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Estimation of the 1994 Sockeye Salmon (*Oncorhynchus nerka*) Escapement to the Horsefly River System

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ESCAPEMENT TO THE HORSEFLY RIVER SYSTEM**

by

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ABSTRACT

Cone, T.E. 1999. Estimation of the 1994 sockeye salmon (*Onchorhynchus nerka*) escapement to the Horsefly River system. Can. Manuscr. Rep. Fish. Aquat. Sci. 2492: 53 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 Horsefly River system supported a major portion of the Fraser River sockeye run prior to the Hell's Gate slide in 1913. In the years between the slide and construction of the Hell's Gate fishway, the run was nearly exterminated. The run has been rebuilding since 1945, establishing a large dominant (greater than 3,000,000 in 1993) and smaller sub-dominant runs (1994). The Horsefly River system supports stocks which spawn in the Horsefly River, Horsefly River Spawning Channel, Little Horsefly River, Moffat Creek and upper and lower McKinley Creek. The 1994 study estimated the escapements of all six component populations using a combination of mark-recapture, visual and fence methods. The mark-recapture program generated an escapement estimate for the entire system except McKinley Creek, which was censused at a fence. For the mark-recapture, sockeye were captured with beach seine nets in the Horsefly River approximately 2 km above the mouth; 5,376 were released with disk tags. The spawning grounds were surveyed through the period of spawning and die-off; 92,951 carcasses were recovered, of which 783 had disk tags. The 1994 Horsefly River system escapement was estimated at 229,883 adult males, 263,675 adult females and 17 jacks (age 3₂ males).

This 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 tag loss and handling stress.

RÉSUMÉ

Cone, T.E. 1999. Estimation of the 1994 sockeye salmon (*Oncorhynchus nerka*) escapement to the Horsefly River system. Can. Manuscr. Rep. Fish. Aquat. Sci. 2492: 53 p.

En 1986, le ministère des Pêches et des Océans (MPO) s'est vu confier par la Commission internationale des pêcheries de saumon du Pacifique (CIPSP) la responsabilité d'estimer l'échappée des stocks de saumon rouge (*Oncorhynchus nerka*) du Fraser. Le MPO a adopté l'approche à deux paliers de la CIPSP dans laquelle les grosses échappées (25 000 et plus) étaient estimées à l'aide de barrières de dénombrement ou d'opérations de marquage-recapture, et les petites échappées (moins de 25 000) étaient estimées par des techniques visuelles.

Avant le glissement de terrain de Hell's Gate, en 1913, le réseau de la Horsefly recevait une bonne partie de la remonte de saumon rouge du Fraser. Dans les années qui se sont écoulées entre le glissement de terrain et la construction de la passe à poisson de Hell's Gate, la remonte a pratiquement disparu. Elle se rétablit progressivement depuis 1945, avec l'apparition d'une forte remonte dominante (plus de 3 000 000 en 1993) et de remontes sous-dominantes plus petites (1994). Le réseau de la Horsefly abrite des stocks qui frayent dans la rivière elle-même, dans le chenal de pont de la rivière, dans la Little Horsefly, dans le ruisseau Moffat et dans le cours supérieur et le cours inférieur du ruisseau McKinley. L'étude de 1994 estimait les échappées de ces six composantes par une combinaison de diverses méthodes (marquage-recapture, méthode visuelle et barrière de dénombrement). Le programme de marquage-recapture a fourni une estimation de l'échappée couvrant l'ensemble du système, à l'exception du ruisseau McKinley, où était installée une barrière de dénombrement. Dans l'opération de marquage-recapture, les saumons rouges étaient capturés à la senne de plage dans la Horsefly à environ 2 km de l'embouchure ; 5 376 ont été libérés après marquage avec un disque. Les frayères ont été surveillées pendant toute la période de fraye et de mortalité ; 92 951 carcasses ont été récupérées, dont 783 portaient des disques. L'échappée du réseau de la Horsefly pour 1994 a été estimée à 229 883 mâles adultes, 263 675 femelles adultes et 17 mâles précoces (âge 3₂).

Ce rapport fait ressortir les biais présents dans les échantillonnages au moment de l'application des marques et de la récupération des carcasses et analyse leur impact potentiel sur les estimations de la population. Il s'achève sur des recommandations visant à améliorer la conception des études, notamment par la redistribution de l'effort d'échantillonnage, des pratiques de répétition des relevés et l'évaluation de la perte de marques et du stress dû à la manipulation.

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 (25,000+), 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 Horsefly River system (Fig. 1) supports the largest sockeye spawning population in the Quesnel River watershed. The river supports large numbers of spawners in both the dominant (1993) and subdominant (1994) cycle years (Appendix 1a). Historically, the Quesnel stock comprised a major portion (30%) of the large quadrennial Fraser River run prior to 1913 (Roos 1991). In recent years, the dominant year Quesnel stock has comprised up to 48% of the total Fraser River sockeye escapement (26-48%, 1977-1993; unpublished data, DFO). Horsefly River sockeye dominate the total Quesnel system escapement, accounting for 63% to 88% of the run in the dominant cycle (1981-1993). It is believed that the Horsefly River run rivaled and exceeded the dominant Adams River run with escapements in excess of 10,000,000 in the dominant cycle years prior to 1909 (Roos 1991). By 1941, the cumulative effect of the 1913 Hell's Gate slide, a dam constructed below the outlet of Quesnel Lake, and placer mining operations in the watershed, decimated the dominant cycle Horsefly River sockeye run. Recorded escapement in 1941 was only 918 (Anon. 1966). Since 1941, aided by the Hell's Gate fishway construction and fishery conservation measures, the Quesnel system run, and the Horsefly River stock in particular, has recovered

rapidly. Escapement exceeded 100,000 in 1953 and 1,000,000 in 1985. The subdominant years have been slower to recover with the first large escapement occurring in 1982 (Appendix 1a). Rebuilding has occurred despite severe pre-spawning mortalities recorded in 1953, 1961, 1965, 1973 and 1977. Studies conducted to investigate the cause of these mortalities and identify possible solutions (Anon. 1966; Williams 1973; and Williams *et al.* 1977) indicated that a combination of *Flexibacter columnaris* infection and above average water temperatures on the spawning grounds were responsible. The studies recommended water temperature control to reduce *F. columnaris* outbreaks. This was implemented through construction of a cold-water intake and a flow control structure at the outlet of McKinley Lake in 1969 (Cooper 1973).

McKinley Creek, the outflow of McKinley Lake, is the only major spawning tributary of the Horsefly River. Recent escapement (1985-1993) has contributed 7-9% of the total Horsefly system escapement in dominant years (Appendix 1b). A small number of sockeye migrate through McKinley Creek and Lake to upper McKinley Creek, where spawning populations have been observed on the dominant and subdominant cycles since 1969 (Appendix 1c). Moffat Creek and Little Horsefly River support small spawning populations, (Appendix 1d and 1e) during the dominant and subdominant runs.

The IPSFC used mark-recapture techniques to estimate the Horsefly River escapement beginning in 1953 on the dominant cycle and since 1978 on the subdominant cycle. In 1989, a counting fence replaced visual counts for estimation of dominant and subdominant year escapements to McKinley Creek. Prior to 1989, McKinley Creek escapement estimates were obtained by stream surveys. This report provides the first published documentation of sockeye escapement estimation in the Horsefly River system. It documents study design, field methods, analytic techniques and results of the 1994 study. Included are estimates of the age and length of adult spawners, escapement by sex and age, and average fecundity for the Horsefly River population. The report concludes with a discussion of the results and recommendations for the design of future studies.

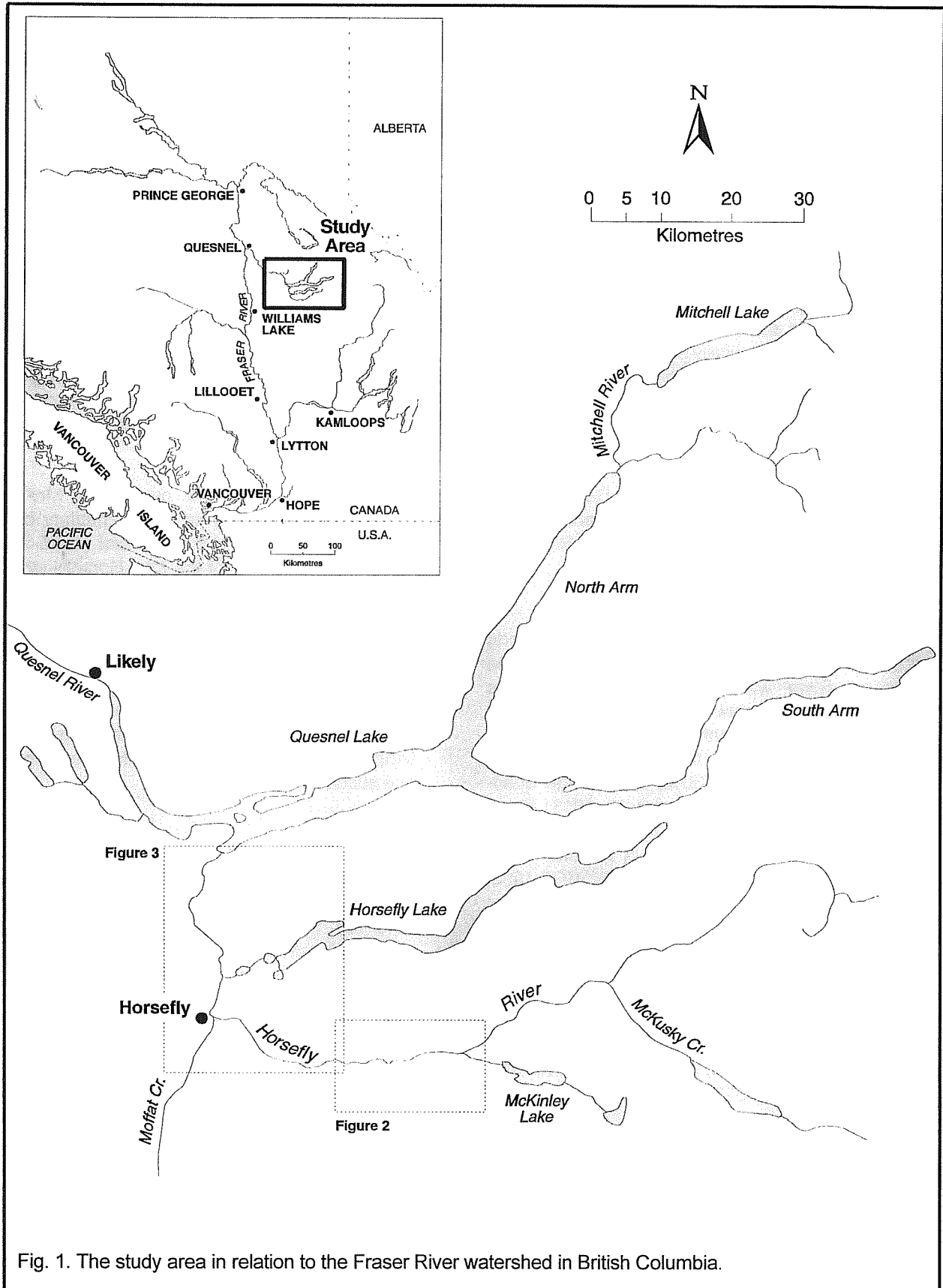


Fig. 1. The study area in relation to the Fraser River watershed in British Columbia.

STUDY AREA

Draining a watershed of 2,756 km² within the Cariboo Mountains, the Horsefly River flows west-north-west for 110 km before emptying into Quesnel Lake. Daily discharge (monitored above McKinley Creek) averages 19.4 m³s⁻¹ (1955-1990) with mean daily maxima (67 m³s⁻¹) and minima (4 m³s⁻¹) occurring in June and February, respectively (Environment Canada 1991). Three tributaries support sockeye spawners; McKinley Creek, Little Horsefly River and Moffat Creek.

The Horsefly River is accessible to sockeye upstream to an impassable falls approximately 62.6 km above the mouth. For enumeration, the river was divided into two areas: the upper Horsefly (Fig. 2a), which includes the mainstem of the river from the falls downstream to 0.5 km below a road bridge that crosses the Horsefly just below Woodjam Creek (37.7 km); and the lower Horsefly (Fig. 2b), which includes the rest of the river. The two areas are isolated by a mid-section stretch (Upper Reaches 6 and 7, and Lower Reach 1) which supports little or no spawning. Each area was further separated into seven recovery reaches to facilitate the data aggregations required for bias testing. Reaches were established based on three criteria: homogeneity of physical characteristics such as gradient, channel morphology and substrate type; the ability of the crews to access and survey a reach in one day; and the existence of easily identifiable land marks to delineate the reaches. The reaches are described below.

Upper Reach 1 was split into two sub areas, 1A and 1B. Sub area 1A (2.5 km) extends from the falls downstream to the forestry recreation camp site (2.5 km). This reach is characterized by riffles, pools and cobble gravel substrate. Spawning is light and restricted to the lower portion of the sub area. Sub area 1B extends downstream to the bridge 0.7 km upstream from the outlet of McKinley Creek (0.8 km). This reach has a similar morphology to reach 1A. Spawning is heavy in this reach.

Upper Reach 2 extends downstream to the confluence with McKinley Creek (0.7 km). River gradient decreases slightly and the morphology is similar to Reach 1. Spawning activity is typically heavy throughout this reach.

Upper reaches 3 to 5 have a lower gradient than Reaches 1 and 2, resulting in a more defined river channel. These reaches are similar in morphology, and are characterized by pools, runs and side channels with sand and gravel substrate. Spawning is heavy throughout these reaches. The downstream ends of reaches 3, 4 and 5 are an overhanging tree (1.5 km), the confluence with Black Creek (1.3 km) and the confluence with Willmot Creek (1.3 km), respectively.

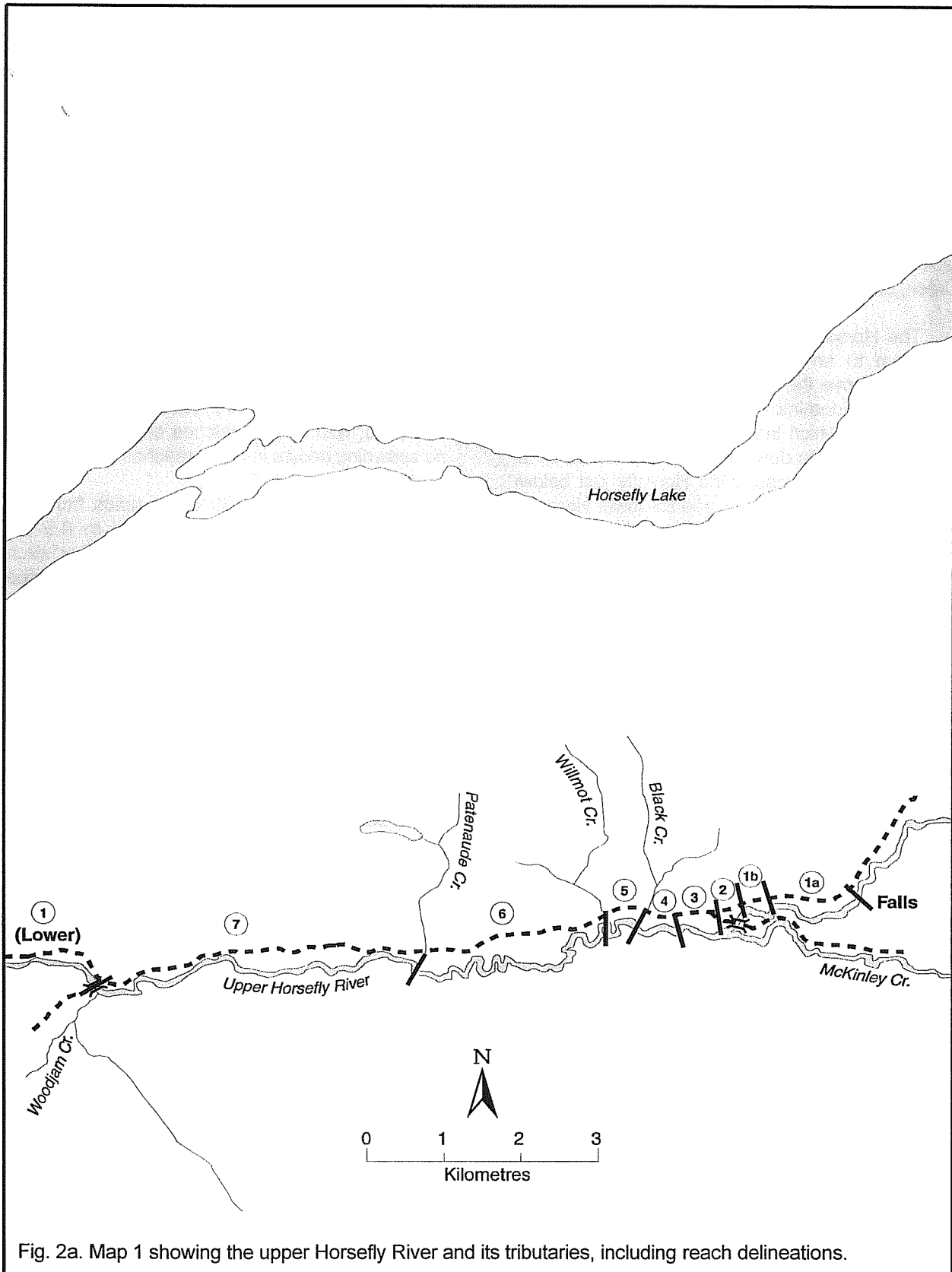
Upper reaches 6 and 7 also have a low gradient, with the river meandering through a broad flood plain. Reach 6 ends at the confluence with Patenaude Creek (8.0 km) and Reach 7 ends 0.5 km below the Woodjam Creek bridge (9.3 km). The substrate in these two reaches is primarily silt and sand, with sparse patches of gravel. Little or no spawning occurs in these reaches.

