	4	5	0	775	1,045	0	779	1,050	0
	5	-	4	2	0	300	290	0	304	292	0
	7	-	37	21	0	3,135	1,684	0	3,172	1,705	0
	30-Oct	5	-	28	16	0	2,884	2,359	0	2,912	2,375
31-Oct	7	-	2	0	0	28	14	0	30	14	0
	8	-	9	8	0	1,132	1,160	0	1,141	1,168	0
	6	-	18	7	0	2,574	1,688	0	2,592	1,695	0
1-Nov	7	-	9	7	0	1,784	1,169	0	1,793	1,176	0
	7	-	33	13	0	3,124	1,255	0	3,157	1,268	0
	8	-	12	4	0	731	645	0	743	649	0
	9	-	6	6	0	569	867	0	575	873	0

<sup>a</sup> One disk tag recovery excluded because elapsed time between release and recovery was less than five days.

Continued

Appendix 6a. Daily sockeye carcass recoveries, by location, mark status and sex, in the lower Shuswap River, 1994, continued.

Date	Reach	Number of surveys	Disk tag present			Untagged			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
3-Nov	3	-	0	1	0	268	576	0	268	577	0
	4	-	3	3	0	627	898	0	630	901	0
	5	-	5	0	0	219	124	0	224	124	0
4-Nov	5	-	11	6	0	1,648	990	0	1,659	996	0
5-Nov	5	-	2	4	0	316	260	0	318	264	0
	6	-	21	13	0	2,497	1,986	0	2,518	1,999	0
	7	-	7	7	0	1,325	782	0	1,332	789	0
6-Nov	6	-	14	6	0	959	731	0	973	737	0
	7	-	6	5	0	1,228	534	0	1,234	539	0
7-Nov	1	-	0	1	0	35	128	0	35	129	0
	8	-	2	2	0	678	428	0	680	430	0
	9	-	0	1	0	124	229	0	124	230	0
9-Nov	3	-	0	1	0	38	142	0	38	143	0
	4	-	0	1	0	462	427	0	462	428	0
	5	-	2	0	0	317	148	0	319	148	0
10-Nov	5	-	13	3	0	1,584	962	0	1,597	965	0
11-Nov	5	-	2	1	0	439	255	0	441	256	0
	6	-	1	1	0	429	359	0	430	360	0
	7	-	6	1*	0	652	369	0	658	370	0
12-Nov	7	-	6	3	0	501	200	0	507	203	0
	8	-	1	4	0	611	406	0	612	410	0
	9	-	0	0	0	67	61	0	67	61	0
Total	1	4	2	4	0	289	715	0	291	719	0
	2	1	0	0	0	90	176	0	90	176	0
	3	9	31	27	0	2,346	4,855	0	2,377	4,882	0
	4	9	37	43	0	5,605	6,192	0	5,642	6,235	0
	5	18	201	117	0	19,286	14,878	0	19,487	14,995	0
	6	9	216	146	0	21,601	16,836	0	21,817	16,982	0
	7	12	143	82	0	14,384	7,650	0	14,527	7,732	0
	8	8	49	36	0	4,437	4,354	0	4,486	4,390	0
	9	6	20	28	0	1,756	2,719	0	1,776	2,747	0
Total	-	-	699	483	0	69,794	58,375	0	70,493	58,858	0

\* One disk tag recovery was excluded because the tag was applied on the Adams River; treated as an untagged recovery.

Appendix 6b. Daily sockeye carcass recoveries, by location, mark status and sex, in the middle Shuswap River, 1994.

Date	Reach	Number of surveys	Disk tag present			Untagged			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
22-Oct	1	-	5	4	0	320	235	0	325	239	0
	2	-	1	1	0	197	66	0	198	67	0
	3	-	5	1	0	236	86	0	241	87	0
26-Oct	1	-	1	1	0	192	258	0	193	259	0
	2	-	3	3	0	327	249	0	330	252	0
	3	-	1	1	0	192	110	1	193	111	1
29-Oct	1	-	0	3	0	159	334	0	159	337	0
	2	-	1	1	0	128	203	0	129	204	0
	3	-	2	1	0	433	357	0	435	358	0
2-Nov	1	-	0	1	0	82	188	0	82	189	0
	2	-	0	1	0	114	101	0	114	102	0
	3	-	2	1	0	105	130	0	107	131	0
8-Nov	1	-	0	0	0	116	128	0	116	128	0
	3	-	0	0	0	39	23	0	39	23	0
	Total	-	6	9	0	869	1,143	0	875	1,152	0
Total	1	5	6	9	0	869	1,143	0	875	1,152	0
	2	4	5	6	0	766	619	0	771	625	0
	3	5	10	4	0	1,005	706	1	1,015	710	1
Total	-	-	21	19	0	2,640	2,468	1	2,661	2,487	1

Appendix 6c. Daily sockeye carcass recoveries, by location, mark status and sex, in the Mabel Lake tributaries, 1994.

