Design and Evaluation of the 1995 Fraser River Pink Salmon *(Oncorhynchus gorbuscha)* Escapement Estimation Study

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DESIGN AND EVALUATION OF THE 1995 FRASER RIVER PINK SALMON (*Oncorhynchus gorbuscha*) ESCAPEMENT ESTIMATION STUDY

by

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ABSTRACT

Schubert, N.D., T.R. Whitehouse, and A.J. Cass. 1997. Design and evaluation of the 1995 Fraser River pink salmon (*Oncorhynchus gorbuscha*) escapement estimation study. Can. Tech. Rep. Fish. Aquat. Sci. 2178: 75 p.

In 1986, the Department of Fisheries and Oceans (DFO) assumed responsibility from the Interna-tional Pacific Salmon Fisheries Commission (IPSFC) for estimating the escapement of Fraser River pink sal-mon (*Oncorhynchus gorbuscha*). DFO adopted the IPSFC system of estimating the escapement of the major stocks using a combination of mainstem tagging and stock-specific mark-recapture studies. In 1993, the first major review of the escapement estimation system in over thirty years resulted in: a) the termination of the stock-specific studies; b) the implementation of a capture-live recapture study in the lower Fraser River with the objective of estimating the system-wide escapement with 95% confidence limits of ±25%; and c) the continuation of the Fraser River mainstem carcass recovery survey to permit the comparison of alternate population estimates. In 1995, the study design was modified to assess: nonrandom mixing of tagged and untagged fish between the capture and live recapture sites; and immediate stress-induced mortality.

In 1995, 24,990 pink salmon were captured in the lower Fraser River at Duncan Bar and released with cinch-up spaghetti tags and secondary marks. Live pink salmon were recaptured at two sites: Ridge-dale Bar, located on the south shore 13.5 km upstream from Duncan Bar; and Strawberry Island, located on the north shore 22.0 km upstream from Duncan Bar. At the former, 31,590 pink salmon were captured, of which 75 (0.24%) had tags. At the latter, 27,939 pink salmon were captured, of which 96 (0.34%) had tags. On the lower Fraser River spawning grounds, 274,047 carcasses were recovered, of which 521 (0.19%) had tags. Bias tests resulted in the rejection of both the Ridgedale Bar and Fraser River spawning ground sam-ples for population estimation. The 1995 escapement, estimated from the Duncan Bar application and Strawberry Island recovery data, was 7.2911 million pink salmon, of which 3.0431 million were male and 4.2480 were female.

The evaluation of nonrandom mixing concluded that contagious migrations of tagging fish occurred at Ridgedale Bar and possibly as far upstream as Strawberry Island. Consequently, the Ridgedale Bar sample was rejected for the purpose of population estimation; the Strawberry Island sample was provisionally accepted subject to an evaluation of mixing in 1997. The evaluation of stress detected evidence of both acute stress-induced mortality and chronic stress effects, although the latter evaluation was equivocal. Neither were quantifiable in their impact on the population estimate; therefore, further investigation was recom-mended for 1997. An evaluation of the Fraser River carcass sample concluded that it was unlikely to provide a representative sample of the system-wide escapement; cancellation of the 1997 survey was recommended.

RÉSUMÉ

Schubert, N.D., T.R. Whitehouse, and A.J. Cass. 1997. Design and evaluation of the 1995 Fraser River pink salmon (*Oncorhynchus gorbuscha*) escapement estimation study. Can. Tech. Rep. Fish. Aquat. Sci. 2178: 75 p.

En 1996, la Commission internationale des pêcheries de saumon du Pacifique chargeait le ministère des Pêches et des Océans (MPO) d'évaluer l'échappée de saumons roses (*Oncorhynchus gorbuscha*) du Fraser. Le MPO a adopté le système d'estimation de la Commission pour les principaux stocks en combinant des études de marquage dans le cours principal et des opérations de marquage-recapture propres à un stock. En 1993, la première grande étude du système d'évaluation de l'échappée effectuée depuis plus de trente ans a donné les résultats suivants : a) l'arrêt des études propres à un stock; b) la mise en oeuvre d'une étude de capture-recapture des poissons vivants dans le cours inférieur du Fraser dans le but d'évaluer l'échappée sur tout le réseau avec une limite de confiance de 95 % (±25 %), et c) la poursuite de l'étude de récupération des carcasses dans le cours principal du Fraser afin d'établir des comparaisons avec les autres estimations de la population. En 1995, le plan de l'étude a été modifié afin d'évaluer le mélange non aléatoire des poissons marqués et non marqués entre les points de capture et de recapture de poissons vivants, et la mortalité immédiate induite par le stress.

En 1995, 24 990 saumons roses ont été capturés dans le cours inférieur du Fraser à la barre Duncan et libérés après avoir été marqués avec des étiquettes spaghetti et des marques secondaires. Les saumons roses vivants ont été recapturés à deux endroits : à la barre Ridgedale, sur la rive sud, à 13,5 km en amont de la barre Duncan, et à l'île Strawberry, sur la rive nord, à 22,0 km en amont de la barre Duncan. Au premier endroit, 31 590 saumons roses ont été capturés, dont 75 (0,24 %) portaient des étiquettes. Au deuxième endroit, on en a capturé 27 939, dont 96 (0,34 %) avec des marques. Dans les frayères du cours inférieur du Fraser, 274 047 carcasses ont été récupérées, dont 521 (0,19 %) portaient des marques. Suite à l'évaluation des biais, on a rejeté les échantillons des frayères de la barre Ridgedale et du Fraser en vue de l'estimation de la population. L'échappée de 1995, estimée à partir des données sur l'application des marques à la barre Duncan et la récupération à l'île Strawberry, comptait 7,2911 millions de saumons roses, dont 3,0431 millions étaient des mâles et 4,2480, des femelles.

L'évaluation du mélange non aléatoire a montré que les migrations contagieuses des poissons marqués se sont produites à la barre Ridgedale et probablement jusqu'à l'île Strawberry en amont. Par conséquent, l'échantillon de la barre Ridgedale n'a pas été retenu pour l'estimation de la population; l'échantillon de l'île Strawberry a été accepté provisoirement, et il sera soumis à une évaluation du mélange en 1997. L'évaluation du stress a montré une mortalité aiguë induite par le stress et des effets de stress chronique, même si la dernière évaluation était équivoque. Aucun de ces effets n'avait un impact quantifiable sur l'estimation de la population. Une autre étude a donc été recommandée pour 1997. Suite à l'évaluation de l'échantillon de carcasses du Fraser, on a conclu qu'elles ne constitueraient guère un échantillon représentatif de l'échappée à l'échelle du réseau, et il a été recommandé d'annuler le relevé de 1997.