Lower Reach 1 (10.3 km) extends from the Woodjam Creek Bridge downstream to 0.5 km above the Englund farm. The top end of the reach is a wide, shallow channel with numerous large boulders and cobble substrate. Gradient increases as the river transits a canyon midway through the reach. Little or no spawning occurs in this reach.

Lower Reach 2 (4.0 km) extends to the intake of the Horsefly River Spawning Channel. The river is channelized with banks of 3 to 6 m and bordered on both sides by agricultural land. Moffat Creek flows into this reach, on the south bank just below the intake of the spawning channel. There is moderate spawning throughout this reach, which has good gravel substrate.

Lower Reach 3 (5.4 km) extends to the confluence of the Little Horsefly River. There is moderate spawning at the top end near the spawning channel where gradients are moderate and the substrate is gravel. The river gradient drops as it approaches the Little Horsefly River confluence. Flows are slow through the middle and bottom end of this reach and the substrate is dominated by silt and sand.

Lower Reach 4 (4.3 km) extends downstream to a rocky bar which is accessible by road. The river gradients are moderate through this reach and the channel is frequently braided as it flows through a series of small steps in exposed bed-



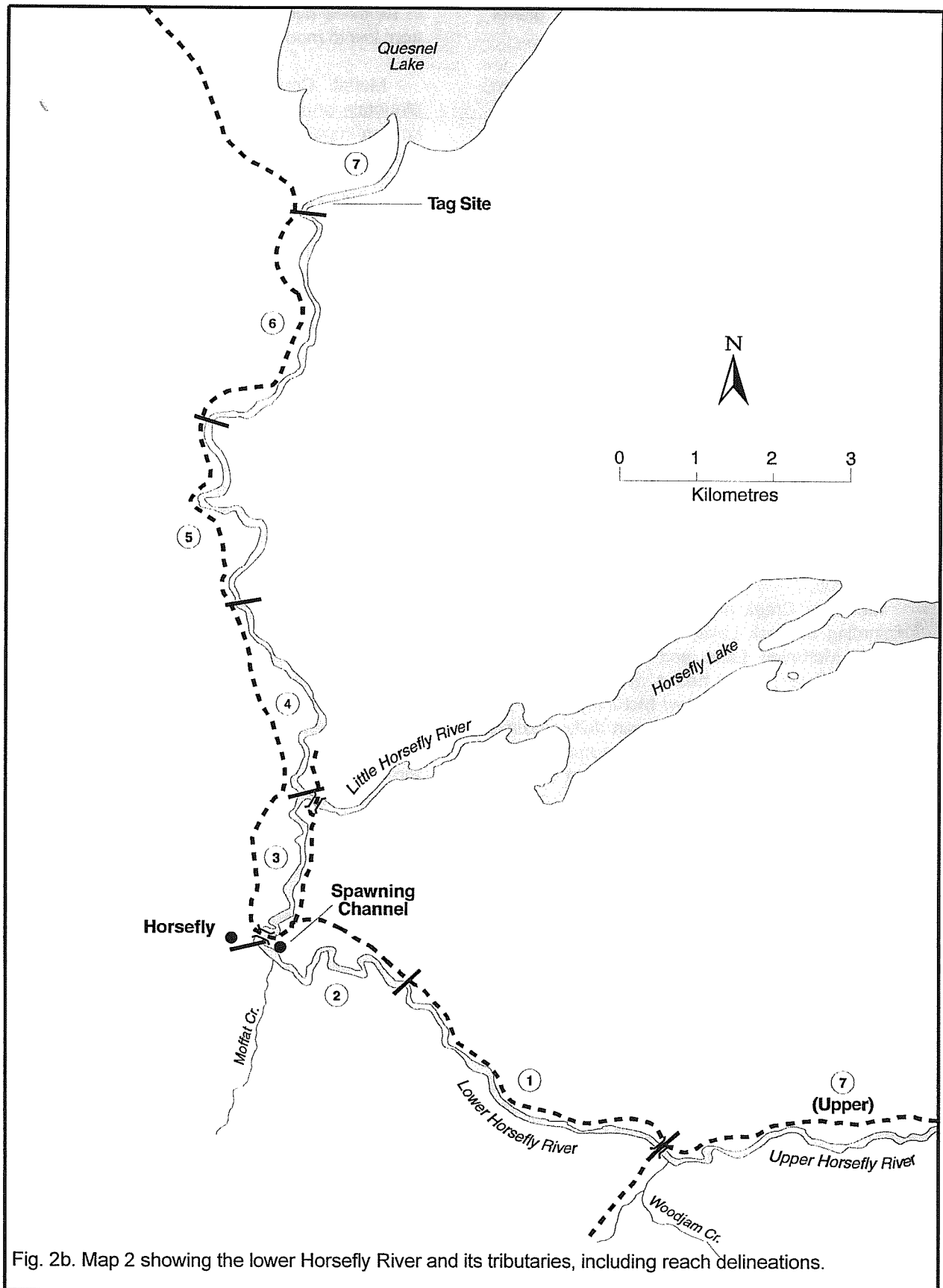


Fig. 2b. Map 2 showing the lower Horsefly River and its tributaries, including reach delineations.

rock. Spawning is light and restricted to gravel bars.

Lower Reach 5 (6.7 km) extends downstream to the Squaw Flats recreation site. This reach has river morphology similar to Lower Reach 4, with a canyon midway through the reach. The lower portion of this reach is a transition zone where the gradient decreases and gravel substrate predominates. Spawning is light and restricted to the gravel bars.

Lower Reach 6 (5.0 km) extends downstream to the tagging site. The river gradient decreases and the channel is braided with gravel substrate. Spawning is moderate through this reach.

Lower Reach 7 (2.0 km) extends to the river mouth at Quesnel Lake. The river is low gradient, channelized and meandering through this reach. Substrate changes from gravel in the upper end of the reach to sand and silt through the middle and lower portions. Some spawning occurs on a gravel bar immediately below the tagging site.

McKinley Creek drains an area of 450 km². Originating at Bosk Lake, it flows west 58.9 km through McKinley Lake and into the Horsefly River. McKinley Creek has a mean annual discharge (measured just below McKinley Lake) of 5.11 m³s⁻¹ (1964-1986) with mean daily maxima (17 m³s⁻¹) and minima (1.6 m³s⁻¹) occurring in May and February respectively (Environment Canada 1991). Upper McKinley Creek flows 44.9 km from Bosk Lake to the west end of McKinley Lake, with spawning sparsely scattered throughout the upper creek. Lower McKinley Creek flows 7.5 km from the McKinley Lake outlet to the Horsefly River. The upper portion of the creek is moderate gradient, with cobble gravel substrate. The lower portion of the creek is lower in gradient with gravel substrate. Spawning is moderate to low in the upper section and heavy in the lower section.

Little Horsefly River originates at the east end of Horsefly Lake and flows southeast 6.5 km, emptying into the Horsefly River at the top end of Lower Reach 4. Two broad shallow lakes, Little Horsefly and Gruhs, separate the river into three sections. All river sections are characterized by a channel width of 10-20 m, an average depth of 0.5-1 m and substrate consisting of sand, mud and gravel. Spawning is scattered on gravel bars

in all three river sections with densities ranging from low to moderate.

Moffat Creek originates at Big Timothy Mountain and has a total stream length of 91.6 km; an impassable falls restricts spawning to the lower 8 km. For 1 km below the falls, the creek is characterized by high gradient, deep water and steep banks with a substrate of boulders, clay and mud; little to no spawning occurs in this section of the creek. The lower 7 km is characterized by open banks, low gradient, shallow riffles and a substrate of cobble, gravel and sand. Spawning is sparse to moderate throughout.

FIELD METHODS

BRIDGE COUNTS

Sockeye were counted visually by an observer stationed on the bridge over the Quesnel River at Likely from August 15 to October 1, 1994. The counts were conducted to provide an index of relative abundance as spawners approached the spawning grounds. Counting effort varied throughout the migration period, with effort increasing as sockeye abundance increased. From August 15 to August 19, fifteen minute counts were conducted four times between 08:00 h and 12:00 h. From August 20 to September 2, counts were conducted twice between 08:00 h and 12:00 h and between 13:00 h and 16:00 h. From September 3 to October 1, fifteen minute counts were conducted three times between 08:00 h and 12:00 h and between 13:00 h and 16:00 h (Appendix 2).

TAG APPLICATION

Survey objectives were to apply tags to 1% of the sockeye as they migrated past a tagging site in the lower Horsefly River. The bridge counts proved inadequate as an independent estimate of abundance for tagging purposes because of the delay between Likely and entry into the Horsefly, as well as the inability to distinguish between Horsefly and co-migrating Mitchell River and Quesnel Lake sockeye. In an attempt to achieve proportional tag application, effort was standardized at four to six sets daily during daylight hours. Sockeye were captured by beach seine net as they migrated past the tagging site.

Sockeye were captured using a 50 m x 7.6 cm x 100 mesh deep beach seine net. The net

was set by 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 water in the net until they were individually removed for tagging and release.

During tagging, captured sockeye which had been tagged previously, which were damaged, or showed advanced stages of maturation were released untagged. For previously tagged fish, the tag number was recorded and the tag was checked; if loose, the fish was retagged with the same disk. All remaining sockeye were removed from the net and marked with Petersen disk tags. Tagging was conducted in a wooden tray (12 cm x 20 cm x 100 cm) with a flexible plastic mesh bottom and a meter stick recessed in one side; the tray was set in a stand elevated above the water surface. The tags consisted of two red 15 mm diameter laminated cellulose acetate disks, threaded through centrally punched holes onto a 77 mm long nickel pin. The pin was inserted using pliers through the musculature and pterygiophore bones approximately 1 cm below the anterior margin 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. Date of capture, disk tag number, nose-fork (NF) length (± 0.1 cm), sex (fish with a NF length less than 50 cm were recorded as jacks) the presence of external marks (gill net, troll, or lamprey) were recorded for each fish, and the condition at release (1 - swam away vigorously, 2 - swam away sluggishly, 3 - required ventilation).

SPAWNING GROUND SURVEYS

Main Survey

Spawning ground surveys were to begin the day after carcasses were first observed, but did not begin until well after the start of die-off. Recovery crews cycled through recovery areas through the entire die-off period, and required one to four days (depending on carcass abundance) to complete each cycle. The river banks were surveyed mostly on foot by two-person crews; inflatable boats were used to assist in covering the distance in some areas. Up to five crews were required at the peak of die-off.

All carcasses which could be retrieved by wading into the river to waist depth were enumerated and were pitched above the high water mark after being examined for tag presence, sex and spawning success. Tags were removed from tagged fish and the tag number, sex, spawning success (0%, 50%, 100% spawned) if female, and carcass condition (F - fresh, T - tainted, R - rotten) was recorded. For untagged carcasses, surveyors recorded the survey date, reach, number of each sex, and female spawning success.

Resurvey

Previously recovered carcasses were resampled late in the recovery period to estimate the number of tagged carcasses whose tag status had been incorrectly identified during the initial survey. The resurvey, conducted by an experienced technician, recorded the number of carcasses examined by date, reach, sex and mark status. Resurvey carcasses were pitched further up the banks of the river or placed in identifiable piles separate from pitched carcasses.

Tributary Survey

Spawning ground surveys were conducted on Little Horsefly River, Moffat Creek and Upper McKinley Creek. These surveys recorded carcasses as reported above as well as visual counts of live sockeye.

McKinley Creek Fence

A counting fence was installed at the mouth of McKinley Creek before sockeye entered the creek and operated until sockeye migration was complete. The fence consisted of 1.5 m x 2.5 m wood frame panels covered with chain link fencing. A trap was constructed above a counting port formed by 2 x 4's held in place by a rock crib. The fence was approximately 50 m above the stream mouth, at the site of an abandoned IPSFC weir. Fish were let through the fence throughout the daylight hours (usually from 09:00 h to 15:00 h), and were counted by species, and in the case of sockeye, by tag status. Carcasses that drifted onto the fence were recorded as above.

Horsefly Spawning Channel

The Horsefly Spawning Channel is a 1,600 m long artificial spawning area which enters the Horsefly River in Lower Reach 2, (operated since 1989; Appendix 1f). Staff of the Salmonid Enhancement Program, DFO load sockeye into the channel midway through the migration period; escapement is estimated from the total numbers of carcasses recovered in the channel.

BIOLOGICAL SAMPLING

Biological samples were obtained following a protocol provided by the Pacific Salmon Commission (PSC). Fifty females were killed during the peak of arrival at the tagging site for fecundity samples. Sampling included nose-hypural plate (standard - STD) length (± 0.1 cm), otoliths and scales (one from each preferred region, as defined by Clutter and Whitesel (1956)). Egg skeins and any loose eggs were removed and preserved in a 10% formaldehyde solution. An additional 50 female and 50 male sockeye were sacrificed for meristic and parasitology investigations conducted by the PSC.

Scale, otolith and length (STD and post-orbital hypural plate - POH) samples were collected from randomly selected sockeye carcasses during die-off for age determination by the PSC. This adult sample consisted of 180 suspected adult males and 180 females sampled from each of the upper and lower Horsefly spawning areas. Each 180 carcass sample was collected in three sets of 60 collected ten days before, during and 10 days after peak die-off.

ANALYTIC PROCEDURES

TESTS FOR SAMPLING SELECTIVITY

A bias profile was developed by evaluating five potential biases within the sampling data; 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. 434-39). Biases were treated in three ways. First, sex-related biases, which are common in mark-recapture studies, were addressed by stratifying the data by sex. Second, stress-related biases

were treated by removing the high stress group from the application sample. Tagged fish that had a notably reduced spawning ground life span (less than five days between tagging and recovery), required ventilation at release, or were recaptured in subsequent beach seine sets were considered to be in the high stress group. Third, the severity of temporal or spatial biases was evaluated by comparing pooled Petersen estimates with those calculated using Darroch's stratified model (Darroch 1961; Arnason *et al.* 1996). Estimates produced by the stratified model were used if the confidence limits of the two models did not overlap.

Period

Temporal bias was assessed using chi-square tests of the application and recovery data stratified by equal periods, approximately equal effort (number 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 comparing the frequency of occurrence of marked and unmarked fish among recovery strata. Recovery sample bias (nonrandom sampling in the recovery sample) was assessed by comparing the recovered: not recovered status (or recovery rates) for tagged fish among application strata.

Location

Spatial application bias was assessed using a chi-square test comparing marked: unmarked carcass frequencies among geographically discrete recovery strata. Recovery data were stratified to allow sufficient sample sizes in each stratum. Recovery bias could not be assessed because the majority of the tags were applied at a single site.

Fish Size

The Kolmogorov-Smirnov two-sample test (Sokal and Rohlf 1981) was used to assess size related bias in the recovery. The application sample was partitioned into recovered and non-recovered components and the NF length-frequency distributions of each were compared. Application bias could not be assessed because the untagged carcasses were not sampled for length.

Fish Sex

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

Stress

Potential bias resulting from handling and tagging stress was assessed in three ways. First, fish with less than five days between tag application and recovery were removed from the sample. Second, two tests were performed to determine whether specific tags should be excluded from the samples: a) the sample was partitioned into fish that required ventilation at release and those which did not, and comparing the recovery rates in each. If a chi-square test showed a significant difference in the recovered: not recovered frequencies, the high stress group was removed from the samples; and b) an identical procedure was used to evaluate fish which were recaptured in subsequent beach seine sets.

Third, a chi-square test compared spawning success between marked and unmarked spawning ground recoveries. Unlike the first series of tests, this test was not used to exclude specific data from the study. Rather, it provided an indicator of whether study design changes would be required in future studies to address a systemic stress problem.

ESTIMATION OF SPAWNER POPULATION

Data Corrections

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

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

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

where:

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

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

$$M_f = M_t - M_m$$

Tag Recognition Error: Resurvey data were used to correct the recovery totals for disk tags which were 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:

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

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 estimate for the Horsefly River system, which includes Horsefly Spawning Channel, Little Horsefly River, and Moffat Creek, were calculated from the mark-recapture data using: a) the pooled Petersen estimator (Seber

1982; p 60); and b) the Darroch (Seber 1982; p 431-445) stratified estimates. Total escapement was calculated as follows:

- 4) Estimated Horsefly River sockeye escapement (N_t):

$$N_t = N_m + N_f$$

where:

N_m = adult male escapement estimate;
 N_f = female escapement estimate;
 analogous to above.

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

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

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 escapements were calculated analogous to the above.

- 6) Variance of the pooled Petersen total population (V_t) estimate was calculated as follows (Ricker, 1975):

$$V_t = V_m + V_f$$

where the variance of sex specific escapement estimate (shown here for males) was calculated as:

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

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

$$N_t \pm 1.96 \sqrt{V_t}$$

Stratified Estimators: When spatial or temporal biases were identified, stratified estimates were calculated using the Darroch's estimator.

The pooled Petersen was preferred because precision is generally higher; however, if the confidence intervals of the pooled and the stratified estimates did not overlap, bias was judged to be severe and the stratified estimator was considered more appropriate. The variance of the stratified Darroch estimator was calculated using the procedures described by Seber (1982, page 433). Software written by Arnason *et al* (1996) was used to calculate the stratified Darroch and Schaeffer estimators.

Jack Population Estimator

Jacks were defined as fish with a NF length of less than 50 cm regardless of sex. If disk tags were applied to jacks, and there were sufficient tagged and untagged recoveries, then escapements were calculated using the pooled Petersen estimator. If no disk tags were applied to jacks, the jack population 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:

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

where:

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

Tributary Stream Population Estimation

Escapements to Little Horsefly River, Moffat Creek and upper McKinley Creek were estimated by expanding the peak live count plus cumulative dead by the IPSFC index of 1.8 (Andrew and Webb 1987). The sex ratio of all recoveries in each stream was used to calculate the male and female portions of the estimate for that stream.

The population estimate for lower McKinley Creek was the total migration past the counting fence, less the estimate for upper McKinley Creek. The sex ratio was calculated from the carcasses recovered on the fence.