Creek	Date	Live Count	Disk tag present			Untagged			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
Noisey Creek	16-Oct	0	0	0	0	0	0	0	0	0	0
	24-Oct	0	0	0	0	0	0	0	0	0	0
Tsuius Creek	23-Oct	94	0	0	0	0	0	0	0	0	0
	28-Oct	59	0	0	0	3	1	0	3	1	0
	4-Nov	12	0	0	0	2	8	0	2	8	0
	Total	-	0	0	0	5	9	0	5	9	0
Wap Creek	16-Oct	300	0	0	0	0	0	0	0	0	0
	18-Oct	346	0	0	0	0	0	0	0	0	0
	24-Oct	195	0	0	0	5	1	0	5	1	0
	30-Oct	67	0	0	0	7	5	0	7	5	0
	13-Nov	-	0	0	0	5	15	0	5	15	0
	Total	-	0	0	0	17	21	0	17	21	0

Appendix 7a. Daily number of sockeye carcasses examined and disk tags recovered, by location and sex, during the re-survey of the lower Shuswap River, 1994.

Date	Reach	Number of surveys	Disk tag present			Total examined			Disk tag incidence		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
21-Oct	3	-	0	0	0	152	167	0	0.000	0.000	-
	4	-	0	0	0	226	166	0	0.000	0.000	-
23-Oct	4	-	2	1	0	2,059	956	0	0.001	0.001	-
	5	-	0	1	0	1,250	1,085	0	0.000	0.001	-
25-Oct	5	-	0	0	0	303	190	0	0.000	0.000	-
	6	-	9	2	0	6,253	4,171	0	0.001	0.000	-
31-Oct	6	-	1	3	0	2,238	1,570	0	0.000	0.002	-
	7	-	1	0	0	1,678	1,004	0	0.001	0.000	-
3-Nov	3	-	0	0	0	86	158	0	0.000	0.000	-
	4	-	2	7	0	3,761	3,730	0	0.001	0.002	-
	5	-	0	1	0	1,092	728	0	0.000	0.001	-
11-Nov	8	-	2	4	0	1,664	1,763	0	0.001	0.002	-
	9	-	1	3	0	766	1,612	0	0.001	0.002	-
12-Nov	7	-	4	4	0	1,664	621	0	0.002	0.006	-
14-Nov	5	-	3	1	0	1,658	1,454	0	0.002	0.001	-
Total	3	2	0	0	0	238	325	0	0.000	0.000	-
	4	3	4	8	0	6,046	4,852	0	0.001	0.002	-
	5	4	3	3	0	4,303	3,457	0	0.001	0.001	-
	6	2	10	5	0	8,491	5,741	0	0.001	0.001	-
	7	2	5	4	0	3,342	1,625	0	0.001	0.002	-
	8	1	2	4	0	1,664	1,763	0	0.001	0.002	-
Total	9	1	1	3	0	766	1,612	0	0.001	0.002	-
	-	-	25	27	0	24,850	19,375	0	0.001	0.001	-

Appendix 7b. Daily number of sockeye carcasses examined and disk tags recovered, by location and sex, during the re-survey of the middle Shuswap River, 1994.

Date	Reach	Number of surveys	Disk tag present			Total examined			Disk tag incidence		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
8-Nov	1	1	0	0	0	335	476	0	0.000	0.000	-
	2	1	1	0	0	462	414	0	0.002	0.000	-
	3	1	2	0	0	431	251	0	0.005	0.000	-
Total	-	-	3	0	0	1,228	1,141	0	0.002	0.000	-

Appendix 8. Fecundity sampling results and analytic details for Shuswap River system sockeye salmon captured in the lower Shuswap River, 1994.