INTRODUCTION

The Fraser River system supports the largest odd-year pink *salmon (Oncorhynchus gorbuscha*) run in British Columbia (Anon. 1995). Historically, escapements were estimated using visual techniques which were poorly suited to the spawning grounds, areas which are typically turbid and subject to frequent fall floods. In 1957, resources became available for the development of more appropriate estimation techniques after the International Pacific Salmon Fisheries Commission (IPSFC) assumed responsibility for the management and assessment of the pink salmon resource. The IPSFC developed a two tiered escapement estimation system whereby the method selected for each stock was based on the number of spawners expected to return to the spawning grounds in a given year (Andrew and Webb MS 1987). For stocks with small expected returns (less than 25,000), a variety of stock-specific visual estimation methods were used. For stocks with large expected returns (more than 25,000), enumeration fences and mark-recapture studies were used.

In practice, the escapements of five stocks were routinely estimated using mark-recapture studies and the pooled Petersen estimator: the Seton, Thompson, Harrison and Vedder-Chilliwack tributary stocks and the Fraser mainstem stock. The tributary escapements were estimated from individual studies; the Fraser mainstem escapement was estimated by applying tags in the lower Fraser River at Duncan Bar and recovering carcasses throughout the watershed. In 1957 and 1959, the mainstem escapement was the difference between the sum of the tributary estimates and the system-wide estimate, as derived from the Duncan Bar tag application and all recoveries (Ward 1959; Vernon *et al.* 1964). In 1961, the mainstem escapement was estimated from the mainstem recoveries, and the Duncan Bar tag application total minus an assumed five percent tag loss and an estimate of the number of tags which escaped to the tributaries or were harvested in the river fisheries (Hourston *et al.* 1965). This system was implemented unchanged by the IPSFC in subsequent years and was adopted by the Department of Fisheries and Oceans (DFO) in 1987.

In a descriptive evaluation of the 1957 study, the IPSFC concluded that the study design was completely effective and would be adequate for future years (Anon. 1958). By 1959 (Vernon *et al.* 1964) and 1961 (Hourston *et al.* 1965), however, concerns were expressed regarding inaccuracies introduced by spatial and temporal application biases, mortality resulting from handling stress, the selective removal of tags by gill nets, and the failure to assess tag loss. Despite these concerns, there is no documentary evidence that any studies were ever implemented to evaluate these potential biases or, indeed, that any substantive changes were made to the 1961 study design until an evaluation of disk tag loss was conducted by DFO in 1989 (Cass and Whitehouse MS 1993). That study reported highly variable tag loss rates ranging from 1% to 26%, invalidating the five percent tag loss assumption of the previous three decades.

Further evaluation of the escapement estimation system did not occur until 1991, when a five million fish discrepancy was noted between the inseason gross escapement estimate based on hydoacoustic and test fishery data provided by the Pacific Salmon Commission (PSC) and the post season estimate based on escapement data provided by DFO. The PSC suggested that this discrepancy was due to some combination of nonrandom tag distributions, tag loss and handling mortality (Anon. 1994a), biases identical to those which concerned Vernon *et al.* (1964) and Hourston *et al.* (1965). In an evaluation of this issue, Schwarz and Taylor (MS 1995) concluded that, while nonrandom tag distributions were not a factor, they could not rule out other potential violations of the mark-recapture assumptions or a significant negative bias in the hydroacoustic and test fishery estimates.

In 1993, concerns regarding reduced project funding, a forecast record escapement, and the optimal allocation of sampling effort prompted the first major review of the escapement estimation system in over thirty years (Cass and Whitehouse MS 1993). The review and the recommendations of a subsequently formed working group led to a redesign of the 1993 escapement estimation study. The major recommendation, to estimate the system-wide escapement with 95% confidence limits of ±25%, resulted in two fundamental changes to the study design: a) a live recapture program was implemented and the results were compared to the mainstem carcass recovery program; and b) all tributary studies