FECUNDITY ESTIMATION

Mean fecundities were calculated by age as follows:

8) Estimated mean fecundity of age class a :

$$\bar{F}_a = \frac{\sum_{i=1}^{n_a} W_{ai} * f_{ai} / W_{ai}}{n_a}$$

where:

- f_{ai} = the number of eggs in a weighed subsample (W_{ai}) of the 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

Sockeye were counted on a daily basis as they migrated past the Quesnel River Bridge at Likely. Counts were conducted for four fifteen minute periods throughout the day, increasing to six times per day after September 2 (Appendix 2). Sockeye were observed on the first day of counts. Two peaks in migration were observed; the first between August 17 and 22, and the second between August 27 and September 1. Migration was

virtually complete late September. Hourly migration was variable, with some disruption from sport fishing and kayaking in the area.

TAG APPLICATION

Daily tagging began on August 23, and continued, with the exception of August 28, until September 21 when the run was virtually complete. Live counts in the upper Horsefly indicated low tag rates, so lower river tagging was suspended on August 28 so the crew could tag in the upper river. Tags were applied in reaches 1B, 2 and 4 of the upper Horsefly River; a total of 284 adult sockeye were tagged. Disk tags were applied to 5,376 adult sockeye (Appendix 3a). Sixteen males and 13 females recovered in McKinley Creek above the fence were removed from the application sample. One male recovered in Summit Creek (a Quesnel Lake tributary) was also removed from the application sample. These data were then adjusted for sex identification error. Twenty female recoveries and 12 male recoveries were misidentified at the time of tag application. When adjusted for this error, an estimated 2,389 (44.4%) males, and 2,987 (55.6%) females were released with disk tags.

Three hundred and fifty-eight tags migrated through the McKinley Creek fence. Tag numbers were recorded only from recovered carcasses; it was not possible to determine the tag numbers of migrants through the fence. After removing the tags recovered, the remaining 329 tags were apportioned across the application period, by sex and by day. This resulted in the removal of 182

Table 1. Disk tags applied, carcasses examined and marks recovered, by sex, for Horsefly River system excluding McKinley Creek) sockeye salmon, 1994.

Sex	Disk tags applied ^a	Carcasses examined ^b	Marks recovered ^b				Total	Percent recovered
			Disk tag and secondary mark ^c	Secondary mark only ^c	Disk tag only	Resurvey adjustment		
Male	2,190	43,728	0	0	356	98	454	20.7%
Female	2,825 ^d	49,222	0	0	427	74	501	17.7%
Jack	0	1	0	0	0	0	0	0.0%
Total	5,015	92,951	0	0	783	172	955	19.0%

^a Corrected for sex identification errors and emigration to McKinley and Summit creeks.

^b Includes recoveries from Moffat Creek and Little Horsefly River.

^c Secondary marks were not applied in 1994.

^d Excludes 2 females with short time out to recovery.

Table 2. Disk tag application and recovery in the Horsefly River system, 1994, for fish which were recaptured 0, 1 and 2 or more times in subsequent beach seine sets.

Times recaptured	Disk tags applied ^a			Disk tags recovered			Percent recovered		
	Male	Female ^b	Jack	Male	Female	Jack	Male	Female	Jack
0	2,295	2,874	0	360	428	0	15.7%	14.9%	-
1	89	108	0	13	12	0	14.6%	11.1%	-
2 or more	5	5	0	0	1	0	0.0%	20.0%	-
Total	94	113	0	13	13	0	13.8%	11.5%	-
Chi-Square Test Result									
0 versus 1 recapture:							0.02	0.88	-
0 versus 2 or more recaptures:							0.12	0.09	-
0 versus 1 or more recaptures:							0.12	0.72	-
Critical Chi-Square ($P = 0.05$):							3.84	3.84	-

^a Corrected for sex identification errors.

^b Excludes two females with short time out to recovery.

male and 147 female tags. This removal is probably in error as to sex ratio, since the ratio is based on fence recoveries which may not reflect those of the spawning ground.

The data were then examined to determine if specific tags should be excluded from subsequent analyses. First, two females recovered less than five days after tag application were removed from the application sample. Second, the sample was partitioned into fish which required ventilation at release and those which did not. One hundred and seven fish (2.0% of total tags applied) required ventilation at release. The recovery rate of this group (11.2%) was not significantly different ($P > 0.05$; chi-square) than nonventilated fish (14.7%), so they were not removed from the application sample. Third, fish which were recaptured in subsequent beach seine sets were evaluated. Tags were applied below the primary spawning areas, so the incidence of recaptures was relatively low: 197 adults were recaptured once, 8 were recaptured twice, one was recaptured three times, and one was recaptured four times (Appendix 3a; Table 2). Further, since fish are actively migrating to the spawning areas, most recaptures (79%) occurred on the same day as tagging. The recovery rate of the recaptured sockeye which were later recovered as carcasses (13.1% adult males and 11.3% females) was not significantly different from nonrecaptured fish (14.7% each sex) ($P > 0.05$; chi-square). The recovery rate of females recaptured more than once

was higher (20.0%) than that for nonrecaptured females; however, this difference was not significant ($P > 0.05$; chi-square). This indicates that the stress from multiple recaptures did not significantly affect recovery rate; therefore, no fish were removed from the application totals. The adjusted estimates of tags applied were 2,190 (43.7%) males and 2,825 (56.3%) females (Table 1, Appendix 3b).

The mean (\pm s.e.) NF length of tagged fish was 61.5 cm (\pm 2.8 cm) for males and 57.9 cm (\pm 2.7 cm) for females. The incidence of net, lamprey and hook marks was 8%, 4% and 2% in males, and 29%, 4% and 1% in females (Appendix 4a and 4b).

SPAWNING GROUND SURVEYS

Main Survey

Between September 2 and October 7, 92,951 adult sockeye carcasses were recovered on the upper and lower Horsefly River, Moffat Creek, and Little Horsefly River spawning grounds (Appendix 5a-c). Reaches of the upper Horsefly were surveyed on average seven times. Reaches of the lower Horsefly were surveyed on average six times. Of the adults, 43,728 (47.0%) were males of which 356 were marked (mark incidence 0.81%), and 49,222 (53.0%) were females of which 427 were marked (mark incidence 0.87%). Only one jack was recovered. The most important

Table 3. Average elapsed time between tag application and recovery and female spawning success (all recoveries), by recovery section, period and sex, in the Horsefly River system (excluding McKinley Creek), 199

Location	Section	Period ^a	Days between tag application and carcass recovery				Jack	Female spawning success	(n)
			Male	(n)	Female	(n)			
Horsefly River	Upper river	Early	17.4	(195)	18.2	(217)	-	98.2%	(18,420)
		Late	14.5	(8)	12.3	(25)	-	99.9%	(9,988)
		Total	17.3	(203)	17.6	(242)	-	98.7%	(28,408)
	Lower river	Early	18.1	(131)	18.7	(156)	-	98.3%	(7,930)
		Late	13.4	(22)	12.5	(31)	-	100.0%	(12,286)
		Total	17.5	(153)	17.6	(187)	-	99.3%	(20,216)
	Total	Early	17.7	(326)	18.4	(373)	-	98.2%	(26,350)
		Late	13.7	(30)	12.4	(56)	-	99.9%	(22,274)
		Total	17.4	(356)	17.6	(429)	-	99.0%	(48,624)

^a Time out to recovery: early = 23-Aug to 04-Sep releases; late = 05-Sep to 21-Sep releases.

Female spawning success: early = 02-Sep to 19-Sep recoveries; late = 20-Sep to 07 Oct recoveries.

recovery areas were reaches Upper 5 (15% of total recovery), Lower 1 (12%), Lower 2 (11%), Upper 1 (10%) and Upper 3 (10%).

The average time between release and recovery for disk tagged males and females was 17 days and 18 days, respectively, and was longer among those tagged earlier in the study (Table 3). Two females were out for <5 days and were removed from the recovery total. Female spawning success averaged 99.0% and was consistently high throughout the study (Table 3).

Resurvey

Resurvey was conducted twice in the upper Horsefly on September 16 and 27, and once in the lower Horsefly over three days: September 28, 29 and October 1 (Appendix 6). A total of 12,733 males and 16,324 females were reexamined; 29 and 28 disk tags were recovered from males and females respectively. An estimated 98 (21.6% of total male tags recovered) and 74 (14.7% of total female tags recovered) 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 454 adult male and 501 female disk tags were recovered, for a disk tag incidence of 20.7% and 17.7%, respectively.

Tributary Surveys

Surveys were conducted on September 17 and 29 on the Little Horsefly River, September 18 and 30 on Moffat Creek, and September 12 and 22 on upper McKinley Creek. The peak live count was observed in the first survey of all three streams. The peak live count for Little Horsefly River was 100 sockeye and a total of 16 untagged male and 14 untagged female carcasses were recovered (Appendix 5b). Female spawning success was 100%. The peak live count for Moffat Creek was 80 sockeye and a total of 78 male and 160 female carcasses were recovered. Of those, 1 male and 3 females were tagged (Appendix 5c). Female spawning success averaged 99.7%. The peak live count for upper McKinley Creek was 441 sockeye and a total of 108 untagged male and 112 untagged female carcasses were recovered (Appendix 5d). Female spawning success averaged 98.2%.

McKinley Creek Fence

The McKinley Creek fence was installed on August 24 and maintained until September 28. Sockeye migrated through the fence daily for 29 days; for the last 7, few or no fish migrated into the creek (Appendix 9a-c). The peak count occurred on August 27, and counts remained high through September 8. A total of 35,389 untagged sockeye, 358 tagged sockeye and 219 chinook were counted through the fence. A total of 1,758

Table 4. Percent at age and mean POH length at age in Horsefly River sockeye sampled on the spawning grounds, 1994.

Recovery location	Sample type	Percent at age				POH length (cm) at age			
		3/2	4/2	5/2	5/3	3/2	4/2	5/2	5/3
Upper river	Male	0.0%	94.2%	5.8%	0.0%	-	48.5	53.5	-
	Female	0.0%	91.0%	7.9%	1.1%	-	46.7	51.3	46.2
	Jack	0.0%	0.0%	0.0%	0.0%	-	-	-	-
Lower river	Male	0.0%	93.0%	6.4%	0.6%	-	48.4	53.5	47.9
	Female	0.0%	90.0%	9.9%	0.0%	-	46.2	50.7	-
	Jack	0.0%	0.0%	0.0%	0.0%	-	-	-	-

male, and 1,503 female carcasses were recovered at the fence. Of these, 16 males and 13 females were marked. One jack was also recovered (Appendix 5e). Female spawning success averaged 92.4%.

Horsefly Spawning Channel

Horsefly Spawning Channel staff conducted carcass recoveries throughout the period of die-off in the channel. A total of 19,597 carcasses (7,976 males and 11,651 females) were recovered. Spawning success of the females was unavailable. It was not possible to determine the total number of tags recovered in the channel due to inconsistencies in data recording.

BIOLOGICAL SAMPLING

Fecundity samples from 43 age 4₂ and 7 age 5₂ sockeye were obtained at the tagging site (Appendix 7). Age 4₂ females had an average standard length of 52.2 cm (\pm 2.1 cm; range 44.9 to 56.0 cm) and an average fecundity of 2,984 eggs (\pm 401 eggs; range 1,944 to 3,635 eggs). Age 5₂ females had an average standard length of 57.1 cm (\pm 3.4 cm; range 49.4 to 60.7 cm) and an average fecundity of 3,877 eggs (\pm 715 eggs) (range 2,757 to 4,943 eggs).

The male and female spawning ground samples consisted predominately of age 4₂ fish with small proportions of ages 5₂ and 5₃ also present. The length at age data are presented in Table 4. Differences in age composition among the three

sample periods were not significant ($P > 0.05$; chi-square), escapement by age was calculated from the pooled sample data.

SAMPLING SELECTIVITY

Period

Disk tag incidence within strata ranged from 0.1% to 1.1% (Table 5a-c), with lower tag incidence later in the study. Differences were significant in all three stratifications examined ($P < 0.05$, chi-square) for males and females. These tests indicate that the objective of proportional tag application was not achieved for either sex.

The percentage of male tags recovered within strata ranged from 8.5% to 19.1% (Table 6a-c); the differences were not significant ($P > 0.05$, chi-square). The percentage of female tags recovered across strata ranged from 11.7% to 18.9%, with significant differences ($P < 0.05$, chi-square) in only one stratification (equal application periods). Data indicate that except for one stratification, proportional carcass recovery was achieved for both sexes.

Location

The mark incidence among five recovery sections (Table 7) ranged from 0.64% in the upper Horsefly to 1.08% in the lower Horsefly. The differences observed were significant ($P < 0.05$; chi-square) for males only. These results indicate that there was non-random application in males only.

Table 5a. Incidence of disk tags in sockeye salmon recovered on the Horsefly River system (excluding McKinley Creek), by recovery period and sex, 1994. Data are stratified by approximately equal recovery periods.

Recovery period	Number of surveys	Carcasses recovered with disk tags			Total recovery			Disk tag incidence		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
02-Sep to 08-Sep	1	50	39	0	6,293	4,498	0	0.8%	0.9%	-
09-Sep to 15-Sep	1	92	109	0	11,564	10,447	0	0.8%	1.0%	-
16-Sep to 22-Sep	2	150	169	0	14,950	17,160	0	1.0%	1.0%	-
23-Sep to 29-Sep	1	61	103	0	9,403	14,748	1	0.6%	0.7%	0.0%
30-Sep to 07-Oct	1	3	7	0	1,518	2,369	0	0.2%	0.3%	-
Chi-Square Test Result:								17.04	20.42	-
Critical Chi-Square (P = 0.05):								9.49	9.49	-

Table 5b. Incidence of disk tags in sockeye salmon recovered on the Horsefly River system (excluding McKinley Creek), by recovery period and sex, 1994. Data are stratified by approximately equal recovery cycles.

Recovery period	Number of surveys	Carcasses recovered with disk tags			Total recovery			Disk tag incidence		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
02-Sep to 07-Sep	1	13	13	0	3,326	2,270	0	0.4%	0.6%	-
08-Sep to 13-Sep	1	66	50	0	6,421	4,896	0	1.0%	1.0%	-
14-Sep to 17-Sep	1	121	137	0	13,252	13,041	0	0.9%	1.1%	-
18-Sep to 24-Sep	1	121	162	0	12,949	16,763	1	0.9%	1.0%	0.0%
25-Sep to 01-Oct	1	34	62	0	6,903	11,044	0	0.5%	0.6%	-
02-Oct to 07-Oct	1	1	3	0	877	1,208	0	0.1%	0.2%	-
Chi-Square Test Result:								29.10	28.05	-
Critical Chi-Square (P = 0.05):								11.07	11.07	-

Table 5c. Incidence of disk tags in sockeye salmon recovered on the Horsefly River system (excluding McKinley Creek), by recovery period and sex, 1994. Data are stratified by approximately equal numbers of total recoveries.

Recovery period	Number of surveys	Carcasses recovered with disk tags			Total recovery			Disk tag incidence		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
02-Sep to 14-Sep	1	118	109	0	13,726	10,920	0	0.9%	1.0%	-
15-Sep to 18-Sep	1	96	120	0	10,747	11,225	0	0.9%	1.1%	-
19-Sep to 23-Sep	1	86	97	0	9,156	11,142	0	0.9%	0.9%	-
24-Sep to 07-Oct	3	56	101	0	10,099	15,935	1	0.6%	0.6%	0.0%
Chi-Square Test Result:								11.39	17.59	-
Critical Chi-Square (P = 0.05):								7.82	7.82	-

Table 6a. Proportion of the disk tag application sample recovered on the Horsefly River system (excluding McKinley Creek), by application period and sex, 1994. Data are stratified by approximately equal application periods.

Application period	Number of sets	Disk tags applied ^a			Carcasses recovered with disk tags			Percent recovered		
		Male	Female	Jack	Mal	Female	Jack	Male	Female	Jack
23-Aug to 27-Aug	22	436	531	-	69	67	0	15.8%	12.6%	-
28-Aug to 01-Sep	19	1,198	1,450	-	204	218	0	17.0%	15.0%	-
02-Sep to 06-Sep	20	384	583	-	66	110	0	17.2%	18.9%	-
07-Sep to 11-Sep	23	78	116	-	7	15	0	9.0%	12.9%	-
12-Sep to 21-Sep	33	94	145	-	10	17	0	10.6%	11.7%	-
Chi-Square Test Result:								6.05	10.72	-
Critical Chi-Square (P = 0.05):								9.49	9.49	-

a. Corrected for sex identification error and emigration.

Table 6b. Proportion of the disk tag application sample recovered on the Horsefly River system (excluding McKinley Creek), by application period and sex, 1994. Data are stratified by approximately equal application efforts.

Application period	Number of sets	Disk tags applied ^a			Carcasses recovered with disk tags			Percent recovered		
		Male	Female	Jack	Mal	Female	Jack	Male	Female	Jack
23-Aug to 27-Aug	22	436	531	0	69	67	0	15.8%	12.6%	-
28-Aug to 02-Sep	23	1,351	1,650	0	232	258	0	17.2%	15.6%	-
03-Sep to 08-Sep	23	250	393	0	39	71	0	15.6%	18.1%	-
09-Sep to 13-Sep	24	106	188	0	12	22	0	11.3%	11.7%	-
14-Sep to 21-Sep	25	47	63	0	4	9	0	8.5%	14.3%	-
Chi-Square Test Result:								4.94	7.34	-
Critical Chi-Square (P = 0.05):								9.49	9.49	-

a. Corrected for sex identification error and emigration.

Table 6c. Proportion of the disk tag application sample recovered on the Horsefly River system (excluding McKinley Creek), 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 ^a			Carcasses recovered with disk tags			Percent recovered		
		Male	Female	Jack	Mal	Female	Jack	Male	Female	Jack
23-Aug to 27-Aug	11	436	531	0	69	67	0	15.8%	12.6%	-
28-Aug to 29-Aug	7	413	431	0	79	73	0	19.1%	16.9%	-
30-Aug to 31-Aug	8	506	594	0	76	86	0	15.0%	14.5%	-
01-Sep to 02-Sep	8	432	625	0	77	99	0	17.8%	15.8%	-
03-Sep to 21-Sep	83	403	644	0	55	102	0	13.6%	15.8%	-
Chi-Square Test Result:								5.92	4.40	-
Critical Chi-Square (P = 0.05):								9.49	9.49	-

^a Corrected for sex identification error and emigration.