Sample number	Age	Standard length (cm)	Skein weight (g)	Skein sub-sample		Estimated fecundity	Actual fecundity	Misc. eggs	Adjusted fecundity
				Weight (g)	Egg count				
1	4 <sub>2</sub>	54.8	413.3	225.1	2,479	4,552	4,624	1	4,625
2	-	52.6	398.1	146.3	1,472	4,005		1	4,006
3	4 <sub>2</sub>	54.6	532.2	152.7	1,248	4,350		8	4,358
4	4 <sub>2</sub>	50.0	397.0	145.1	1,315	3,598		4	3,602
5	4 <sub>2</sub>	54.7	421.7	148.2	1,482	4,217		2	4,219
6	4 <sub>2</sub>	50.4	416.9	198.5	1,874	3,936	3,860	14	3,874
7	4 <sub>2</sub>	52.7	405.7	146.1	1,340	3,721		5	3,726
8	4 <sub>2</sub>	51.9	386.5	152.1	1,295	3,291		0	3,291
9	4 <sub>2</sub>	54.1	404.0	151.1	1,344	3,593		2	3,595
11	4 <sub>2</sub>	52.6	399.2	147.2	1,397	3,789		0	3,789
12	4 <sub>2</sub>	53.1	464.4	250.8	2,341	4,335	4,408	0	4,408
13	4 <sub>2</sub>	52.1	288.9	143.0	1,402	2,832		1	2,833
14	4 <sub>2</sub>	54.0	467.1	160.1	1,553	4,531		2	4,533
15	4 <sub>2</sub>	54.0	498.9	160.8	1,505	4,669		1	4,670
16	4 <sub>2</sub>	53.0	448.8	148.9	1,298	3,912		3	3,915
17	4 <sub>2</sub>	51.6	395.6	217.0	2,004	3,653	3,626	10	3,636
18	4 <sub>2</sub>	49.4	311.2	145.6	1,558	3,330		12	3,342
19	4 <sub>2</sub>	55.6	505.3	165.2	1,276	3,903		17	3,920
20	4 <sub>2</sub>	51.0	326.7	147.7	1,519	3,360		11	3,371
21	-	56.6	552.4	163.0	1,242	4,209		17	4,226
22	4 <sub>2</sub>	51.2	349.2	178.1	2,072	4,063	4,062	12	4,074
23	4 <sub>2</sub>	52.9	420.2	142.4	1,455	4,293		14	4,307
24	4 <sub>2</sub>	53.8	428.3	150.6	1,034	2,941		15	2,956
25	4 <sub>2</sub>	52.5	385.9	143.1	1,413	3,810		11	3,821
26	-	54.9	472.9	152.1	1,277	3,970		16	3,986
27	4 <sub>2</sub>	53.2	459.1	249.1	1,958	3,609	3,639	8	3,647
28	4 <sub>2</sub>	55.0	329.7	146.6	1,885	4,239		6	4,245
29	4 <sub>2</sub>	54.4	411.9	156.7	1,528	4,016		0	4,016
30	4 <sub>2</sub>	51.7	372.8	147.3	1,453	3,677		0	3,677
31	4 <sub>2</sub>	53.9	407.7	150.2	1,571	4,264		0	4,264
32	4 <sub>2</sub>	53.8	433.0	231.2	2,128	3,985	3,970	1	3,971
33	4 <sub>2</sub>	51.0	375.2	139.9	1,362	3,653		1	3,654
34	4 <sub>2</sub>	56.1	372.2	147.7	1,616	4,072		1	4,073
36	4 <sub>2</sub>	52.9	333.7	144.0	1,398	3,240		2	3,242
37	4 <sub>2</sub>	52.2	373.1	143.4	1,355	3,525		3	3,528
38	4 <sub>2</sub>	52.6	294.9	158.9	2,000	3,712	3,785	2	3,787
39	4 <sub>2</sub>	50.6	314.1	141.1	1,650	3,673		3	3,676
40	4 <sub>2</sub>	50.8	292.9	144.5	1,273	2,580		0	2,580
41	4 <sub>2</sub>	56.1	465.4	154.2	1,356	4,093		0	4,093
42	4 <sub>2</sub>	54.7	423.4	147.3	1,245	3,579		0	3,579
43	4 <sub>2</sub>	52.3	439.4	209.9	1,815	3,799	3,836	1	3,837
44	4 <sub>2</sub>	55.5	479.7	141.7	1,266	4,286		5	4,291
45	4 <sub>2</sub>	52.5	390.0	153.0	1,465	3,734		3	3,737
46	-	56.6	429.2	152.2	1,443	4,069		0	4,069
47	4 <sub>2</sub>	54.0	453.2	145.0	1,267	3,960		1	3,961
48	4 <sub>2</sub>	58.6	424.4	208.8	2,974	6,045	5,981	1	5,982
49	4 <sub>2</sub>	52.7	312.2	146.0	1,509	3,227		1	3,228
50	4 <sub>2</sub>	55.0	396.0	145.8	1,382	3,754		0	3,754
10	4 <sub>2</sub>	52.4	372.4	150.6	1,380	3,412		1	3,413
35	4 <sub>2</sub>	52.0	334.9	147.5	1,434	3,256		0	3,256
Mean	-	53.3	403.6	161.7	1558.2	3,846	4,179	4	3,853

Appendix 9. Proportion at age and mean length (Standard and POH) at age, by location, sex and sample period, from the adult sample of sockeye carcasses recovered on the Shuswap River system spawning grounds, 1994. <sup>a</sup>

Location	Sex	Sampling Period	Age	Sample size	Percent	Standard length (cm)		POH length (cm)	
						Mean	Standard deviation	Mean	Standard deviation
Lower Shuswap River	Male	Total	4 <sub>2</sub>	93	100.0%	-	-	48.3	2.16
			Unaged	22	-	-	-	49.3	1.52
	Female	Total	4 <sub>2</sub>	92	100.0%	-	-	47.0	1.70
			Unaged	27	-	-	-	46.5	1.87
Middle Shuswap River	Male	Total	4 <sub>2</sub>	92	100.0%	-	-	48.0	2.05
			Unaged	20	-	-	-	47.5	2.98
	Female	Total	4 <sub>2</sub>	77	100.0%	-	-	46.6	1.85
			Unaged	38	-	-	-	46.3	1.73

<sup>a</sup> Mean lengths and standard deviations were calculated from length data rounded to the nearest centimeter.