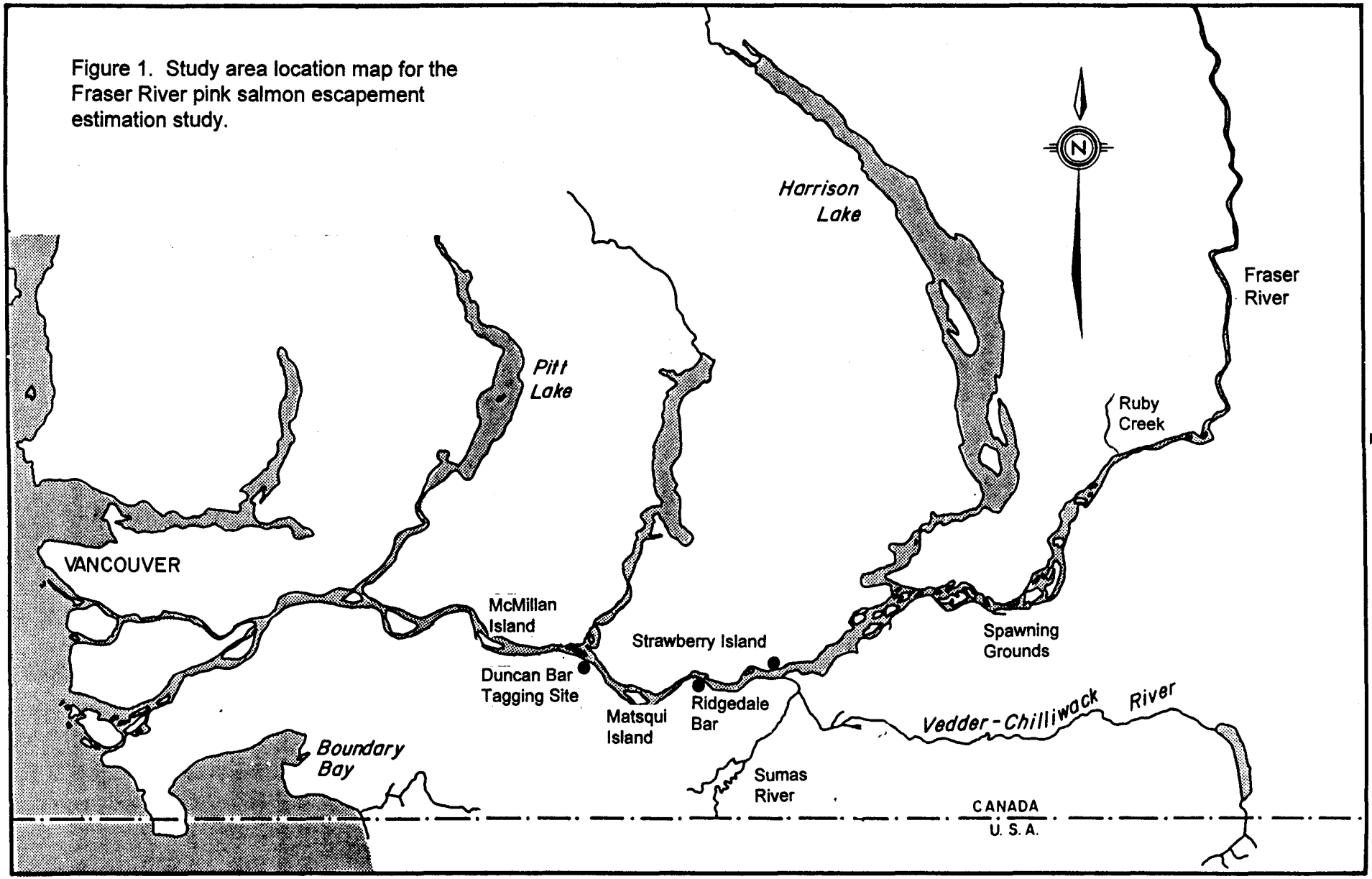


Figure 1. Study area location map for the Fraser River pink salmon escapement estimation study.

were terminated. While these changes eliminated the potential for future stock-specific assessments, they addressed the mandated budget reduction and produced an assessment program which was consistent with the fisheries management approach (Fraser River pink stocks are managed in aggregate because the individual stocks cannot be discriminated as they comigrate through the fisheries). Other study modifications implemented in 1993 (Cass *et al.* MS 1995) are described below:

- Tagging procedures were modified to: a) assess disk tag loss through a double tagging experiment; b) assess the utility of cinch-up spaghetti tags as a replacement for disk tags; c) reduce handling stress by limiting holding time to a maximum of 45 minutes; and d) assess the effect of holding time on disk tag recovery rates and distributions;
- Spawning ground recovery procedures were modified to: a) increase survey effort; b) make the surveys spatially and temporally more systematic; and c) estimate the number of disk tags missed during the initial survey;
- Analytic procedures were modified to assess the violation of the assumptions underlying the Petersen estimator by comparing estimates from the pooled and Stratified estimators.

In an evaluation of the 1993 study, the Pacific Stock Assessment Review Committee (Anon. 1994b) concluded that the basic structure of the 1993 study should be repeated in 1995, and recommended program changes intended to evaluate: a) non-random mixing of tagged and untagged fish between the capture and live recapture sites; b) acute handling mortality; and c) the vulnerability of disk tagged fish to alternate sampling gears or, alternately, replace disk tags with a tag type which would not make the fish more vulnerable to the expected in-river gill net fisheries. Specific changes to the 1995 study design to address these and other issues are described below:

- Tagging procedures were modified as follows: a) disk tags were replaced with cinch-up spaghetti tags to address concerns regarding the differential vulnerability of tagged fish to gill nets; b) opercular punches were applied to all tagged fish to assess tag loss; and c) two tag colours were used to assess recovery bias;
- The mixing of tagged and untagged fish was assessed by: a) increasing the duration of the tag application shift from eight hours in previous years to up to 12 hours; b) establishing a second live recapture site approximately 7 km downstream from the original site and on the opposite side of the river (this also addressed recovery sample size concerns); c) increasing the duration of the recovery shift to up to 10 hours and staggering shift start times, thereby increasing the effective recovery period to up to 12 hours per day; and d) assessing the magnitude of and tag incidence in non-shore oriented migrants by setting drifted gill nets outside the range of the beach seine nets;
- Handling stress was evaluated by: a) applying tags using normal and low stress handling procedures; and b) evaluating the tag incidence of carcasses near the tagging site, from the upstream end of McMillian Island to the upstream end of Matsqui Island.

This report documents the study design, field methods, analytic techniques and results of the 1995 Fraser River pink salmon escapement estimation study. Reported here are the 1995 escapement estimates, and the results of comparison of live and carcass recoveries, stress evaluations, and bias tests to assess mark-recapture assumptions. The analytic techniques for estimating escapement relied on the Stratified Population Analysis System (SPAS) software for common mark-recapture estimators (Arnason *et al.* 1996). The report concludes with a discussion of the results and recommendations for future studies.

STUDY AREA

The Fraser is the largest river in British Columbia, draining most of the southern half of the province. The river originates in the Rocky Mountains and flows north through the Rocky Mountain Trench then south through the Interior Plateau and Coast Mountains before turning west for the final 150 km to the Strait of Georgia. The current study focused on the lower 135 km below Ruby Creek (Fig. 1). In this area, the river flows through a wide alluvial valley bounded to the north by the Coast Mountains. The river channel has an aver-

age width of 600 m, with a maximum freshet width of 5 km in some areas (Fraser *et al.* 1982).

The geomorphology of the study area is distinctly different below and above the Sumas River mouth (Fig. 1). The lower area has a relatively low gradient and a the river is slow moving and deep as it flows primarily in a dyked, single broad channel. The river carries a heavy silt load and is tidal at all stages of the hydrograph as far upstream as Mission (Hoos and Packman 1974). All of the live capture sites were located in this part of the river. Fish capture and tagging occurred at Duncan Bar, which is located on the south shore 68 km from the mouth (Fig. 1). The capture site is located downstream from all spawning areas and has been used since the inception of the study in 1957. The site is a long, shallowly sloping gravel and sand beach, the wetted portion of which is heavily silted, especially at low tide. Live recapture occurred at Ridgedale Bar, located on the south shore 13.5 km upstream from Duncan Bar, and at Strawberry Island, located on the north shore 22 km upstream from Duncan Bar. The former is a short, shallowly sloping gravel and sand beach where, because the gradient is higher and tidal influence less, the substrate is much less silty than at Duncan Bar. The latter is a short, sharply sloping gravel and cobble beach located immediately downstream from the Sumas River mouth. The gradient here is higher and the current faster, resulting in a largely silt-free substrate.