Table 7. Proportion of the Horsefly River system sockeye (excluding McKinley Creek) recovery sample marked disk tags, by recovery location and sex, 1994.

Recovery river	Recovery Section	Carcasses recovered with disk tags ^a			Total carcasses examined ^a			Disk tag incidence		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
Upper Horsefly	Reach 1-2	42	79	0	6,534	7,558	0	0.64%	1.05%	-
	Reach 3-4	81	83	0	8,893	9,076	0	0.91%	0.91%	-
	Reach 5-7	80	80	0	11,898	12,016	0	0.67%	0.67%	-
Lower Horsefly	Reach 1-2	86	107	0	10,211	11,876	0	0.84%	0.90%	-
	Reach 3-7	67	78	0	6,192	8,696	1	1.08%	0.90%	-
Chi-Square Test Result:								11.97	8.94	-
Critical Chi-Square (P = 0.05):								9.49	9.49	-

^a Including Little Horsefly River and Moffat Creek recoveries.

Table 8. Proportion of the disk tag application sample recovered on the Horsefly River system (excluding McKinley Creek), by sex and 3 cm increments of nose-fork length, 1994.

Nose-fork length (cm)	Disk tags applied ^a			Carcasses recovered with disk tags			Percent recovered		
	Male	Female	Total	Male ^b	Female	Total	Male	Female	Total
34-36.9	0	0	0	0	0	0	-	-	-
37-39.9	0	0	0	0	0	0	-	-	-
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	6	16	22	1	3	4	16.7%	18.8%	18.2%
52-54.9	27	219	246	3	28	31	11.1%	12.8%	12.6%
55-57.9	130	1,222	1,352	15	167	182	11.5%	13.7%	13.5%
58-60.9	698	1,041	1,739	93	157	250	13.3%	15.1%	14.4%
61-63.9	1,015	229	1,244	155	37	192	15.3%	16.2%	15.4%
64-66.9	334	108	442	62	19	81	18.6%	17.6%	18.3%
67-69.9	68	16	84	8	1	9	11.8%	6.3%	10.7%
70-72.9	16	0	16	4	0	4	25.0%	-	25.0%
73-75.9	0	0	0	0	0	0	-	-	-
Kolmogorov-Smirnov 2-sample test Dmax (continuous data; see text):							0.055	0.036	-
Kolmogorov-Smirnov 2-sample test Dcritical (P=0.05):							0.080	0.072	-

^a Corrected for sex identification error; excludes 83 males and 116 females which were not measured.

^b Excludes 15 males and 15 females which were not measured at release.

Fish Size

Recovery rates ranged from a low of 6.3% in females to a high of 25.0% in males with no trend in recovery rates with increasing size. In this study, size had no effect on recovery rates in either sex ($P < 0.05$; Kolmogorov-Smirnov two-sample test) (Table 8).

Fish Sex

There was no difference ($P > 0.05$; chi-square) in the sex composition of the marked and unmarked spawning ground recoveries (Table 9). Thus, the application sample was unbiased with respect to sex. There was also no difference ($P > 0.05$; chi-square) in the sex composition of the recovered and non-recovered components of the

Table 9. Sex composition of Horsefly River system (excluding McKinley Creek) adults in the disk tag application and spawning ground samples, 1994. ^a

Sex	Application sample, by recovery status ^b				Recovery sample, by mark status			
	Sample size	Recovered	Not recovered	Total	Sample size	Marked	Unmarked	Total
Male	2,190	45.5%	43.3%	43.7%	43,728	45.5%	47.1%	47.0%
Femal	2,825	54.5%	56.7%	56.3%	49,223	54.5%	52.9%	53.0%
	Chi-Square Test Result:			1.13	Chi-Square Test Result:			0.73
	Critical Chi-Square (P = 0.05):			3.84	Critical Chi-Square (P = 0.05):			3.84

^a Data are from Table 1.

^b Corrected for sex identification error.

Table 10. Spawning success of female sockeye in the Horsefly River system (excluding McKinley Creek) by recovery status and recovery area, 1994.

	Spawning success				Percent spawn
	0%	50%	100%	Total	
Marked	20	14	393	427	93.7%
Unmarked	436	87	48,272	48,795	99.0%
Total	456	101	48,665	49,222	99.0%
	Chi-Square Test Result:			247.05	
	Critical Chi-Square (P = 0.05):			5.99	
<u>Marked</u>					
Upper reach 1-Lower reach 4	20	12	332	364	92.9%
Lower reach 5-7	0	2	61	63	98.4%
Total	20	14	393	427	93.7%
	Chi-Square Test Result:			2.62	
	Critical Chi-Square (P = 0.05):			5.99	
<u>Unmarked</u>					
Upper reach 1-Lower reach 4	400	74	41,121	41,595	98.9%
Lower reach 5-7	36	12	6,981	7,029	99.4%
Total	436	86	48,102	48,624	99.0%
	Chi-Square Test Result:			13.17	
	Critical Chi-Square (P = 0.05):			5.99	

application sample (Table 9). Therefore, the recovery sample was also unbiased with respect to sex.

handling and tagging stress introduced bias to this study.

Stress

A chi-square test comparing spawning success (0%, 50% and 100%) between tagged and untagged females indicated significant differences ($P < 0.05$; chi-square; Table 10). Data was further stratified by comparing areas close to the tagging site and those above. There was no significant difference between areas in the marked fish ($P > 0.05$; chi-square), while there was for unmarked fish ($P < 0.05$; chi-square). It does not appear that

SPAWNER POPULATION ESTIMATES

The 1994 sockeye escapement estimates for the mark-recapture study area, which includes Horsefly Spawning Channel, Little Horsefly River and Moffat Creek, and for the entire system (including McKinley Creek) are presented in Tables 11 and 12, respectively, and are discussed below. Jack (NF length of less than 50 cm) abundance did not meet the minimum requirement for a mark recapture estimate, so the escapement was cal-

Table 11. Escapement estimates and 95% confidence limits, by age and sex, for Horsefly River system (excluding McKinley Creek) adults and jacks, 1994.

Stratification type	Estimator	Sex	Escapement at age ^a					95% confidence limit on total escapement	
			3/2	4/2	5/2	5/3	Total	Lower	Upper
Pooled	Petersen	Male	0	197,105	12,855	612	210,572	191,345	229,799
		Female	0	250,823	24,684	1,593	277,100	253,007	301,193
		Total	0	447,928	37,539	2,205	487,672	456,848	518,496
		Jack	6	0	0	0	6	-	-
Temporal ^b	Darroch	Male	-	-	-	-	231,729	177,626	285,831
		Female	-	-	-	-	295,789	262,701	328,877

^a Does not include 50 males and 100 females sacrificed for biological samples.

^b Used a 5x5 matrix: 23-27 Aug, 28 Aug to 01 Sep, 02-06 Sep, 07-11 Sep and 12-21 Sep application; 02-08 Sep, 09-15 Sep, 16-22 Sep, 23-29 Sep, and 30 Sep to 07 Oct recovery.

Table 12. Escapement estimates, by sex, for Horsefly River system (including tributaries) sockeye adults and jacks, 1994.

	Peak live count	Cumulative dead count	Adult escapement			Jack
			Male	Female	Total	
Horsefly system						
Mark-recapture estimate ^a	n/a	n/a	210,622	277,200	487,828	6
Horsefly tributaries						
Horsefly Channel ^b	n/a	19,597	7,946	11,651	19,597	0
Little Horsefly River	100	20	115	101	216	0
Moffat Creek	80	125	121	248	369	0
Horsefly River ^c			202,440	265,200	467,646	6
McKinley Creek						
Fence	n/a	n/a	19,261	16,475	35,747	11
Upper McKinley Creek	441	207	572	594	1,166	0
Lower McKinley Creek ^d	n/a	n/a	18,689	15,881	34,581	11
Study area total ^e			229,883	293,675	523,575	17

^a Includes 50 males and 100 females sacrificed for biological samples.

^b Estimates provided by the Salmonid Enhancement Program.

^c Calculated as the difference between the mark-recapture estimate for the system and the tributary estimates.

^d Calculated as the difference between the fence count and the Upper McKinley Creek estimate.

^e Calculated as the sum of the mark-recapture estimate and the McKinley Creek fence estimate.

culated using Equation 7, and was estimated at 6 fish.

River. Escapement was estimated for adult males and females only.

Petersen Estimator

Pooled Petersen estimates were calculated from the data presented in Table 1 and include the recoveries from Moffat Creek and Little Horsefly

The 1994 sockeye adult escapement for the Horsefly River system (excluding McKinley Creek) was estimated at $487,672 \pm 30,824$ (6.3%) (Table 11). The escapement of males and females was $210,572 \pm 19,227$ (9.1%) and $277,100 \pm 24,093$

(8.7%), respectively. Age specific escapements were estimated from the data in Appendix 8.

Stratified Estimators

Because a temporal bias was identified in the sampling data, stratified estimates were calculated using the Darroch estimator (Table 11). The data were initially stratified into a five (application period) by five (recovery period) matrix (Table 5c). To meet model requirements the initial matrices were collapsed into 4 x 1 arrays.

The Darroch estimates of male and female escapement were 10.0% and 6.7% (respectively) greater than the corresponding Petersen estimates. The estimates were not significantly different from the pooled Petersen estimates and overlapped the 95% confidence limits of the Petersen estimates; therefore, the Petersen estimates are accepted.

Visual Estimates

The adult sockeye escapement estimate was 216 (115 males, 101 females) for Little Horsefly River, 369 (121 males, 248 females) for Moffat Creek, and 1,166 (572 males, 594 females) for upper McKinley Creek (Table 12). The Horsefly Spawning Channel adult sockeye escapement, based on a total dead pitch of the channel, was 19,597 (7,946 males, 11,651 females) (R. Dickson, Channel Operator, pers. com.).

Fence Estimates

The total count through the lower McKinley Creek fence was 37,747 (19,261 males, 16,475 females, 11 jacks with the sex composition estimated from carcass recoveries on the fence). When adjusted for escapement to the upper McKinley Creek, the escapement to lower McKinley Creek was 34,581 (18,689 males, 15,881 females, and 11 jacks; Table 12).

Study Area Estimates

The escapement estimate for the Horsefly River was adjusted for those escapements to Moffat Creek, Little Horsefly River, and the Horsefly Spawning Channel, resulting in an estimated

escapement of 202,440 males, 265,200 females and 6 jacks to the Horsefly River (Table 12). The study area estimate was 229,883 males, 293,675 females and 17 jacks.

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 Horsefly study addressed the closure assumption through temporal and spatial design elements. Temporally, the study was designed to encompass the entire period of immigration, spawning and die-off. Spatially, the study included the entire accessible portion of the river and efforts were made to ensure that all fish would be vulnerable to the application or recovery surveys. Emigration from the study area to Quesnel Lake and its tributaries, and McKinley Creek was possible. In the case of McKinley, all tags emigrating from the Horsefly were counted through the fence and removed from the application totals. Surveys were conducted on Quesnel Lake and its tributaries to ensure closure. For the purposes of this study it is expected that the closure assumption was satisfied.

Identification of Tag Status

The failure to correctly identify the tag status of a carcass is common 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. 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 during initial survey was evaluated by resurveying 34% of the carcasses previously recovered; the percentage of the tags missed was 18.0% of total tags recovered or 172 tags. Resurvey resulted in the addition of a large number of tags to the overall recoveries. Procedural changes must be implemented to reduce the missed tag incidence in future studies: staff training must re-emphasize the importance of carefully examining each carcass; resurveys should be conducted more frequently over all areas so that immediate feedback and retraining can occur before the peak of die off.

Three concerns arise with the design of the resurvey sample and the analytic treatment of the resurvey data. First, the resurvey was relatively unsystematic, i.e. resurvey occurred far less frequently than the initial surveys and did not representatively sample all spatial and temporal components of the run. Specifically, the resurveys began well after the start of the initial surveys and only covered the upper river twice and the lower river once. This issue should be addressed in future studies by conducting a more representative resurvey. Second, variance associated with resurvey is not accounted for in the population variance estimate. Consequently, the precision of the population estimate was overstated. This should be addressed in the analysis of future studies. Third, if estimator variance is to be minimized, simulation studies are required to determine the optimal allocation of effort between the initial and resurvey sampling stages.

Tag Loss

The undetected loss of disk tags between application and recovery would result in an underestimate of the number of tagged carcasses in the population and an overestimate of escapement. Tag loss can result from poor tag application technique, tangling of the tag in the net when re-

captured, or the fighting which is common among males during spawning. It can be evaluated 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 was not assessed: secondary marks were not used. A 1989 tag loss study, however, reported an average 3.5% (range 0% to 9.7%) loss of the primary tag 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 about 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 3.5% or 17,000 sockeye (range 0 to 47,300). Clearly, tag loss may introduce substantial bias into the population estimates and its assessment must be an integral part of all future mark-recapture studies.

Tagging Effects

Tagging can influence subsequent catchability if, for example, a tagged fish becomes more vulnerable to a fishery, to technicians or to predators. This type of tagging effect had little impact on the current study because: there were no 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, there was no indication that predators were removing significant numbers of sockeye, tagged or otherwise.

The capture, holding and tagging of fish can subject sockeye to physiological stress (Ricker 1975). Two potentially serious tagging effects are: a) subacute stress-induced behavioural changes which violate the assumption of constant and equal probability of recovery; and b) acute or short-term mortality, which violates the closure assumption 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 minor, or it may be manifest in subtle behavioural 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, 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 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 could increase the probability that the fish would wash ashore and could result in a higher recovery rate among the stressed group. This response violates 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, violating 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 may indicate 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 susceptible to stress; low stress study techniques should be considered.

Third, stress may result in a reduced life span for the stressed fish. Shorter time spans between release and death among tagged fish 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 migration past the tagging site and death for untagged fish; such an assessment was unavailable in the current study. In contrast, acute stress should be detectable because behaviour was assessed immediately after release; fish requiring ventilation could be removed from the sample if stress was indicated.

In the current study, handling stress was minimized by ensuring that the capture and tagging processes were as stress-free as possible.

This was done by selecting a tagging site that was close to the mouth of the Horsefly River, below the areas of heavy spawning, and in an area of moderate flow with clean gravel substrate, so that fish were not stressed while being held for tagging. Tagging and holding time were also minimized to reduce stress. These conditions were intended to minimize stress induced mortality while at the same time permit the complete mixing of tagged and untagged fish. Evaluation detected only minor subacute or acute stress effects in 1994: two females may have suffered tagging stress. These fish were recovered <5 days after being tagged and were removed from the data set. While both were removed, it is worth noting that both had spawned successfully.

In summary, none of the tests conducted demonstrated stress-induced tagging effects in the 1994 Horsefly study. The possibility that subacute and acute stresses may have effects cannot be discounted. Two design changes are recommended to permit such an assessment in the future: a) to evaluate the Horsefly stock's susceptibility to stress and the potential impact of subacute stress on the study results, high and low stress tag application techniques should be developed; and b) to permit a more thorough assessment of acute tagging effects, surveys of the river above and below the tagging site should begin immediately after the start of tagging.

Sampling Selectivity

The assumptions of equal probability of capture and recapture and simple random sampling are violated in virtually all mark-recapture studies and are generally considered to be an unattainable ideal (Otis *et al.* 1978). These conditions can be relaxed to some extent, however, without introducing bias in the population estimate. Junge (1963) showed that selectivity can exist in both the application and recovery 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 sampling occurs, it can be at least partially addressed by using a stratified population estimator.

The design of the current study attempted to address the assumption of equal probability of recapture by making both tag application and recovery as representative as possible. Daily tag-

Table 13. Bias profile for the 1994 Horsefly River sockeye escapement estimation study. a

Sample	Bias type	Test of	Between	Test result
Application	Temporal	Tag incidence:	Equal recovery periods	Early bias in both sexes
			Equal recovery effort	Bias in males and females
			Equal numbers of recoveries	Bias in males and females
	Spatial	Tag incidence:	Five recovery areas	Bias in males
	Fish sex	Sex ratio:	Marked/unmarked recoveries	No bias
Recovery	Stress	Recovery rate:	Ventilated/nonventilated releases	No bias
		Recovery of a tag within 5-days of rel:	-	
		Recovery rate:	Live recaptured/not recaptured	No bias
	Statistical	Spawning success:	Tagged/untagged recoveries	Higher spawning success in untagged
		Minimum recovery of 5 tags:	-	No bias
	Temporal	Recovery rate:	Equal application periods	Mid period bias in females
			Equal application effort	No bias
			Equal numbers applied	No bias
	Fish size	Size-frequency distrib:	Recovered/nonrecovered tags	No bias
	Fish sex	Sex ratio:	Recovered/nonrecovered tags	No bias

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

ging effort was standardized and the fish were captured using gear (beach seine net) expected to minimize selectivity. Standardized effort can still fail to provide a representative sample of migrating sockeye, however, due to variability in: river conditions; the proportion of the fish which migrate at night; daily set times; and the technique used during each set. Equal probability of recapture (or in this case, recovery) was addressed by cycling through the spawning ground surveys on a fixed number of days regardless of carcass abundance. Again, standardized effort can be compromised by variable river conditions or staff levels. Random mixing was addressed by looking at the mark incidence across reaches. Areas where the study design could not be fully implemented are discussed below.

Sample representativeness could not be tested definitively because the true population parameters were not known. Instead, a bias profile was constructed by examining the samples for

five potential biases as indicators of weaknesses: temporal, spatial, fish size, fish sex, and stress (Table 13). Two biases were detected in the application and recovery samples: a) a temporal application bias for early and mid period spawners in most stratifications; and b) a temporal recovery bias for mid period females in one stratification.

The temporal biases reflected a number of study design problems. Efforts to conserve operating budget resulted in a delayed program start-up. This had a number of effects on tag application, the first being that tagging commenced eight days after the first fish were observed at Likely Bridge. Migration time from Likely to Horsefly River appears to be approximately four days when comparing passage at Likely with daily tagging (Fig. 3). A substantial number of fish may have passed the tagging site prior to the first day of tagging, August 23. This would result in an overall reduced tag incidence among early spawners and, because males generally arrive on

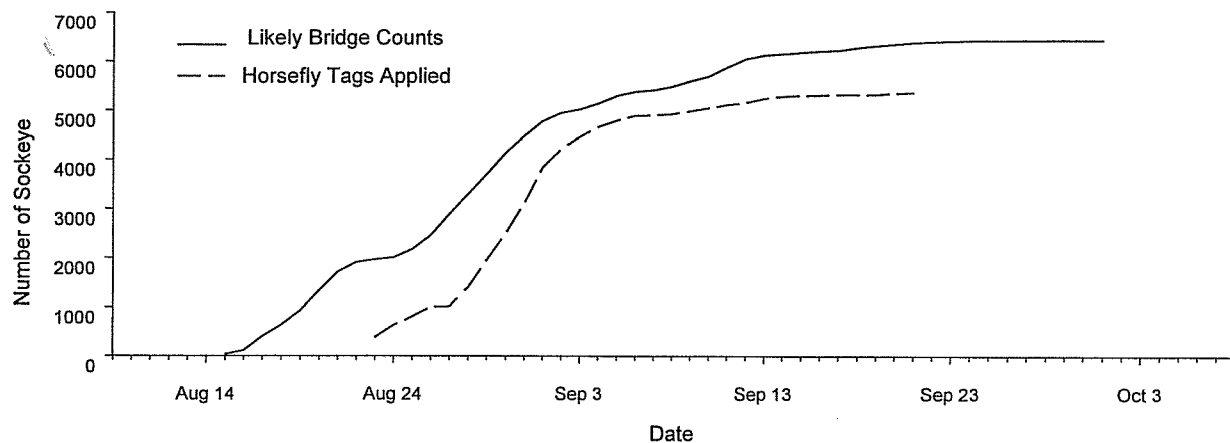


Figure 3. Comparison of cumulative Likely Bridge counts and tags applied in the Horsefly River, 1994.

the spawning grounds earlier than females (Killick 1955), a disproportionate reduction in tag incidence among males during the early part of recovery. Program data supports this: comparing the number of males and females tagged in the first days of application, more females were captured than males; and survey of the upper river revealed few tags present. A one day effort was made on August 28 to apply tags to fish already present in the upper areas to increase the tag incidence. There was no concurrent tagging effort on August 28 in the lower river, however, so any fish migrating on that day were not tagged. This may have further reduced early tag rates. Capture at the tagging site was peaking from August 29 to September 1, so numbers of fish missed on August 28 may have been substantial.

The recovery survey started 10 days after tagging commenced, which was below the average time out to recovery (17-18 days). Carcasses were, already present in the upper river on August 27, however, indicating that fish had begun to die as tagging was beginning. Delaying recovery would mean fish suffering from acute stress at the beginning of tagging would probably not be detected. Future studies must address these temporal issues by ensuring that: a) application effort begins at the onset of migration; b) application must continue through the duration of spawning migration; and c) recovery begins within four days after the start of tagging activity.

The spatial bias that was detected in the male sample is likely attributable to the delayed start in tag application and behavioural differences between the sexes following spawning. Bias of this nature will be minimized by addressing the above recommendations in future study designs.

RECOMMENDATIONS

1. The resurvey of carcass recovery areas is an important component of a mark-recapture study because errors can be made in the identification of disk tagged fish during the initial survey. The following changes are recommended to reduce the incidence of missed tags and improve the resurvey component of future studies:

- 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 immediate feedback and retraining to crew members who miss disk tags;
- The resurvey should be made spatially and temporally more representative;
- Analytic methods should incorporate the variance of the resurvey sampling stage into the variance of the population estimator;
- Simulation studies should be undertaken to determine the optimum allocation of effort between the initial and resurvey sampling.

2. Secondary tags or marks should be applied to sockeye released with disk tags to permit the assessment of disk tag loss. In future programs it is recommended that all disk tagged fish receive a sex-specific opercular punch as a secondary mark.

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. Three study design changes are recommended to assess the role of stress in future Horsefly studies and to remove the potentially confounding influence of stress effects from the evaluation of sampling selectivity:

- To evaluate the Horsefly 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 and compared with current methods;
- To permit a more thorough assessment of acute tagging effects, surveys of the river above and below the tagging site should begin immediately after the start of tagging;
- Because the stress from holding a fish in the net before tagging may increase with time, holding time should be recorded for all tagged fish.

4. Two study design changes are recommended to assess the sampling selectivity issues identified in the 1994 study:

- Live capture should begin no later than two days after sockeye are observed at the Likely Bridge counting site. Sampling effort should be consistent through the entire run;
- To ensure that application and recovery effort are consistent over the respective periods of immigration and die-off, staff levels must be increased during the coincidental sampling periods.

5. Study design changes are recommended to improve the sampling of areas considered tributary to the Horsefly River:

- To address concerns of possible bias in sex ratios for McKinley Creek, effort should be made to increase recovery efforts in the creek itself;

- Surveys of Little Horsefly and Moffat should begin earlier and occur more frequently to ensure adequate coverage.

6. Effort should be made to coordinate with channel staff to ensure that carcasses from the channel are not injected into Horsefly River recoveries and that tags recovered in the channel are recorded so that they may be removed from the application totals.

7. 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. 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 Horsefly River, 1938-1994.

Year	Arrival	Period of peak spawning	Escapement				Percent spawning success	Effective females
			Total	Jacks	Males	Females		
1938	-	-	0	0	0	0	0.0%	0
1939	-	-	7	0	3	4	100.0%	4
1940	Sep 01	Sep 08-Sep 14	74	46	11	17	100.0%	17
1941	Aug 15	Aug 25-Aug 30	918	0	451	467	95.0%	444
1942	-	-	0	0	0	0	0.0%	0
1943	-	-	0	0	0	0	0.0%	0
1944	-	-	5	0	2	3	100.0%	3
1945	Aug 14	Sep 07-Sep 08	4,441	0	1,032	3,409	99.0%	3,374
1946	Aug 15	Aug 30	104	0	43	61	71.4%	44
1947	-	-	11	2	3	6	100.0%	6
1948	-	-	100	0	50	50	95.0%	48
1949	Aug 08	Sep 01-Sep 05	30,000	0	10,170	19,830	95.0%	18,839
1950	Aug 23	Aug 25-Aug 27	385	0	115	270	95.0%	257
1951	Aug 20	Aug 26	49	0	27	22	40.0%	9
1952	Aug 12	Aug 26-Sep 03	7,013	6,829	92	92	55.8%	51
1953	Aug 04	Aug 27-Aug 29	105,440	8	45,146	60,286	75.0%	45,184
1954	Aug 23	Sep 02-Sep 05	274	0	137	137	97.3%	133
1955	Aug 21	Sep 05	63	0	31	32	95.0%	30
1956	Aug 18	Aug 31	2,556	2,482	37	37	95.0%	35
1957	Aug 05	Sep 02-Sep 05	214,254	0	78,540	135,714	95.0%	127,218
1958	Aug 15	Sep 07-Sep 10	1,784	0	535	1,249	98.4%	1,229
1959	-	-	49	0	24	25	95.0%	24
1960	Aug 19	^a	3,029	2,748	123	158	73.9%	117
1961	Aug 5	Aug 28-Aug 31	277,305	9	108,394	168,902	38.0%	64,200
1962	Aug 23	Aug 30-Sep 04	1,001	0	430	571	95.0%	526
1963	Aug 12	Aug 25-Aug 29	86	3	36	47	84.8%	40
1964	Aug 25	Sep 10-Sep 12	15,315	15,061	162	92	83.3%	77
1965	Aug 06	Aug 29-Sep 03	359,232	10	164,408	194,814	53.2%	103,661
1966	Aug 15	Sep 03-Sep 06	1,607	0	543	1,064	91.5%	973
1967	Aug 14	Sep 01-Sep 05	119	0	59	60	40.0%	24
1968	Aug 20	Sep 03-Sep 08	5,686	4,996	345	345	95.0%	328
1969	Aug 07	Aug 27-Sep 01	236,219	5	98,846	137,368	49.7%	68,204
1970	Aug 24	Sep 04-Sep 07	1,350	5	453	892	41.8%	373
1971	-	Aug 30-Sep 01	171	0	65	106	15.4%	16
1972	Aug 20	Sep 05-Sep 10	2,859	2,769	33	57	60.0%	34
1973	Aug 14	Aug 29-Sep 02	238,278	0	107,793	130,485	72.4%	94,471
1974	-	Sep 06-Sep 10	4,459	0	1,846	2,613	99.0%	2,587
1975	-	^b	101	4	44	53	100.0%	53
1976	Sep 07	Sep 15-Sep 20	1,279	1,233	14	32	100.0%	32
1977	Aug 09	Sep 01-Sep 08	431,920	22	207,675	224,223	61.8%	138,641
1978	Aug 20	Sep 04-Sep 10	7,287	0	3,552	3,735	98.4%	3,675
1979	-	Sep 12-Sep 15	511	0	243	268	88.6%	238
1980	-	Sep 10	2,815	2,541	137	137	60.0%	82
1981	Aug 11	Aug 24-Sep 05 ^c	661,614	31	309,213	352,370	81.5%	287,094
1982	-	-	30,317	0	14,839	15,478	98.1%	15,177
1983	-	Sep 04-Sep 08	1,998	0	650	1,348	75.5%	1,018
1984	-	Sep 04-Sep 08	5,606	4,782	291	533	95.5%	509
1985	Aug 10	^d	957,198	0	441,878	515,320	94.9%	525,523

^a Two peaks: Sep 05-Sep 07 and Sep 14-Sep 18.

^b Two peaks: Aug 30-Sep 02 and Sep 15-Sep 18.

^c Estimate includes Lower McKinley Creek.

^d Two peaks: Sep 06-Sep 10 and Sep 12-Sep 16.

Continued

Appendix 1a. 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 Horsefly River, 1938-1994, continued.

Year	Arrival	Period of peak spawning	Escapement				Percent spawning success	Effective females
			Total	Jacks	Males	Females		
1986	-	^e	144,757	6	63,500	81,251	93.6%	75,975
1987	-	^e	16,745	13	6,064	10,668	84.0%	8,964
1988	Aug 11	^f	19,775	14,247	1,696	3,832	89.1%	3,413
1989	-	Sep 05-Sep 14 ^g	1,462,605	0	718,643	743,962	96.2%	731,903
1990	Aug 15	Sep 03-08	398,468	0	178,411	220,057	98.5%	216,790
1991	-	-	19,754	0	9,877	9,877	100.0%	9,877
1992	-	-	6,777	2,686	1,943	2,148	100.0%	2,148
1993	Aug 20	Sep 18-Sep 23 ^h	1,650,083	254	650,262	999,567	99.4%	993,519
1994	Aug 15-20	Sep 09-Sep 12	467,646	6	202,440	265,200	99.0%	262,551

^e Two peaks: Sep 06-Sep 08 and Sep 08-Sep 12.

^f Two peaks: Aug 30-Sep 03 and mid Sep.

^g Estimate includes Little Horsefly River.

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 McKinley Creek, 1953-1994. ^a

Year	Arrival	Period of peak spawning	Escapement				Percent spawning success	Effective females
			Total	Jacks	Males	Females		
1953	-	-	3,141	0	1,345	1,796	75.0%	1,346
1954	-	-	0	0	0	0	0.0%	0
1955	-	-	0	0	0	0	0.0%	0
1956	-	-	94	92	1	1	100.0%	1
1957	Aug 05	Sep 02-Sep 05	6,698	0	2,478	4,220	95.0%	4,009
1958	-	-	0	0	0	0	0.0%	0
1959	-	-	0	0	0	0	0.0%	0
1960	-	-	0	0	0	0	0.0%	0
1961	Aug 05	Sep 03-Sep 06	18,400	0	7,432	10,968	35.0%	3,839
1962	-	-	0	0	0	0	0.0%	0
1963	-	-	0	0	0	0	0.0%	0
1964	-	-	0	0	0	0	0.0%	0
1965	-	-	0	0	0	0	0.0%	0
1966	-	-	0	0	0	0	0.0%	0
1967	-	-	0	0	0	0	0.0%	0
1968	-	-	0	0	0	0	0.0%	0
1969	-	Aug 25-Aug 30	19,512	0	7,785	11,727	33.9%	3,973
1970	-	-	0	0	0	0	0.0%	0
1971	-	-	0	0	0	0	0.0%	0
1972	-	Sep 12	526	508	6	12	85.7%	10
1973	-	Sep 01-Sep 07	10,942	0	4,356	6,586	74.4%	4,897
1974	-	-	0	0	0	0	0.0%	0
1975	-	-	100	4	44	52	100.0%	52
1976	-	Sep 15-Sep 20	783	533	78	172	100.0%	172
1977	-	-	33,064	2	14,771	18,291	38.4%	7,018
1978	-	Sep 01-Sep 03	85	0	41	44	98.4%	43
1979	-	-	0	0	0	0	0.0%	0
1980	-	-	0	0	0	0	0.0%	0
1981	-	^b	0	0	0	0	0.0%	0
1982	-	Sep 03-Sep 07	5,578	0	2,511	3,067	95.1%	2,918
1983	-	Aug 25	38	0	12	26	75.5%	20
1984	-	Mid Sep	472	402	25	45	66.7%	30
1985	-	Sep 08-Sep 12	82,553	0	34,753	47,800	95.3%	45,567
1986	-	Sep 08-Sep 12	4,973	0	2,182	2,791	79.4%	2,217
1987	-	Sep 05-Sep 07	63	0	22	41	89.5%	37
1988	-	Sep 07-Sep 15	3,440	3,116	156	168	53.9%	91
1989	-	Sep 05-Sep 10	113,330	0	51,237	62,093	98.5%	61,180
1990	Aug 24	Sep 03-Sep 08	11,365	0	5,089	6,276	0.0%	0
1991	-	-	^b 0	0	0	0	0.0%	0
1992	-	-	0	0	0	0	0.0%	0
1993	Aug 22	Sep 18-Sep 23	163,470	4	66,276	97,190	82.0%	79,627
1994	Aug 24	Sep 08-Sep 12	34,581	11	18,689	15,881	92.4%	14,347

^a No surveys recorded prior to 1953.

^b Estimate included in Horsefly River totals.

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 had spawned effectively in upper McKinley Creek, 1969-1994. ^a

Year	Arrival	Period of peak spawning	Escapement				Percent spawning success	Effective females
			Total	Jacks	Males	Females		
1969	-	Aug 25-Aug 30	8,424	0	3,361	5,063	33.9%	1,715
1970	-	-	0	0	0	0	0.0%	0
1971	-	-	0	0	0	0	0.0%	0
1972	-	-	0	0	0	0	0.0%	0
1973	-	Sep 01-Sep 07	4,162	0	1,656	2,506	74.4%	1,863
1974	-	-	0	0	0	0	0.0%	0
1975	-	-	0	0	0	0	0.0%	0
1976	-	Sep 15-Sep 20	2	0	1	1	100.0%	1
1977	-	-	8,024	0	3,549	4,475	38.4%	1,717
1978	-	Sep 05-Sep 07	5	0	2	3	100.0%	3
1979	-	-	0	0	0	0	0.0%	0
1980	-	Sep 15	347	313	17	17	91.7%	16
1981	-	Sep 01-Sep 07	15,775	0	7,186	8,589	73.2%	6,284
1982	-	Sep 03-Sep 07	79	0	36	43	95.1%	41
1983	-	-	0	0	0	0	0.0%	0
1984	-	-	0	0	0	0	0.0%	0
1985	-	Sep 03-Sep 07	14,999	0	5,980	9,019	96.4%	8,690
1986	-	Sep 03-Sep 07	662	0	290	372	93.4%	347
1987	-	-	0	0	0	0	0.0%	0
1988	-	Mid Sep	36	36	0	0	0.0%	0
1989	-	Sep 05-Sep 10	4,500	0	2,034	2,466	100.0%	2,466
1990	Aug 24	Sep 03-Sep 08	378	0	169	209	98.5%	206
1991	-	-	0	0	0	0	0.0%	0
1992	-	-	0	0	0	0	0.0%	0
1993	Late Aug	Sep 18-Sep 23	5,902	0	1,641	4,261	99.7%	4,248
1994	Aug 20	Sep 08-Sep 12	1,166	0	572	594	98.2%	583

^a No surveys recorded prior to 1969.

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 had spawned effectively in Little Horsefly River, 1938-1994.