In the upper area between the Sumas River and Ruby Creek, the gradient is higher and the river flows in a wandering gravel-bed channel that often braids into multiple channels separated by gravel bars and treed islands (Kellerhals *et al.* MS 1987). The spring freshet deposits large quantities of gravel, creating numerous bars and a constantly shifting river channel (Anon. 1963). The flood channel is wide, but as water levels decline in the fall, the river flows in several shallow, higher velocity channels where pink spawning can be heavy. For the purpose of the current study, this area was stratified into 17 sections (Fig. 2) to facilitate systematic sampling.

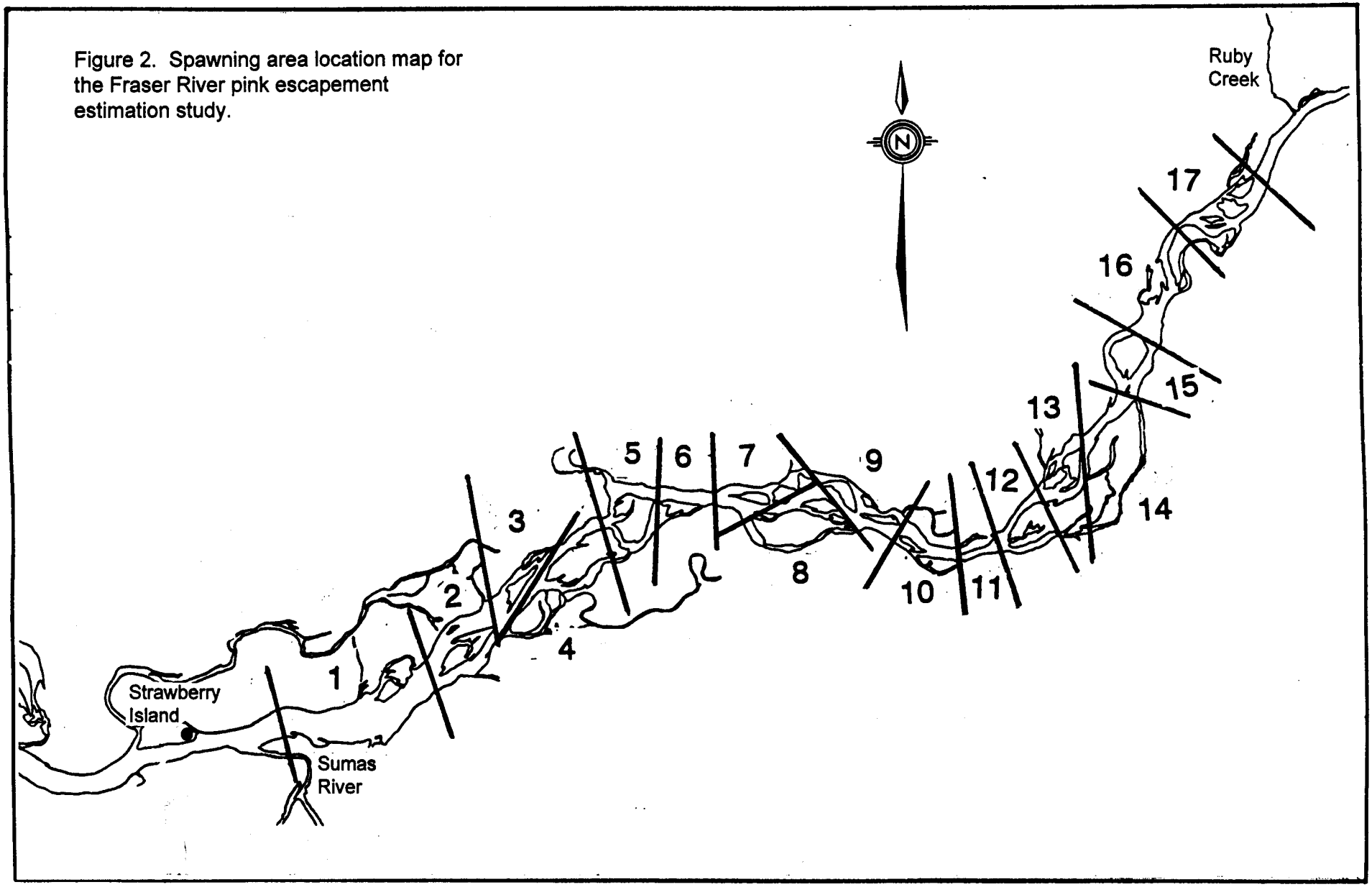
FIELD METHODS

TAG APPLICATION

The study objective was to apply tags in proportion to the daily abundance of pink salmon returning to the Fraser River system. Because an independent estimate of abundance was unavailable, proportional tag application was addressed by standardizing effort at 7-10 sets per day. In practice, however, proportional tagging was not achieved when abundance was high because the catch could not be processed within 45 minutes per set, a standard intended to minimize stress. Furthermore, it was often necessary to limit catches during the peak of the run by setting the net closer to shore and using only part of the net, operational practices consistent with those used over the last 16 years (R. Gerrard, Duncan Bar crew chief, pers. comm.).

Tagging began shortly after pink salmon were first reported in the PSC test fishery and continued daily until the run was virtually complete. Pinks were captured by an 8-12 person crew working a variety of shifts encompassing the period 7 a.m. and 7 p.m. A 150 m x 7.5 m x 5 cm-mesh beach seine net was set from a converted commercial gill net vessel in a downstream arc and withdrawn from the river to enclose an area of water along the river bank. Captured fish were held in the net until removal for tagging. Previously tagged fish were identified upon recapture and immediately processed to avoid additional stress. The tag number was recorded and the tag checked; if damaged by recapture, it was replaced with a new tag. Mortalities were removed from the river, and the tag number was deleted from the data set. Other species, and pinks which were damaged or showed advanced stages of maturation, were released untagged. The remaining fish were removed from the net and marked with cinch-up spaghetti tags in a wooden tray (12 cm x 20 cm x 100 cm) constructed with a flexible plastic bottom and a metre stick recessed in one side. Equal numbers of fish were representatively tagged using green or orange cinch-up tags, and using standard or low stress procedures. Standard procedures entailed tagging the fish in a tray elevated from the water surface and releasing it by throwing it a short distance over the net's cork line. Low stress procedures entailed tagging the fish in a tray immersed in 15 cm of water and releasing it by lowering a section of the cork line; at no time was the fish removed from the water. Handling time for both procedures averaged 25-30 seconds. In addition to the above, the following general fish handling guidelines were established in 1995: activity within

Figure 2. Spawning area location map for the Fraser River pink escapement estimation study.



the net was minimized to reduce siltation; fish were removed from the water only when a tagger was ready and processed as quickly as possible; when removed from the water, the fish were cradled in two hands rather than dangled by the caudal peduncle; and when released over the cork line, the fish were gently thrown the minimum necessary distance.