Year	Arrival	Period of peak spawning	Escapement				Percent spawning success	Effective females
			Total	Jacks	Males	Females		
1938	-	-	0	0	0	0	0.0%	0
1939	-	-	0	0	0	0	0.0%	0
1940	-	-	0	0	0	0	0.0%	0
1941	-	Oct 05	27	0	13	14	95.0%	13
1942	-	-	0	0	0	0	0.0%	0
1943	-	-	0	0	0	0	0.0%	0
1944	-	-	4	0	2	2	100.0%	2
1945	-	-	0	0	0	0	0.0%	0
1946	-	-	0	0	0	0	0.0%	0
1947	-	-	0	0	0	0	0.0%	0
1948	-	-	0	0	0	0	0.0%	0
1949	-	-	0	0	0	0	0.0%	0
1950	Oct 01	-	13	0	6	7	100.0%	7
1951	-	-	0	0	0	0	0.0%	0
1952	-	-	2	2	0	0	0.0%	0
1953	-	-	0	0	0	0	0.0%	0
1954	Sep 21	Oct 08-Oct 12	7	0	3	4	100.0%	4
1955	-	-	0	0	0	0	0.0%	0
1956	Oct 01	Oct 06-Oct 10	5	0	2	3	100.0%	3
1957	-	-	38	0	14	24	95.0%	23
1958	-	Oct 15-Oct 20	14	0	7	7	100.0%	7
1959	Sep 15	Sep 25	27	11	11	5	100.0%	5
1960	Sep 21	^a	23	12	5	6	100.0%	6
1961	-	-	40	0	17	23	16.7%	4
1962	Sep 15	Sep 28-Oct 03	72	0	29	43	87.5%	38
1963	-	-	0	0	0	0	0.0%	0
1964	-	-	355	217	56	82	100.0%	82
1965	-	-	0	0	0	0	0.0%	0
1966	Sep 25	-	4	0	2	2	100.0%	2
1967	-	-	0	0	0	0	0.0%	0
1968	-	Sep 20-Sep 25	73	68	2	3	100.0%	3
1969	Aug 07	Aug 27-Sep 01	40	0	17	23	49.7%	11
1970	-	-	0	0	0	0	0.0%	0
1971	-	-	0	0	0	0	0.0%	0
1972	-	-	18	18	0	0	0.0%	0
1973	-	-	4	0	2	2	100.0%	2
1974	-	-	0	0	0	0	0.0%	0
1975	-	-	0	0	0	0	0.0%	0
1976	-	-	32	32	0	0	0.0%	0
1977	-	Sep 12-Sep 16	106	0	55	51	63.8%	33
1978	-	-	0	0	0	0	0.0%	0
1979	-	-	0	0	0	0	0.0%	0
1980	-	-	0	0	0	0	0.0%	0
1981	-	-	2	0	1	1	100.0%	1
1982	-	-	0	0	0	0	0.0%	0
1983	-	-	0	0	0	0	0.0%	0
1984	-	-	45	45	0	0	0.0%	0
1985	-	-	17,030	0	7,806	9,224	96.8%	8,929

^a Two peaks: Sep 21-Sep 28 and Oct 08-Oct 16.

Continued

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 had spawned effectively in the Little Horsefly River, 1938-1994, continued.

Year	Arrival	Period of peak spawning	Escapement				Percent spawning success	Effective females
			Total	Jacks	Males	Females		
1986	-	-	0	0	0	0	0.0%	0
1987	-	-	0	0	0	0	0.0%	0
1988	-	Mid Sep	401	381	5	15	100.0%	15
1989	-	^b	0	0	0	0	0.0%	0
1990	-	^b	0	0	0	0	0.0%	0
1991	-	-	0	0	0	0	0.0%	0
1992	-	-	0	0	0	0	0.0%	0
1993	Mid Aug	Sep 18-Sep 23	21,361	0	7,038	14,323	99.7%	14,280
1994	Aug 15	Sep 08-Sep 12	216	0	115	101	100.0%	101

^b Included in Horsefly River estimate.

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 had spawned effectively in Moffat Creek, 1989-1994.^a

Year	Arrival	Period of peak spawning	Escapement				Percent spawning success	Effective females
			Total	Jacks	Males	Females		
1989	-	Sep 08-Sep 14	10,665	0	5,579	5,086	99.5%	5,058
1990	-	-	0	0	0	0	0.0%	0
1991	-	-	0	0	0	0	0.0%	0
1992	-	-	0	0	0	0	0.0%	0
1993	Mid Aug	Sep 18-Sep 23	7,099	0	2,268	4,831	99.2%	4,793
1994	Aug 25	Sep 08-Sep 12	369	0	121	248	99.7%	247

^a No surveys recorded prior to 1989.

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 had spawned effectively in the Horsefly Spawning Channel, 1989-1994.^a

Year	Arrival	Period of peak spawning	Escapement				Percent spawning success	Effective females
			Total	Jacks	Males	Females		
1989	-	-	23,300	0	11,422	11,878	98.3%	11,670
1990	-	Sep 03-Sep 08	29,274	0	17,531	11,743	100.0%	11,744
1991	-	-	18,815	0	7,163	11,652	95.6%	11,139
1992	-	-	2,124	353	873	898	100.0%	898
1993	-	-	17,891	0	6,008	11,883	93.3%	11,083
1994	-	-	19,597	0	7,946	11,651	99.0%	11,539

^a Channel not operated prior to 1989.

Appendix 2. Daily sockeye counts, by 15-minute period, from the Likely Bridge over the Quesnel River, 1994.
(count times only identified as a.m. or p.m.)

Date	Number of sockeye counted by time period								Mean
	A.M. count				P.M. count				
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	
15-Aug	5	50	28	35	-	-	-	-	30
16-Aug	143	92	45	48	-	-	-	-	82
17-Aug	458	364	260	70	-	-	-	-	288
18-Aug	381	174	184	198	-	-	-	-	234
19-Aug	409	295	211	238	-	-	-	-	288
20-Aug	414	542	-	-	100	605	-	-	415
21-Aug	408	315	-	-	407	379	-	-	377
22-Aug	317	311	-	-	43	127	-	-	200
23-Aug	68	31	-	-	54	54	-	-	52
24-Aug	11	10	-	-	59	88	-	-	42
25-Aug	237	200	-	-	136	116	-	-	172
26-Aug	368	412	-	-	137	214	-	-	283
27-Aug	612	272	-	-	419	421	-	-	431
28-Aug	650	611	-	-	176	215	-	-	413
29-Aug	570	629	-	-	176	215	-	-	398
30-Aug	570	629	-	-	163	372	-	-	434
31-Aug	400	363	-	-	388	237	-	-	347
01-Sep	316	346	-	-	281	287	-	-	308
02-Sep	314	213	-	-	88	84	126	-	165
03-Sep	84	57	117	-	31	47	67	-	67
04-Sep	196	262	166	-	27	26	60	-	123
05-Sep	167	282	252	-	67	73	116	-	160
06-Sep	116	105	79	-	57	76	65	-	83
07-Sep	35	56	69	-	8	17	17	-	34
08-Sep	17	62	80	-	139	78	63	-	73
09-Sep	107	112	84	-	150	119	115	-	115
10-Sep	146	185	153	-	82	4	6	-	96 ^a
11-Sep	218	237	304	-	181	114	78	-	189
12-Sep	232	205	244	-	133	130	78	-	170
13-Sep	87	116	39	-	29	96	97	-	77
14-Sep	25	35	17	-	20	26	23	-	24
15-Sep	10	15	18	-	37	34	58	-	29
16-Sep	20	23	34	-	32	20	15	-	24
17-Sep	29	37	25	-	8	11	7	-	20
18-Sep	46	37	43	-	16	105	93	-	57
19-Sep	43	53	28	-	10	49	50	-	39
20-Sep	38	32	9	-	21	30	49	-	30
21-Sep	50	31	33	-	42	16	43	-	36
22-Sep	15	19	24	-	14	19	11	-	17
23-Sep	18	5	13	-	13	25	10	-	14
24-Sep	7	11	14	-	9	11	10	-	10
25-Sep	13	6	5	-	7	4	7	-	7
26-Sep	2	3	3	-	-	-	-	-	3
27-Sep	3	1	6	-	1	2	1	-	2
28-Sep	2	8	9	-	5	1	9	-	6
29-Sep	0	2	0	-	0	2	3	-	1
30-Sep	1	1	0	-	1	2	4	-	2
01-Oct	0	0	0	-	1	1	3	-	1
Mean	175	164	76	118	90	108	44	-	135

^a Kayakers disrupted the sockeye migration for last two counts of the day.

Appendix 3a. Daily application of disk tags, by location and sex (field estimate), to sockeye salmon in the Horsefly River, 1994.

Date	Reach	Number of sets	Original field estimate of sex composition			Recaptures ^a		
			Male	Female	Jack	Male	Female	Jack
23-Aug	Lower 6	6	172	204	0	3	2	0
24-Aug	Lower 6	5	115	137	0	0	4	0
25-Aug	Lower 6	3	82	94	0	0	5	0
26-Aug	Lower 6	5	97	99	0	10	8	0
27-Aug	Lower 6	3	6	10	0	0	0	0
28-Aug	Upper 1,2,4	3	213	171	0	1	0	0
29-Aug	Lower 6	4	260	299	0	7	10	0
30-Aug	Lower 6	4	272	269	0	2	2	0
31-Aug	Lower 6	4	272	337	0	14	9	0
01-Sep	Lower 6	4	299	431	0	21	19	0
02-Sep	Lower 6	4	182	196	0	7	6	0
03-Sep	Lower 6	4	103	145	0	2	10	0
04-Sep	Lower 6	4	84	124	0	7	10	0
05-Sep	Lower 6	4	56	74	0	3	4	0
06-Sep	Lower 6	4	44	59	0	5	6	0
07-Sep	Lower 6	4	3	0	0	0	0	0
08-Sep	Lower 6	6	16	10	0	1	1	0
09-Sep	Lower 6	6	19	37	0	1	0	0
10-Sep	Lower 6	6	26	43	0	1	3	0
11-Sep	Lower 6	4	29	35	0	0	0	0
12-Sep	Lower 6	4	23	24	0	1	4	0
13-Sep	Lower 6	4	26	56	0	1	3	0
14-Sep	Lower 6	5	24	25	0	2	3	0
15-Sep	Lower 6	4	6	15	0	5	3	0
16-Sep	Lower 6	0	0	0	0	0	0	0
17-Sep	Lower 6	5	9	9	0	0	1	0
18-Sep	Lower 6	0	0	0	0	0	0	0
19-Sep	Lower 6	0	0	0	0	0	0	0
20-Sep	Lower 6	5	6	19	0	0	0	0
21-Sep	Lower 6	6	3	7	0	0	0	0
Total	-	-	2,447	2,929	0	94	113	0

^a One hundred and eighty-four fish were recaptured once, 8 were recaptured twice, one was recaptured three times and one was recaptured four times.

Appendix 3b. Daily application of disk tags, by location and sex (correction for sex identification error), to sockeye salmon in the Horsefly River, 1994, (corrected for emigration through McKinley fence and Summit Creek).

Date	Reach	Number of sets	Corrected for sex identification error ^a			Corrected for emigration ^b		
			Male	Female	Jack	Male	Femal ^c	Jack
23-Aug	Lower 6	6	168	208	0	155	196	0
24-Aug	Lower 6	5	112	140	0	100	140	0
25-Aug	Lower 6	3	80	96	0	80	84	0
26-Aug	Lower 6	5	95	101	0	95	101	0
27-Aug	Lower 6	3	6	10	0	6	10	0
28-Aug	Upper 1,2,4	3	208	176	0	196	151	0
29-Aug	Lower 6	4	254	305	0	217	280	0
30-Aug	Lower 6	4	266	275	0	253	263	0
31-Aug	Lower 6	4	265	344	0	253	331	0
01-Sep	Lower 6	4	292	438	0	279	425	0
02-Sep	Lower 6	4	178	200	0	153	200	0
03-Sep	Lower 6	4	101	147	0	88	147	0
04-Sep	Lower 6	4	82	126	0	82	125	0
05-Sep	Lower 6	4	55	75	0	30	63	0
06-Sep	Lower 6	4	43	60	0	31	48	0
07-Sep	Lower 6	4	3	0	0	3	0	0
08-Sep	Lower 6	6	16	10	0	16	10	0
09-Sep	Lower 6	6	18	38	0	18	38	0
10-Sep	Lower 6	6	25	44	0	13	44	0
11-Sep	Lower 6	4	28	36	0	28	24	0
12-Sep	Lower 6	4	22	25	0	22	25	0
13-Sep	Lower 6	4	25	57	0	25	57	0
14-Sep	Lower 6	5	23	26	0	23	14	0
15-Sep	Lower 6	4	6	15	0	6	15	0
16-Sep	Lower 6	0	0	0	0	0	0	0
17-Sep	Lower 6	5	9	9	0	9	9	0
18-Sep	Lower 6	0	0	0	0	0	0	0
19-Sep	Lower 6	0	0	0	0	0	0	0
20-Sep	Lower 6	5	6	19	0	6	19	0
21-Sep	Lower 6	6	3	7	0	3	6	0
Total	-	-	2,389	2,987	0	2,190	2,825	0

^a See Methods for sex identification error correction procedure.

^b See Results for emigration correction procedure.

^c Also includes the removal of two females with short time out to recovery.

Appendix 4a. Incidence of net, lamprey and hook marks among adult male sockeye examined at tag application in the Horsefly River, 1994.^a

Date	Number of adult males examined	Net marks		Lamprey marks		Hook marks	
		Number	Percent	Number	Percent	Number	Percent
23-Aug	172	20	11.6%	15	8.7%	16	9.3%
24-Aug	115	13	11.3%	9	7.8%	0	0.0%
25-Aug	82	9	11.0%	6	7.3%	6	7.3%
26-Aug	97	12	12.4%	6	6.2%	3	3.1%
27-Aug	6	1	16.7%	0	0.0%	0	0.0%
28-Aug	213	14	6.6%	2	0.9%	2	0.9%
29-Aug	260	11	4.2%	17	6.5%	4	1.5%
30-Aug	272	16	5.9%	15	5.5%	2	0.7%
31-Aug	272	22	8.1%	21	7.7%	4	1.5%
01-Sep	299	31	10.4%	11	3.7%	3	1.0%
02-Sep	182	10	5.5%	2	1.1%	3	1.6%
03-Sep	103	4	3.9%	0	0.0%	3	2.9%
04-Sep	84	8	9.5%	3	3.6%	3	3.6%
05-Sep	56	3	5.4%	3	5.4%	0	0.0%
06-Sep	44	3	6.8%	0	0.0%	0	0.0%
07-Sep	3	0	0.0%	0	0.0%	0	0.0%
08-Sep	16	1	6.3%	0	0.0%	0	0.0%
09-Sep	19	2	-	0	-	0	-
10-Sep	26	1	3.8%	0	0.0%	0	0.0%
11-Sep	29	3	10.3%	0	0.0%	0	0.0%
12-Sep	23	5	21.7%	0	0.0%	0	0.0%
13-Sep	26	3	11.5%	0	0.0%	0	0.0%
14-Sep	24	1	4.2%	0	0.0%	0	0.0%
15-Sep	6	1	16.7%	0	0.0%	0	0.0%
16-Sep	0	0	-	0	-	0	-
17-Sep	9	1	11.1%	0	0.0%	0	0.0%
18-Sep	0	0	-	0	-	0	-
19-Sep	0	0	-	0	-	0	-
20-Sep	6	0	0.0%	0	0.0%	0	0.0%
21-Sep	3	0	0.0%	0	0.0%	1	33.3%
Total	2,447	195	8.0%	110	4.5%	50	2.0%

^a Not corrected for sex identification error.

Appendix 4b. Incidence of net, lamprey and hook marks among adult female sockeye examined at tag application in the Horsefly River, 1994.^a

Date	Number of adult females examined ^a	Net marks		Lamprey marks		Hook marks	
		Number	Percent	Number	Percent	Number	Percent
23-Aug	204	39	19.1%	7	3.4%	3	1.5%
24-Aug	137	29	21.2%	9	6.6%	1	0.7%
25-Aug	94	28	29.8%	7	7.4%	2	2.1%
26-Aug	99	22	22.2%	6	6.1%	2	2.0%
27-Aug	10	6	60.0%	1	10.0%	0	0.0%
28-Aug	171	18	10.5%	1	0.6%	0	0.0%
29-Aug	299	74	24.7%	17	5.7%	1	0.3%
30-Aug	269	56	20.8%	7	2.6%	0	0.0%
31-Aug	337	94	27.9%	14	4.2%	6	1.8%
01-Sep	431	132	30.6%	10	2.3%	2	0.5%
02-Sep	196	46	23.5%	0	0.0%	1	0.5%
03-Sep	145	33	22.8%	0	0.0%	0	0.0%
04-Sep	124	34	27.4%	9	7.3%	0	0.0%
05-Sep	74	20	27.0%	2	2.7%	0	0.0%
06-Sep	59	11	18.6%	1	1.7%	1	1.7%
07-Sep	0	0	-	0	-	0	-
08-Sep	10	1	10.0%	0	0.0%	0	0.0%
09-Sep	37	3	8.1%	0	-	0	-
10-Sep	43	6	14.0%	0	0.0%	0	0.0%
11-Sep	35	5	14.3%	0	0.0%	0	0.0%
12-Sep	24	6	25.0%	0	0.0%	0	0.0%
13-Sep	56	13	23.2%	0	0.0%	0	0.0%
14-Sep	25	2	8.0%	0	0.0%	0	0.0%
15-Sep	15	2	13.3%	2	13.3%	0	0.0%
16-Sep	0	0	-	0	-	0	-
17-Sep	9	5	55.6%	0	0.0%	0	0.0%
18-Sep	0	0	-	0	-	0	-
19-Sep	0	0	-	0	-	0	-
20-Sep	19	4	21.1%	0	0.0%	0	0.0%
21-Sep	7	2	28.6%	0	0.0%	0	0.0%
Total	2,929	691	23.6%	93	3.2%	19	0.6%

^a Not corrected for sex identification error.

Appendix 5a. Daily sockeye carcass recoveries, by location, mark status and sex, in the Horsefly River, 1994.

Date	Reach	Number of surveys	Disk tag present			Untagged			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
02-Sep	U1	-	0	0	0	174	103	0	174	103	0
	U2	-	0	1	0	119	49	0	119	50	0
	U3	-	0	0	0	164	101	0	164	101	0
	U4	-	2	2	0	171	94	0	173	96	0
	U5	-	2	0	0	314	189	0	316	189	0
03-Sep	U7	-	0	0	0	6	13	0	6	13	0
	L1	-	0	0	0	105	97	0	105	97	0
	L2	-	0	0	0	42	39	0	42	39	0
05-Sep	U1	-	2	2	0	333	206	0	335	208	0
	U2	-	0	0	0	212	129	0	212	129	0
	U3	-	0	1	0	264	180	0	264	181	0
	U4	-	0	1	0	292	167	0	292	168	0
	U5	-	3	4	0	588	462	0	591	466	0
	U6	-	2	2	0	396	298	0	398	300	0
06-Sep	L4	-	0	0	0	0	2	0	0	2	0
	L5	-	0	0	0	20	17	0	20	17	0
	L6	-	2	0 ^b	0	113	111	0	115	111	0
08-Sep	U1	-	3	12	0	630	610	0	633	622	0
	U2	-	2	1	0	223	189	0	225	190	0
	U3	-	10	5	0	550	416	0	560	421	0
	U4	-	6	4	0	520	352	0	526	356	0
	U5	^a	16	4	0	1,007	635	0	1,023	639	0
09-Sep	U5	-	0	0	0	108	144	0	108	144	0
	U6	-	8	5	0	889	633	0	897	638	0
10-Sep	L1	^a	7	5	0	743	514	0	750	519	0
	L2	^a	1	4	0	437	363	0	438	367	0
11-Sep	L1	-	0	1	0	134	43	0	134	44	0
	L2	-	5	2	0	419	335	0	424	337	0
	L3	-	0	0	0	4	1	0	4	1	0
	L4	-	0	0	0	6	3	0	6	3	0
	L5	-	2	3	0	79	79	0	81	82	0
	L6	-	4	2	0	490	421	0	494	423	0
	L7	-	2	2	0	39	28	0	41	30	0
12-Sep	L6	^a	0	0	0	77	80	0	77	80	0
13-Sep	U1	-	11	24	0	1,537	1,658	0	1,548	1,682	0
	U3	-	16	16	0	1,377	1,347	0	1,393	1,363	0
	U4	-	12	6	0	1,026	703	0	1,038	709	0
14-Sep	U2	^a	0	2	0	157	91	0	157	93	0
	U5	-	8	11	0	1,821	1,662	0	1,829	1,673	0
	L1	-	13	22	0	1,695	1,783	0	1,708	1,805	0
	L2	-	3	4	0	434	450	0	437	454	0
15-Sep	U2	-	6	9	0	596	538	0	602	547	0
	U6	-	7	8	0	1,338	1,309	0	1,345	1,317	0
	L2	-	17	12	0	1,214	1,082	0	1,231	1,094	0
	L3	-	2	1	0	178	216	0	180	217	0
	L4	-	0	1	0	56	91	0	56	92	0
	L6	-	16	10	0	1,132	1,238	0	1,148	1,248	0
	L7	-	4	8	0	305	431	0	309	439	0
16-Sep	L5	-	6	3	0	255	295	0	261	298	0
	L7	-	6	3	0	255	295	0	261	298	0
17-Sep	U1	-	8	13	0	891	1,281	0	899	1,294	0
	U2	-	3	5	0	302	336	0	305	341	0
	L1	-	2	0	0	150	198	0	152	198	0
	L2	-	1	8	0	76	13	0	77	21	0

Continued

Appendix 5a. Daily sockeye carcass recoveries, by location, mark status and sex, in the Horsefly River, 1994, continued.

Date	Reach	Number of surveys	Disk tag present			Untagged			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
19-Sep	U3	-	18	20	0	1,154	1,465	0	1,172	1,485	0
	U4	-	8	11	0	1,509	1,589	0	1,517	1,600	0
	U5	^a	12	8	0	1,687	1,471	0	1,699	1,479	0
20-Sep	U5	-	6	8	0	613	928	0	619	936	0
	U6	-	8	14	0	784	1,123	0	792	1,137	0
22-Sep	L1	-	11	10	0	1,162	1,520	0	1,173	1,530	0
	L2	-	15	17	0	1,347	1,776	0	1,362	1,793	0
23-Sep	L1	-	1	3	0	301	295	0	302	298	0
	L2	-	2	1	0	298	452	0	300	453	0
	L4	-	1	1	0	36	101	0	37	102	0
	L5	-	4	4	0	179	325	0	183	329	0
24-Sep	L2	-	0	0	0	44	59	0	44	59	0
	L3	-	3	9	0	795	783	0	798	792	0
	L6	-	12	21	0	991	2,126	0	1,003	2,147	0
	L7	-	6	6 ^b	0	468	679	1	474	685	1
25-Sep	U1	-	4	7	0	655	1,119	0	659	1,126	0
	U2	-	2	0	0	430	775	0	432	775	0
	U4	-	3	5	0	905	1,160	0	908	1,165	0
	U5	-	5	8	0	1,072	1,175	0	1,077	1,183	0
26-Sep	U2	-	1	2	0	155	279	0	156	281	0
	U3	-	6	12	0	836	1,370	0	842	1,382	0
	U6	-	2	6	0	549	1,172	0	551	1,178	0
	L7	-	0	0	0	61	60	0	61	60	0
28-Sep	L1	-	5	9	0	806	1,455	0	811	1,464	0
	L2	-	2	2	0	418	550	0	420	552	0
29-Sep	L2	-	0	4	0	179	410	0	179	414	0
	L3	-	0	2	0	120	175	0	120	177	0
	L4	-	1	1	0	38	121	0	39	122	0
	L5	-	0	2	0	63	104	0	63	106	0
01-Oct	L6	-	1	0	0	356	669	0	357	669	0
	L7	-	1	2	0	184	308	0	185	310	0
	U1	-	0	1	0	53	51	0	53	52	0
02-Oct	U2	-	0	0	0	25	65	0	25	65	0
	U3	-	0	0	0	24	32	0	24	32	0
	U4	-	0	0	0	20	17	0	20	17	0
	U5	-	0	0	0	14	19	0	14	19	0
	U6	-	0	0	0	36	79	0	36	79	0
03-Oct	U7	-	1	2	0	596	624	0	597	626	0
04-Oct	L1	-	0	0	0	40	156	0	40	156	0
05-Oct	L2	-	0	0	0	4	22	0	4	22	0
	L3	-	0	0	0	25	54	0	25	54	0
06-Oct	L4	-	0	0	0	14	28	0	14	28	0
	L5	-	0	0	0	14	24	0	14	24	0
07-Oct	L6	-	0	0	0	1	12	0	1	12	0
	L7	-	0	0	0	10	22	0	10	22	0

Continued

Appendix 5a. Daily sockeye carcass recoveries, by location, mark status and sex, in the Horsefly River, 1994, continued.

Date	Reach	Number of surveys	Disk tag present			Untagged			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
Total	U1	7	28	59	0	4,273	5,028	0	4,301	5,087	0
	U2	9	14	20	0	2,219	2,451	0	2,233	2,471	0
	U3	7	50	54	0	4,369	4,911	0	4,419	4,965	0
	U4	7	31	29	0	4,443	4,082	0	4,474	4,111	0
	U5	9	52	43	0	7,224	6,685	0	7,276	6,728	0
	U6	6	27	35	0	3,992	4,614	0	4,019	4,649	0
	U7	2	1	2	0	602	637	0	603	639	0
	L1	9	39	50	0	5,136	6,061	0	5,175	6,111	0
	L2	12	46	54	0	4,912	5,551	0	4,958	5,605	0
	L3	5	5	12	0	1,122	1,229	0	1,127	1,241	0
	L4	6	2	3	0	150	346	0	152	349	0
	L5	6	10	17	0	660	980	0	670	997	0
	L6	7	35	33	0	3,160	4,657	0	3,195	4,690	0
	L7	6	15	13	0	1,017	1,392	1	1,032	1,405	1
	Total	-	355	424	0	43,279	48,624	1	43,634	49,048	1

^a Partial survey.

^b One disk tag recovery excluded because elapsed time between release and recovery was less than five days.

Appendix 5b. Daily sockeye live counts and carcass recoveries, by location, mark status and sex, in Little Horsefly River, 1994.

Date	Live count	Number of surveys	Disk tag present			Untagged			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
17-Sep	100	-	0	0	0	10	10	0	10	10	0
29-Sep	15	-	0	0	0	6	4	0	6	4	0
Total	-	2	0	0	0	16	14	0	16	14	0

Appendix 5c. Daily sockeye live counts and carcass recoveries, by location, mark status and sex, in Moffat Creek, 1994.

Date	Live count	Number of surveys	Disk tag present			Untagged			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
18-Sep	80	-	0	3	0	41	81	0	41	84	0
30-Sep	0	-	1	0	0	36	76	0	37	76	0
Total	-	2	1	3	0	77	157	0	78	160	0

Appendix 5d. Daily sockeye live counts and carcass recoveries, by location, mark status and sex, in upper McKinley Creek, 1994.

Date	Live count	Number of surveys	Disk tag present			Untagged			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
12-Sep	441	-	0	0	0	107	100	0	107	100	0
22-Sep	45	-	0	0	0	1	12	0	1	12	0
Total	-	2	0	0	0	108	112	0	108	112	0

Appendix 5e. Daily carcass recoveries, by mark status and sex, from the enumeration fence in McKinley Creek, 1994.

Appendix 5e. Daily carcass recoveries, by mark status and sex, from the enumeration fence in McKinley Creek, 1994.

Date	Live count	Number of surveys	Disk tag present			Untagged			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
24-Aug	-	-	0	0	0	0	1	0	0	1	0
27-Aug	-	-	0	0	0	1	0	0	1	0	0
28-Aug	-	-	0	0	0	1	0	0	1	0	0
29-Aug	-	-	0	0	0	2	0	0	2	0	0
30-Aug	-	-	0	0	0	5	4	0	5	4	0
31-Aug	-	-	0	0	0	7	3	0	7	3	0
01-Sep	-	-	0	0	0	9	3	0	9	3	0
02-Sep	-	-	0	0	0	15	4	0	15	4	0
03-Sep	-	-	0	0	0	11	10	0	11	10	0
04-Sep	-	-	1	0	0	28	12	0	29	12	0
05-Sep	-	-	1	0	0	34	15	0	35	15	0
06-Sep	-	-	0	1	0	67	30	0	67	31	0
07-Sep	-	-	0	1	0	51	19	0	51	20	0
08-Sep	-	-	1	1	0	61	32	0	62	33	0
09-Sep	-	-	0	0	0	87	49	0	87	49	0
10-Sep	-	-	1	0	0	69	35	0	70	35	0
11-Sep	-	-	1	0	0	75	47	0	76	47	0
12-Sep	-	-	0	1	0	124	67	0	124	68	0
13-Sep	-	-	2	1	0	129	78	1	131	79	1
14-Sep	-	-	0	1	0	100	63	0	100	64	0
15-Sep	-	-	2	1	0	107	68	0	109	69	0
16-Sep	-	-	1	1	0	67	58	0	68	59	0
17-Sep	-	-	1	0	0	87	88	0	88	88	0
18-Sep	-	-	1	0	0	109	114	0	110	114	0
19-Sep	-	-	3	0	0	105	103	0	108	103	0
20-Sep	-	-	1	1	0	41	75	0	42	76	0
21-Sep	-	-	0	3	0	91	118	0	91	121	0
22-Sep	-	-	0	0	0	101	123	0	101	123	0
23-Sep	-	-	0	0	0	62	85	0	62	85	0
24-Sep	-	-	0	1	0	33	68	0	33	69	0
25-Sep	-	-	0	0	0	21	42	0	21	42	0
26-Sep	-	-	0	0	0	19	29	0	19	29	0
27-Sep	-	-	0	0	0	8	20	0	8	20	0
28-Sep	-	-	0	0	0	15	27	0	15	27	0
									0	0	0
Total	-	-	16	13	0	1,742	1,490	1	1,758	1,503	1

Appendix 6. Daily number of sockeye carcasses examined and disk tags recovered, by location and sex, during the re-survey of the Horsefly River, 1994.

Date	Reach	Number of surveys	Disk tag present			Total examined			Disk tag incidence		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
16-Sep	U1	^a	0	1	-	185	185	-	0.000	0.005	-
	U2	-	1	0	-	268	240	-	0.004	0.000	-
	U3	-	0	1	-	686	532	-	0.000	0.002	-
	U4	-	0	4	-	901	695	-	0.000	0.006	-
	U5	-	1	0	-	518	620	-	0.002	0.000	-
	U6	-	0	0	-	408	317	-	0.000	0.000	-
27-Sep	U2	-	3	1	-	306	625	-	0.010	0.002	-
	U3	-	4	2	-	726	1,212	-	0.006	0.002	-
	U4	-	3	5	-	1,316	1,896	-	0.002	0.003	-
	U5	-	5	6	-	2,932	5,329	-	0.002	0.001	-
28-Sep	L1	-	5	2	-	1,054	1,378	-	0.005	0.001	-
	L2	^a	1	2	-	509	921	-	0.002	0.002	-
29-Sep	L2	-	1	1	-	962	1,275	-	0.001	0.001	-
	L3	-	0	0	-	407	391	-	0.000	0.000	-
	L4	^a	0	0	-	54	82	-	0.000	0.000	-
01-Oct	L5	-	2	0	-	168	294	-	0.012	0.000	-
	L6	-	3	3	-	1,333	2,332	-	0.002	0.001	-
Total	U1	1	0	1	-	185	185	-	0.000	0.005	-
	U2	2	4	1	-	574	865	-	0.007	0.001	-
	U3	2	4	3	-	1,412	1,744	-	0.003	0.002	-
	U4	2	3	9	-	2,217	2,591	-	0.001	0.003	-
	U5	2	6	6	-	3,450	5,949	-	0.002	0.001	-
	U6	1	0	0	-	408	317	-	0.000	0.000	-
	L1	1	5	2	-	1,054	1,378	-	0.005	0.001	-
	L2	2	2	3	-	1,471	2,196	-	0.001	0.001	-
	L3	1	0	0	-	407	391	-	0.000	0.000	-
	L4	1	0	0	-	54	82	-	0.000	0.000	-
	L5	1	2	0	-	168	294	-	0.012	0.000	-
	L6	1	3	3	-	1,333	2,332	-	0.002	0.001	-
Total	-	-	29	28	-	12,733	18,324	0	0.002	0.002	-

^a Partial surveys.

Appendix 7. Fecundity sampling results and analytic details for sockeye salmon captured in the Horsefly River, 1994.

Sample number	Age	Standard length (cm) ^a	Skein weight (g)	Skein sub-sample		Estimated fecundity	Actual fecundity	Misc. eggs	Adjusted fecundity
				Weight (g)	Egg count				
1	4 ₂	49.2	231.4	110.5	1,291	2,704		2	2,706
2	4 ₂	48.5	225.6	123.9	1,437	2,617	2,624	5	2,629
3	4 ₂	53.6	255.4	110.5	1,226	2,834		9	2,843
4	4 ₂	49.2	202.6	103.5	1,099	2,151		6	2,157
5	4 ₂	53.0	302.3	160.2	1,667	3,146	3,168	3	3,171
6	4 ₂	50.7	161.5	102.0	1,677	2,655		24	2,679
7	4 ₂	52.5	247.9	108.6	1,432	3,269		6	3,275
8	4 ₂	51.9	296.4	122.7	1,498	3,619		12	3,631
9	4 ₂	52.4	298.5	134.0	1,393	3,103		6	3,109
10	4 ₂	56.0	307.8	139.7	1,446	3,186	3,149	0	3,149
11	4 ₂	49.5	231.0	105.8	1,094	2,389		2	2,391
12	4 ₂	48.8	283.8	116.6	1,368	3,330		3	3,333
13	4 ₂	52.0	225.3	110.0	1,229	2,517		0	2,517
14	4 ₂	51.5	291.8	122.5	1,263	3,009		9	3,018
15	4 ₂	49.0	238.6	133.6	1,453	2,595	2,587	10	2,597
16	4 ₂	52.3	377.2	145.1	1,243	3,231		10	3,241
17	4 ₂	53.0	270.9	117.2	1,323	3,058		15	3,073
18	4 ₂	53.0	278.2	120.2	1,325	3,067		22	3,089
19	4 ₂	51.0	223.5	134.0	1,427	2,380	2,380	16	2,396
20	4 ₂	55.2	364.4	142.0	1,362	3,495		10	3,505
21	4 ₂	51.9	246.1	113.4	1,423	3,088		10	3,098
22	4 ₂	52.0	322.0	120.0	1,354	3,633		2	3,635
23	4 ₂	54.0	305.3	198.1	2,190	3,375	3,376	2	3,378
24	4 ₂	54.2	283.9	132.5	1,491	3,195		3	3,198
25	4 ₂	51.5	241.6	103.3	1,427	3,337		0	3,337
26	4 ₂	53.0	289.6	116.3	1,277	3,180		5	3,185
27	4 ₂	53.5	266.3	179.7	2,012	2,982	2,970	2	2,972
28	4 ₂	54.8	362.8	141.3	1,323	3,397		3	3,400
29	4 ₂	55.5	339.9	142.3	1,507	3,600		4	3,604
30	4 ₂	53.3	290.7	120.3	1,335	3,226		2	3,228
31	4 ₂	44.9	176.6	121.1	1,333	1,944	1,957	0	1,957
32	4 ₂	52.7	302.0	122.6	1,228	3,025		5	3,030
33	4 ₂	51.0	227.9	105.3	1,288	2,788		1	2,789
34	4 ₂	53.0	249.0	120.8	1,372	2,828		4	2,832
35	4 ₂	53.5	254.5	110.7	1,132	2,602		2	2,604
36	4 ₂	52.2	225.3	124.1	1,765	3,204	3,205	1	3,206
37	4 ₂	53.1	282.4	115.8	1,197	2,919		3	2,922
38	4 ₂	51.6	250.7	110.3	1,280	2,909		3	2,912
39	4 ₂	51.8	199.8	102.2	1,397	2,731		3	2,734
40	4 ₂	52.9	304.7	157.9	1,391	2,684	2,721	6	2,727
41	4 ₂	53.1	259.1	110.0	1,035	2,438		0	2,438
42	4 ₂	54.4	287.1	115.5	1,218	3,028		0	3,028
43	4 ₂	54.3	361.0	143.2	1,437	3,623		9	3,632
1	5 ₂	57.4	364.0	142.4	1,414	3,614		5	3,619
2	5 ₂	49.4	253.5	110.0	1,189	2,740		17	2,757
3	5 ₂	56.4	417.1	160.6	1,443	3,748		12	3,760
4	5 ₂	57.3	312.8	121.8	1,349	3,464		10	3,474
5	5 ₂	60.7	508.3	181.1	1,761	4,943		0	4,943
6	5 ₂	59.2	467.0	175.1	1,688	4,502		4	4,506
7	5 ₂	59.0	390.8	148.6	1,550	4,076		1	4,077
Mean	4 ₂	52.2	270.8	125.3	1,388	2,979	2,814	6	2,985
	5 ₂	57.1	387.6	148.5	1,485	3,870	-	7	3,877

^a Actual measurements; not adjusted for shrinkage which occurs in carcass recoveries.