The 140 mm long cinch-up tag consisted of three components: a 47 mm long, 3 mm diameter plastic tube numbered with a unique code; an 89 mm long conically serrated plastic strap; and a 4 mm wide, hollow conical head with expandable teeth at the narrow end. The strap was threaded into a hollow 15 cm long stainless steel needle which was inserted with pliers through the musculature and pterygiophore bones approximately 12 mm below the anterior portion of the dorsal fin. The needle was then removed and the tag secured tightly over the dorsal surface by inserting the strap into the tag head. Each tagged fish received a secondary mark to permit an assessment of tag loss. One or two 7 mm diameter holes were punched through the right operculum of males and females, respectively, using a single hole punch. Care was taken to avoid gill tissue damage. Date of capture, tag number, nose-fork (NF) length (±0.1 cm), sex and marks (troll, gill net, lamprey or *Flexibacter columnaris* scars) were recorded for each fish released with a disk tag. Condition at release was recorded as 1 (swam away vigorously), 2 (swam away sluggishly) or 3 (required ventilation). The start and end time was recorded for each set.

LIVE RECOVERY

Beach Seine Net

Live recapture was conducted in the lower Fraser River at Ridgedale Bar (km 81.5) and Strawberry Island (km 90) (Fig. 1) with the objective of proportionally sampling the total return of pink salmon to the Fraser River system. This objective was addressed by standardizing effort at 7-12 sets per day. The crew worked approximately eight hours per day early and late in the study, and one of two nine-hour shifts (7 a.m. to 4 p.m.; 10 a.m. to 7 p.m.) during the main part of the migration. Alternate shifts were worked at each site, extending the effective daily monitoring period to 12 hours. Start times were switched weekly at each site.

At each site, pinks were captured using a 65 m x 7.5 m x 5.0 cm-mesh beach seine net which was set from a power boat by a six person crew. For each set, the catch was enumerated by species and released; pink salmon were recorded by sex, tag, secondary mark and mark status, and the tag number was recorded for all tagged fish. An experienced technician remained onsite to verify tag and mark identification.

Drifted Gill Net

Drifted gill nets were used at Ridgedale Bar and Strawberry Island to assess: a) whether substantial numbers of pink salmon migrated off-shore beyond the reach of the beach seine nets; and b) when off-shore migrants were detected, whether the spaghetti tag incidences in the beach seine and gill net samples were similar. The gill net was constructed from a 61 m x 4.6 m x 12.7 cm-mesh No. 19 light green web hung at a 2:1 ratio. It was set perpendicular to the shore by a two person crew in power boat and allowed to drift for 15 minutes. Early in the run, 2-8 sets were made daily at each site; near the peak, 9-13 sets were made on alternate days at each site. For each set, the catch was enumerated by species and released; pink salmon were recorded by sex, tag and secondary mark status, and the tag number recorded for all tagged fish.

CARCASS RECOVERY

Spawning Ground Survey

The lower Fraser River mainstem between the Sumas River and Ruby Creek was surveyed on foot during the die-off period. All known spawning areas in the 45 km recovery area were surveyed by a crew of 6-21 technicians (crew size was adjusted with carcass abundance) every three to seven days. The surveys began when carcasses were first observed and continued until the die-off was complete.

All carcasses which were retrievable along the shore were enumerated (predator kills were excluded from the survey), cut in two with a machete and returned to the river bank. Carcass recoveries were recorded by date, area, sex, tag and secondary mark status, carcass

condition (fresh, tainted or rotten) and female spawning success (0%, 50%, and 100% spawned). If a tag was present, it was retrieved and the tag number recorded before the carcass was processed.

Spawning Ground Resurvey

Previously surveyed carcasses were resurveyed throughout the recovery period every 3-11 days to estimate the number of tagged carcasses which had not been correctly identified during the main survey. The resurvey, conducted by an experienced technician, recorded carcasses by date, area, sex and tag status.

Tag Application Area Survey

The lower Fraser River mainstem between the east end of McMillan Island (km 57) and the east end of Matsqui Island (km 75) was surveyed by a two person crew during the tagging and early die-off period. The survey was restricted to the islands and the south shore of the Fraser River because log booms and a sharp drop-off precluded the deposition of carcasses along the north shore. The objective of the survey was to determine whether acute stress resulted in a higher tag incidence near the tagging site. We assumed that, because this area was well below all spawning areas, fresh carcasses recovered here would likely reflect handling stress. Daily procedures were identical to those described for the main survey, except the area was surveyed five times per week.

ANALYTIC PROCEDURES

Analytic procedures are presented in three sections. First, the data were evaluated and corrected for sex and tag identification error, tag loss, and acute stress effects. Second, a bias profile was developed by evaluating five potential biases; temporal, spatial, fish size, fish sex, and tag recognition. The purpose of this section was two-fold. The test results provided: a) tangible indicators of weaknesses in the study design which were presented in a format which was easily accessible for the planning of future studies; and b) the basis for more sophisticated evaluations of bias and of the need for the adoption of stratified estimators. Third, 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 438). The severity of temporal bias was evaluated by comparing the simple or pooled Petersen estimates with those calculated using a stratified Darroch estimator. The later were used if the confidence intervals did not overlap.

DATA CORRECTIONS

Sex Identification Error

The tag application data were corrected for sex identification error by comparing the sexes recorded at release and carcass recovery. Error may have occurred for two reasons: a) the development of sexually dimorphic traits was often not advanced and internal examinations could not be made; and b) sex may have been identified correctly but recorded in error during the sometimes hectic tagging operation. The Ridgedale Bar and Strawberry Island live recovery data were not corrected because we were unable to directly measure the error; the Duncan Bar correction was not applicable to these sites because both the sample populations and the individuals identifying them were different. The correction of carcass recovery data was unnecessary because identification of the sex of fully developed pink adults is relatively unambiguous; the few ambiguous recoveries were examined carefully and incised for internal examination. Sex identification error was corrected using the procedure described by Staley (1990) in the following steps. First, known errors detected at carcass recovery were corrected. Second, changes were made to fish which were not recovered based on the error rate found in the recovered tags. The data were stratified by application procedure (high or low stress), tag colour and fish size. Changes, made only for release dates on which errors were observed, were weighted by the error rate in the recovery sample as follows:

1) Estimated true number of males released with tags and secondary marks:

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

where:

M^*_m = the field estimate of the number of males released with tags and secondary marks;

Mt = the total number of pinks released with tags and secondary marks;

$R_{m,f}$ = the number of females recovered with tags which were released as males;

$R_{f,m}$ = the number of males recovered with tags which were released as females;

R_f = the number of females recovered with tags;

R_m = the number of males recovered with tags.