Appendix 8a. 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 lower Horsefly River spawning grounds, 1994.

Location	Sex	Sampling Period	Age	Sample size	Percent	Standard length (cm) ^a		POH length (cm) ^a	
						Mean	Standard deviation	Mean	Standard deviation
Lower Horsefly River	Male	Sept. 13	5 ₃	0	0.0%	-	-	-	-
			5 ₂	3	5.1%	60.1	2.4	52.4	2.2
			4 ₂	56	94.9%	55.8	2.0	48.7	0.8
			3 ₂	0	0.0%	-	-	-	-
			Unaged	1	-	61.6	-	55.3	-
		Sept. 21	5 ₃	0	0.0%	-	-	-	-
			5 ₂	2	3.6%	61.3	0.3	55.0	1.5
			4 ₂	54	96.4%	55.1	2.2	48.3	1.9
			3 ₂	0	0.0%	-	-	-	-
			Unaged	4	-	56.1	1.1	48.8	0.4
		Sept. 26	5 ₃	1	1.8%	56.0	-	47.9	-
			5 ₂	6	10.5%	61.2	4.6	53.6	4.0
			4 ₂	50	87.7%	55.2	2.3	48.3	1.8
			3 ₂	0	0.0%	-	-	-	-
			Unaged	3	-	55.4	0.5	48.2	0.9
		Total	5 ₃	1	0.6%	56.0	-	47.9	-
			5 ₂	11	6.4%	60.9	3.4	53.5	3.2
			4 ₂	160	93.0%	55.4	2.1	48.4	1.8
			3 ₂	0	0.0%	-	-	-	-
			Unaged	8	-	56.5	2.2	49.4	2.5
	Female	Sept. 13	5 ₃	0	0.0%	-	-	-	-
			5 ₂	6	10.3%	55.8	3.1	50.3	2.7
			4 ₂	52	89.7%	50.9	1.9	46.1	1.6
			Unaged	2	-	53.0	-	47.4	-
		Sept. 21	5 ₃	0	0.0%	-	-	-	-
			5 ₂	7	11.9%	56.8	1.9	51.2	1.7
			4 ₂	52	88.1%	51.2	1.6	46.3	1.3
			Unaged	1	-	51.0	-	46.0	-
		Sept. 26	5 ₃	0	0.0%	-	-	-	-
			5 ₂	4	7.4%	55.6	1.6	50.1	1.9
			4 ₂	50	92.6%	50.8	1.8	46.0	1.6
			Unaged	6	-	50.9	1.4	46.2	1.2
		Total	5 ₃	0	0.0%	-	-	-	-
			5 ₂	17	9.9%	56.2	2.3	50.7	2.1
			4 ₂	154	90.1%	51.0	1.8	46.2	1.5
			Unaged	9	-	51.2	1.4	46.3	1.1

^a Mean lengths and standard deviations were calculated from length data rounded to the nearest millimeter (+/-0.05mm).

Appendix 8b. 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 upper Horsefly River spawning grounds, 1994.

Location	Sex	Sampling Period	Age	Sample size	Percent	Standard length (cm) ^a		POH length (cm) ^a	
						Mean	Standard deviation	Mean	Standard deviation
Upper Horsefly River	Male	Sept. 15	5 ₃	0	0.0%	-	-	-	-
			5 ₂	2	3.4%	61.7	0.7	54.0	0.4
			4 ₂	57	96.6%	55.3	1.7	48.6	1.5
			3 ₂	0	0.0%	-	-	-	-
			Unaged	1	-	55.4	-	49.5	-
		Sept. 19	5 ₃	0	0.0%	-	-	-	-
			5 ₂	2	3.6%	59.4	0.2	52.0	0.1
			4 ₂	54	96.4%	55.1	2.1	48.5	1.6
			3 ₂	0	0.0%	-	-	-	-
			Unaged	4	-	54.7	1.7	48.7	1.4
		Sept. 25	5 ₃	0	0.0%	-	-	-	-
			5 ₂	6	10.5%	61.5	2.0	53.8	1.9
			4 ₂	51	89.5%	55.6	1.7	48.5	1.6
			3 ₂	0	0.0%	-	-	-	-
			Unaged	3	-	55.2	2.8	49.0	4.0
		Total	5 ₃	0	0.0%	-	-	-	-
			5 ₂	10	5.8%	61.1	1.8	53.5	1.6
			4 ₂	162	94.2%	55.3	1.9	48.5	1.6
			3 ₂	0	0.0%	-	-	-	-
			Unaged	8	-	54.9	1.9	48.9	2.3
	Female	Sept. 15	5 ₃	0	0.0%	-	-	-	-
			5 ₂	8	13.3%	56.9	3.3	51.6	3.3
			4 ₂	52	86.7%	51.7	2.1	47.0	1.7
			Unaged	0	-	-	-	-	-
		Sept. 19	5 ₃	1	1.7%	51.9	-	47.1	-
			5 ₂	4	6.9%	55.0	5.3	51.6	6.4
			4 ₂	53	91.4%	51.4	1.8	46.9	1.7
			Unaged	2	-	53.8	5.3	48.7	4.6
		Sept. 25	5 ₃	1	1.7%	51.0	-	45.2	-
			5 ₂	2	3.4%	57.8	0.4	50.1	1.9
			4 ₂	56	94.9%	51.9	1.8	46.5	1.4
			Unaged	1	-	49.9	-	44.0	-
		Total	5 ₃	2	1.1%	51.5	0.6	46.2	1.3
			5 ₂	14	7.9%	56.5	3.7	51.3	3.2
			4 ₂	161	91.0%	51.7	1.9	46.7	1.6
			Unaged	3	-	52.5	4.4	47.1	4.2

^a Mean lengths and standard deviations were calculated from length data rounded to the nearest millimeter (+/- 0.05mm).

Appendix 8c. 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 upper McKinley Creek spawning grounds, 1994.

Location	Sex	Sampling Period	Age	Sample size	Percent	Standard length (cm) ^a		POH length (cm) ^a	
						Mean	Standard deviation	Mean	Standard deviation
Upper McKinley Creek	Male	to	5 ₃	0	0.0%	-	-	-	-
			5 ₂	18	31.0%	59.3	2.5	51.5	2.4
			4 ₂	40	69.0%	55.5	2.1	48.1	1.7
			3 ₂	0	0.0%	-	-	-	-
	Female	to	Unaged	2	-	56.7	0.1	48.9	0.4
			5 ₃	0	0.0%	-	-	-	-
			5 ₂	34	59.6%	56.7	1.7	50.9	1.7
			4 ₂	23	40.4%	51.8	1.8	46.5	1.4
			Unaged	3	-	53.5	0.8	48.7	0.7

^a Mean lengths and standard deviations were calculated from length data rounded to the nearest millimeter (+/- 0.05mm).

Appendix 9a. Daily untagged sockeye counts, by one hour period, through the McKinley Creek fence, 1994.

Date	Temp. (C)	From: To:	Number of sockeye counted by time period										Daily Total	Mortalities on fence		
			7:00 8:00	8:00 9:00	9:00 10:00	10:00 11:00	11:00 12:00	12:00 13:00	13:00 14:00	14:00 15:00	15:00 16:00	16:00 17:00		Male	Female	Jack
24-Aug	19.4		-	-	119	-	-	1	1	1	5	-	127	-	1	-
25-Aug	20.0		-	-	-	305	-	-	24	46	0	-	375	-	-	-
26-Aug	19.0		-	-	32	71	-	-	6	112	17	-	238	-	-	-
27-Aug	20.0		-	670	596	1,247	737	107	605	360	146	-	4,468	1	-	-
28-Aug	20.0	274	1,048	757	46	-	-	410	-	-	-	-	2,535	1	-	-
29-Aug	20.0		-	625	741	687	115	208	196	-	-	-	2,572	2	-	-
30-Aug	19.0		-	322	309	409	420	204	112	205	0	-	1,981	5	4	-
31-Aug	17.0		-	518	716	587	309	334	303	306	72	-	3,145	7	3	-
01-Sep	18.0		-	303	586	320	237	157	11	115	113	-	1,842	9	3	-
02-Sep	15.0		-	51	470	359	238	401	305	508	106	-	2,438	15	4	-
03-Sep	14.0		-	193	738	493	335	219	205	250	59	-	2,492	11	10	-
04-Sep	15.0		-	-	377	523	226	115	220	244	-	-	1,705	28	12	-
05-Sep	17.5		-	-	382	307	231	238	137	59	-	-	1,354	34	15	-
06-Sep	15.0		-	-	356	504	327	262	255	240	-	192	2,136 ^a	67	30	-
07-Sep	15.0		-	-	374	346	222	94	176	156	-	-	1,368	51	19	-
08-Sep	14.0		-	-	181	372	226	205	204	120	-	-	1,308	61	32	-
09-Sep	15.0		-	-	89	111	94	94	107	101	5	-	601	87	49	-
10-Sep	12.0		-	-	152	213	119	27	94	75	-	-	680	69	35	-
11-Sep	14.5		-	-	115	101	56	61	58	78	-	-	469	75	47	-
12-Sep	12.0		-	-	53	72	97	64	62	34	-	-	382	124	67	-
13-Sep	14.0		-	-	43	71	132	81	65	85	-	-	477	129	78	1
14-Sep	14.0		-	-	158	153	108	164	95	102	-	-	780	100	63	-
15-Sep	15.0		-	-	255	204	142	139	104	101	-	-	945	107	68	-
16-Sep	16.0		-	-	54	59	81	74	73	82	-	-	423	67	58	-
17-Sep	11.0		-	-	-	-	52	-	-	-	-	-	52	87	88	-
18-Sep	15.0		-	-	20	50	2	10	39	-	-	-	121	109	114	-
19-Sep	15.0		-	-	15	34	17	25	19	26	23	-	159	105	103	-
20-Sep	14.0		-	-	10	5	11	-	10	8	-	-	44	41	75	-
21-Sep	11.0		-	-	-	-	52	45	19	16	6	-	138	91	118	-
22-Sep	13.0		-	-	-	-	-	-	-	-	-	-	0	101	123	-
23-Sep	13.0		-	-	-	-	14	-	-	-	-	-	14	62	85	-
24-Sep	-		-	-	-	-	-	-	-	-	-	-	0	33	68	-
25-Sep	14.0		-	-	-	-	20	-	-	-	-	-	20	21	42	-
26-Sep	14.0		-	-	-	-	-	-	-	-	-	-	0	19	29	-
27-Sep	14.0		-	-	-	-	-	-	-	-	-	-	0	8	20	-
28-Sep	14.0		-	-	-	-	-	-	-	-	-	-	0	15	27	-
Total													35,389	1,742	1,490	1

^a Count done between 19:00 hrs and 20:00 hrs.

Appendix 9c. Daily chinook counts, by one hour period, through the McKinley Creek fence, 1994.

Number of chinook counted by time period														
Temp.	From:	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	Daily		
Date	(C)	To:	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	Total	
24-Aug	19.4		-	-	-	11	-	1	-	-	-	-	12	
25-Aug	20.0		-	-	-	1	-	-	-	-	-	-	1	
26-Aug	19.0		-	-	1	-	-	-	2	-	-	-	3	
27-Aug	20.0		-	1	-	2	4	-	5	8	8	-	28	
28-Aug	20.0		2	3	10	-	-	-	10	-	-	-	25	
29-Aug	20.0		2	2	7	2	6	4	-	-	-	-	23	
30-Aug	19.0		-	-	3	4	4	2	2	2	-	-	17	
31-Aug	17.0		-	-	-	7	7	8	14	8	4	-	48	
01-Sep	18.0		-	-	8	2	5	10	1	2	1	-	29	
02-Sep	15.0		1	2	3	-	-	-	-	-	-	-	6	
03-Sep	14.0		-	-	-	-	3	2	1	-	-	-	6	
04-Sep	15.0		-	-	-	-	-	-	1	-	-	-	1	
05-Sep	17.5		-	-	-	-	-	2	-	-	-	-	2	
06-Sep	15.0		-	-	-	-	-	2	2	1	-	2	7 ^a	
07-Sep	15.0		-	-	-	1	1	-	2	2	-	-	6	
08-Sep	14.0		-	-	-	2	-	-	-	-	-	-	2	
09-Sep	15.0		-	-	-	-	-	-	-	-	-	-	0	
10-Sep	12.0		-	-	-	-	-	-	-	-	-	-	0	
11-Sep	14.5		-	-	-	-	-	2	-	-	-	-	2	
12-Sep	12.0		-	-	-	-	-	-	-	-	-	-	0	
13-Sep	14.0		-	-	-	-	-	-	-	-	-	-	0	
14-Sep	14.0		-	-	-	-	-	-	-	-	-	-	0	
15-Sep	15.0		-	-	-	-	-	-	-	-	-	-	0	
16-Sep	16.0		-	-	-	-	-	-	-	-	-	-	0	
17-Sep	11.0		-	-	-	-	-	-	-	-	-	-	0	
18-Sep	15.0		-	-	-	-	-	-	-	-	-	-	0	
19-Sep	15.0		-	-	-	-	-	-	-	1	-	-	1	
20-Sep	14.0		-	-	-	-	-	-	-	-	-	-	0	
21-Sep	11.0		-	-	-	-	-	-	-	-	-	-	0	
22-Sep	13.0		-	-	-	-	-	-	-	-	-	-	0	
23-Sep	13.0		-	-	-	-	-	-	-	-	-	-	0	
24-Sep	-		-	-	-	-	-	-	-	-	-	-	0	
25-Sep	14.0		-	-	-	-	-	-	-	-	-	-	0	
26-Sep	14.0		-	-	-	-	-	-	-	-	-	-	0	
27-Sep	14.0		-	-	-	-	-	-	-	-	-	-	0	
28-Sep	14.0		-	-	-	-	-	-	-	-	-	-	0	
Total													219	

^a Count done between 19:00 hrs and 20:00 hrs.

Appendix 9b. Daily tagged sockeye counts, by one hour period, through the McKinley Creek fence, 1994.

		Number of tagged sockeye counted by time period												Mortalities on fence	
	Temp.	From:	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	Daily		
Date	(C)	To:	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	Total	Male	Female
24-Aug	19.4		-	-	-	-	-	-	-	-	-	-	0	-	-
25-Aug	20.0		-	-	-	-	-	-	-	-	-	-	0	-	-
26-Aug	19.0		-	-	-	-	-	-	-	-	1	-	1	-	-
27-Aug	20.0		-	-	1	5	3	-	3	-	-	-	12	-	-
28-Aug	20.0		-	5	4	-	-	-	2	-	-	-	11	-	-
29-Aug	20.0		-	6	8	9	2	1	3	-	-	-	29	-	-
30-Aug	19.0		-	1	4	5	2	0	0	2	-	-	14	-	-
31-Aug	17.0		-	3	6	3	3	4	0	2	2	-	23	-	-
01-Sep	18.0		-	1	3	5	2	2	-	-	3	-	16	-	-
02-Sep	15.0		-	-	10	4	1	10	4	3	-	-	32	-	-
03-Sep	14.0		-	2	11	7	4	3	4	2	-	-	33	-	-
04-Sep	15.0		-	-	2	6	3	1	1	3	-	-	16	1	-
05-Sep	17.5		-	-	3	3	5	4	2	4	-	-	21	1	-
06-Sep	15.0		-	-	3	11	5	5	3	4	-	2	33 ^a	-	1
07-Sep	15.0		-	-	10	16	6	1	2	4	-	-	39	-	1
08-Sep	14.0		-	-	6	9	6	3	2	1	-	-	27	1	1
09-Sep	15.0		-	-	-	-	2	2	2	5	-	-	11	-	-
10-Sep	12.0		-	-	2	2	4	-	1	1	-	-	10	1	-
11-Sep	14.5		-	-	-	1	3	-	1	4	-	-	9	1	-
12-Sep	12.0		-	-	0	1	-	-	4	-	-	-	5	-	1
13-Sep	14.0		-	-	0	1	1	-	1	1	-	-	4	2	1
14-Sep	14.0		-	-	2	-	-	1	-	1	-	-	4	-	1
15-Sep	15.0		-	-	2	3	-	1	-	-	-	-	6	2	1
16-Sep	16.0		-	-	-	-	-	1	-	-	-	-	1	1	1
17-Sep	11.0		-	-	-	-	-	-	-	-	-	-	0	1	-
18-Sep	15.0		-	-	-	1	-	-	-	-	-	-	1	1	-
19-Sep	15.0		-	-	-	-	-	-	-	-	-	-	0	3	-
20-Sep	14.0		-	-	-	-	-	-	-	-	-	-	0	1	1
21-Sep	11.0		-	-	-	-	-	-	-	-	-	-	0	-	3
22-Sep	13.0		-	-	-	-	-	-	-	-	-	-	0	-	-
23-Sep	13.0		-	-	-	-	-	-	-	-	-	-	0	-	-
24-Sep	-		-	-	-	-	-	-	-	-	-	-	0	-	1
25-Sep	14.0		-	-	-	-	-	-	-	-	-	-	0	-	-
26-Sep	14.0		-	-	-	-	-	-	-	-	-	-	0	-	-
27-Sep	14.0		-	-	-	-	-	-	-	-	-	-	0	-	-
28-Sep	14.0		-	-	-	-	-	-	-	-	-	-	0	-	-
Total													358	16	13

^a Count done between 19:00 hrs and 20:00 hrs.