2) Estimated true number of females released with tags:

$$M_f = M_t - M_m$$

Tag Recognition Error

Resurvey data were used to correct the carcass recovery totals for tags which were missed in the initial survey. Note that, because tags were removed on the initial survey, we were unable to estimate the number of fish with only secondary marks which had been missed in the initial survey. Because the apparent tag loss rate was low, however, this bias was likely small. The number of missed tags was calculated by sex as follows:

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

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

where:

R_{is} = the number of tags recovered on the initial survey;

R_{rs} = the number of tags recovered on the resurvey;

C_{rs} = the number of carcasses examined on the resurvey;

C_{rs} = the number of carcasses examined on the initial survey.

Tag Loss

Because all fish released with a tag also received a permanent secondary mark, tag loss between application and live and carcass recovery was addressed by summing the recoveries with both tags and secondary marks and those with secondary marks only.

Handling Stress

Before testing the live and carcass recovery data for bias, we evaluated the application sample for handling and tagging stress in two ways. First, four tests were performed to determine whether specific tags should be excluded from the application sample: a) tagged carcasses recovered in the lower Fraser River between McMillan and Matsqui islands may have originated from fish which had been stressed by capture and tagging and died in the local area, or fish which migrated upstream, spawned normally, and were flushed downstream as carcasses. We assumed that any tagged carcass recovered in this area within five days of release by either the Duncan Bar tagging crew or the application area roving crew reflected acute handling stress and removed the fish from the application sample; b) the application sample was partitioned into fish tagged using the high and low stress methods. If a chi-square test showed a significant difference in the proportions recovered, the high stress group was removed from the samples; c) the application sample was partitioned into fish which required ventilation at release and those which did not. If a chi-square test showed a significant difference in the proportions recovered, the high stress group was removed from the samples; and d) an identical procedure was used to evaluate tagged fish which were recaptured in subsequent sets at Duncan Bar.

Second, a chi-square test was used to compare percent spawning success between marked and unmarked spawning ground recoveries. This test was not used to exclude specific data from the study, but to indicate whether capture and tagging stress was a systemic problem which must be addressed in the design of future studies.

TESTS FOR SAMPLING SELECTIVITY

Period

Temporal bias was assessed using chi-square tests of application and recovery data stratified by equal periods, approximately equal

effort (numbers of sets or passes through the sampling area), and approximately equal numbers of pinks tagged or recovered. Three stratifications were used to facilitate the interpretation of a positive test result. A positive result in all three stratifications would likely indicate a true bias, while a single positive result may represent an artifact of the selected stratification scheme. None of the three stratifications prejudges the appropriate stratification for use in population estimation, which is determined by the requirements of each stratified model.

Application sample bias (unequal probability of capture) was assessed by stratifying the recovery samples as above and comparing the mark incidence among recovery strata, where mark incidence was the proportion of the fish marked with a tag or secondary mark. Application bias was further tested by stratifying the live recapture data into three daily periods and comparing the mark incidence in each.

Recovery sample bias (non-random sampling in the recovery samples) was assessed by stratifying the application sample as above and comparing the proportions recovered among application strata in each of the recovery samples. Recovery bias was further tested by stratifying the application sample into three daily periods and comparing the proportions recovered in each of the recovery samples.

Location

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

Fish Size

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

Fish Sex

Sex related bias was assessed using chi-square tests. Application bias was examined by comparing the sex ratio of the marked and unmarked fish in the recovery samples. Recovery bias was examined in each of the three recovery samples by partitioning the application sample into recovered and non-recovered components and comparing the sex composition in each. For recovery sites with significant sex related bias, the population estimates were calculated from data stratified by sex.

Recovery Vulnerability of Tags

Recovery bias was assessed by applying tag with one of two colours, one which contrasted with the skin colour of the fish (orange) and one which did not (green), and comparing the proportions recovered at each site. This procedure evaluated whether: a) the presence of a highly noticeable tag would change the vulnerability of a fish to recovery as a carcass; and b) tag colour would influence the correct identification of a tagged fish during live recovery.

ESTIMATION OF SPAWNER POPULATION

Separate estimates of the escapement of pink salmon to the Fraser River system (including Indian fishery harvest above Duncan Bar) at the time of tag application were estimated from the live recoveries at Ridgedale Bar and Strawberry Island and the carcass recoveries in the lower Fraser River mainstem. The escapement estimates were calculated using: a) the simple or pooled Petersen estimator (Seber 1982; p 60); and b) the Darroch (Darroch 1961) estimator for stratified populations (Seber 1982; p 431-445) as described by Plante (1990) and Arnason *et al.* (1996). The Plante stratified estimator is the only method that gives maximum likelihood population estimates when the number of release strata is less than the number of recovery strata. For a description of the estimators, see Arnason *et al.* (1996) (p 29-31). Population estimates were calculated from mark-recapture data adjusted for sex identification error, stress effects and missed tags.

Table 1. Spaghetti tags applied at Duncan bar, live fish examined at Ridgedale Bar and Strawberry Island, carcasses recovered on the lower Fraser River mainstem spawning grounds, and spaghetti tags and secondary marks recovered, by sex and site, for Fraser River system study area pink salmon, 1995.

Sex	Site	Tags and marks applied [a]	Total live or dead fish examined [b]	Marks recovered					
				Tag and secondary mark	Secondary mark only	Tag only	Resurvey adjustment	Total	% recovered
Male	Duncan Bar	11,361	-	-	-	-	-	-	-
	Ridgedale Bar	-	14,767	40	0	0	0	40	0.35%
	Strawberry Island	-	12,326	45	0	0	0	45	0.40%
	Spawning grounds	-	106,524	181	5	0	22	208	1.83%
Female	Duncan Bar	13,629	-	-	-	-	-	-	-
	Ridgedale Bar	-	16,823	34	1	0	0	35	0.26%
	Strawberry Island	-	15,613	51	0	0	0	51	0.37%
	Spawning grounds	-	167,523	287	2	0	24	313	2.30%

[a] Corrected for sex identification errors; immediate mortalities removed.

[b] Live at Ridgedale Bar and Strawberry Island; dead on the spawning grounds.

Tag release and recovery data were stratified into weekly intervals to avoid small samples and numerical problems that cause maximum likelihood iterations to fail. Further pooling occurred as necessary to satisfy the assumptions of model fit. Model fit was assessed using Plante's (1990) goodness-of-fit test as provided in output from SPAS. The maximum likelihood Darroch model was used if its confidence limits did not overlap with those of the pooled Petersen estimator; however, the latter was the preferred model because its precision is generally higher. If the 95% confidence intervals of the pooled and stratified estimates did not overlap when the assumptions of equal recovery proportion of tagged fish among strata and complete mixing were not met, however, the bias was judged to be significant and the maximum likelihood estimator was considered most appropriate.

RESULTS

TAG APPLICATION

From September 1 to October 5, 1995, the beach seine net was set an average of eight times per day (range 5-11) to catch and apply spaghetti tags and secondary marks to 25,017 pink salmon (Table 1; Appendices 1a-1b). Other species captured included 26 chinook adults (*O. tshawytscha*), 13 chinook jacks, 594 coho adults (*O. kisutch*), 201 sockeye (*O. nerka*), 115 chum (*O. keta*) and 1 steelhead (*O. mykiss*) (Appendix 1c).

The daily tagging period varied: early in the study (Sept. 1 to 11), fish were tagged approximately eight hours per day, from 8 a.m. to 4 p.m.; during the peak (Sept. 12 to Oct. 2), fish were tagged 10-12 hours per day, from approximately 7 a.m. to 7 p.m.; late in the study (Oct. 3 to 5), fish were tagged approximately eight hours per day, from 7 a.m. to 3 p.m.

Before further analyses, we adjusted the release data for sex identification error and immediate mortality. When the application and carcass recovery data were compared, the sex of 11 (6.1%) males and 21 (7.3%) females had been recorded incorrectly at release. When adjusted for this error, an estimated 11,372 (45.5%) males and 13,645 (54.5%) females were released with disk tags. A further 8 males and 14 females recovered dead at the tagging site were removed from the sample. The data were then tested to determine if specific tags should be excluded from subsequent analyses. First, fish with less than five days between tag application and carcass recovery were removed from the application sample. None were detected in the spawning ground survey; however, three males and two females were recovered in

the tag application area survey, all of which were recovered on the same day of release. Second, the sample was partitioned into fish which required ventilation at release and those which did not; 34 males (0.30%) and 52 females (0.38%) required ventilation. The proportions which were recovered at Ridgedale (0.00% and 0.00% for males and females, respectively), Strawberry Island (2.94% and 0.00%), and the spawning grounds (2.94% and 3.85%) were not significantly different from the nonventilated fish (Table 2). Consequently, they were not removed from the application sample. When condition at release was compared between high and low stress tagging procedures, however, release condition No. 2 was significantly higher in the latter. Third, an identical procedure was used to evaluate fish which were recaptured in subsequent sets. The tags were applied to actively migrating fish; consequently, the incidence of recaptures was low. Only nine males and eight females were recaptured once, and only one female was recaptured twice (Table 3). The proportion of the recaptured males and females which was later recovered as carcasses (none were recaptured live) (0.0% and 11.1%) was not significantly different from the nonrecaptured fish (1.8% and 2.3%) (Table 3).

The final spaghetti tag application sample, therefore, was adjusted for fish: a) that were misidentified by sex at application; and b) recovered less than five days after release. The fiinal release totalled 11,361 males and 13,629 females (Table 1; Appendices 1a-1b). Of those totals, half received green tags (49.8% and 49.6% of the males and females, respectively) and half were tagged using the high stress technique (56.7% and 53.4%).

The mean NF length for males and females was 54.0 cm and 51.4 cm, respectively; none were sampled for age. The incidence of net, lamprey and hook marks was 0.6%, 0.0% and 1.2% in males (Appendix 1d), and 1.3%, 0.0% and 0.9% in females (Appendix 1e), respectively.

LIVE RECOVERY

Beach Seine Net

Ridgedale Bar: From September 2 to October 6, 1995, the beach seine net was set an average of nine times per day (range 0-11) to catch 14,767 males and 16,823 females (Table 1; Appendix 2a). Forty (0.27%) of the males and 35 (0.21%) of the females had either a spaghetti tag, secondary mark or both. Only one female had only a secondary mark, a tag loss rate of 0.00% and 2.85% among males and females, respectively. The incidence of net, lamprey and hook marks among all pink salmon recaptured at Ridgedale Bar was 4.5%, 0.2% and 1.7%, respectively (Appendix 2b). Other species in the catch included 45 chinook adults, 8 chinook jacks, 799 coho adults, 24 coho jacks, 63 sockeye, 73 chum, 2 steelhead and 140 cutthroat (*Salmo clarki*) (Appendix 2c).

The daily recovery period changed by week, with shift start times varying between about 7-8 a.m. and 10 a.m. Early (Sept. 2 to 13) and late (Oct. 1 to 6) in the study, sets were made approximately eight hours per day; during the peak (Sept. 14 to 30), sets were made 10-11 hours per day. No sets were made on September 22 due to equipment failure.

Strawberry Island: From September 2 to October 6, 1995, the beach seine was set an average of nine times per day (range 0-13) to catch 12,326 males and 15,613 females (Table 1; Appendix 3a). Forty-five (0.37%) of the males and 51 (0.33%) of the females had a spaghetti tag and secondary mark; none had only a secondary mark. The incidence of net, lamprey and hook marks among all pinks recaptured at Strawberry Island was 0.6%, 0.0% and 0.8%, respectively (Appendix 3b). The catch of other species included 162 chinook adults, 266 coho adults, 114 sockeye, 113 chum, 155 cutthroat, 2 Dolly Varden (*Salvelinus malma*), and 2 sturgeon (*Acipencer spp.*) (Appendix 3c).

The daily recovery period changed by week, with shift start times varying between about 7 a.m. and 10 a.m. Attempts were made to fish for 10-12 hours per day through the study; however, equipment failure limited or eliminated fishing effort on September 4, 10 and 30 and on October 2 and 3.

Drifted Gill Net

Ridgedale Bar: On 11 days between September 2-19, 1995, a drifted gill net was set an average of eight times per day to catch 24 males and 17 females, none of which had a tag or

Table 2. Tag application by release condition and stress level, and recovery by release condition and location, in pink salmon tagged and recovered in the lower Fraser River, 1995. [a]

	Male condition at release [b]			Female condition at release [b]		
Category	1	2	3	1	2	3
Number released with tags						
High Stress	6,277	135	20	7,040	187	31
Low Stress	4,690	196	14	6,039	281	21
Total	10,967	331	34	13,079	468	52
Ridgedale Bar recoveries						
Number	35 [d]	4	0	34	0	0
Percent recovered	0.32%	1.21%	0.00%	0.26%	0.00%	0.00%
Strawberry Island recoveries						
Number	44	0	1	50	1	0
Percent recovered	0.40%	0.00%	2.94%	0.38%	0.21%	0.00%
Spawning ground recoveries						
Number	169	11	1	273	12	2
Percent recovered	1.54%	3.32%	2.94%	2.09%	2.56%	3.85%

	Males				Females			
Chi-square test results	χ^2 value	df	*P*	Result	χ^2 value	df	*P*	Result
Condition at release by stress group:	37.484	2	0.000	Highly sig.	35.743	2	0.000	Highly sig.
Condition at release by recovery site: [c]								
Ridgedale Bar	0.240	1	0.624	Not sig.	0.260	1	0.610	Not sig.
Strawberry Island	2.318	1	0.128	Not sig.	0.391	1	0.532	Not sig.
Spawning grounds	0.317	1	0.573	Not sig.	0.619	1	0.432	Not sig.

[a] Not corrected for sex identification error; immediate mortalities removed.

[b] Release condition was not recorded for all fish.

[c] Pools release coded 1 and 2; Liklihood Ratio χ^2 test used due to low expected frequencies in some release code cells.

[d] Release condition was not recorded for 1 male.

Table 3. Tag application and spawning ground recovery for fish which were recaptured once and twice or more in subsequent beach seine sets in the lower Fraser River at Duncan Bar, 1995.

	Tags applied [a]			Tags recovered			Percent recovered		
Recapture status	Male	Female	Total	Male	Female	Total	Male	Female	Total
Not recaptured	11,353	13,619	24,972	208	312	520	1.8%	2.3%	2.1%
Recaptures									
1 recapture	9	8	17	0	1	1	0.0%	12.5%	5.9%
2 recaptures	0	1	1	0	0	0	-	0.0%	0.0%
Total	9	9	18	0	1	1	0.0%	11.1%	5.6%
Chi-Square Test Result:									
Not recaptured versus all recaptures:							0.695	0.426	-
Critical Chi-Square (df = 1; α = 0.05):							3.840	3.840	-

[a] Corrected for sex identification errors.

secondary mark (Appendix 4a). Other species in the catch included 6 chinook, 2 coho, 81 sockeye, 3 chum and 2 sturgeon. Gill netting was terminated when it became apparent that virtually all of the pink salmon migrated close to shore.

Strawberry Island: On 10 days between September 2-18, 1995, a drifted gill net was set an average of eight times per day to catch 31 males and 26 females, none of which had a tag or secondary mark (Appendix 4b). Other species in the catch included 1 coho, 33 sockeye and 1 chum. As observed at Ridgedale Bar, most pink salmon migrated close to shore.

CARCASS RECOVERY

Spawning Ground Survey

From September 22 to October 25, 1995, the lower Fraser River mainstem between the Sumas River and Ruby Creek was surveyed eight times (survey frequency varied between areas) to recover 106,524 males and 167,523 females (Table 1; Appendix 5). Of that total 186 (0.17%) males and 289 (0.17%) females had either a spaghetti tag, secondary mark or both. Five males and two females had only a secondary mark, a tag loss rate of 2.69% and 0.69%, respectively. Of the tags, green tags accounted for 55.8% and 50.2% of the males and females, respectively. The most important recovery areas were areas 13 (16% of the total recovery), 9 (15%), 2 (8%) and 8 (8%). High water beginning on about October 17 flushed most of the remaining carcasses from the system. Female spawning success averaged 99.3 % and was consistently high throughout the study.

Spawning Ground Resurvey

From September 29 to October 25, 1995, previously surveyed areas were resurveyed four times (resurvey frequency varied between areas) to recover 33,914 males and 55,910 females, including 7 and 8 spaghetti tags, respectively (Appendix 6). An estimated 22 (10.6%) and 24 (7.7%) spaghetti 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 208 male and 313 female spaghetti tags were recovered, for a tag incidence of 0.20% and 0.19%, respectively.

Tag Application Area Survey

From September 8 to October 11, 1995, the lower Fraser River between the east ends of McMillan and Matsqui islands was surveyed 24 times to recover 861 males and 729 females (Appendix 7). Of that total 6 (0.70%) males and 4 (0.55%) females had either a spaghetti tag and secondary mark; none had only a secondary mark. The survey included both the tagging (Sept. 8 to Oct. 5) and post-tagging (Oct. 6 to 11) periods. During the former, 426 males and 142 females were recovered, of which 5 (1.17%) and 3 (2.11%) had tags. Five of these tags had been applied on the same day they were recovered, and three had been out for at least eight days. This group, therefore, likely included both fish suffering acute handling stress and those which had spawned successfully and drifted downstream as carcasses. During the latter period, 435 males and 587 females were recovered, of which 1 (0.23%) and 1 (0.17%) had tags. Both tags had been out for over ten days. This group, therefore, likely included only fish which had spawned successfully and drifted downstream as carcasses.

TRAVEL TIME BETWEEN SITES

Ridgedale Bar

Travel time over the 13.5 km between Duncan and Ridgedale bars ranged from 3.8 hours to 10 days among males and 5.7 hours to 6 days among females (Table 4a). Sixty-three percent of the males and 74% of the females were recaptured on the same day they were tagged; most (88% and 92%) had been tagged before 10:00 h and none had been tagged after 14:30 h. (Table 4b; Fig. 3). Travel time averaged 6.9 hours (1.96 kmh^{-1}) among males and 7.3 hours (1.85 kmh^{-1}) among females. A further 30% of the males and 21% of the females were recaptured one day after tagging; all had been tagged after 10:00 h. Travel time averaged 17.3 hours (0.78 kmh^{-1}) among males and 17.7 hours (0.76 kmh^{-1}) among females. The remaining fish (8% of the males and 6% of the females) were recapured more than one day after release.

Strawberry Island

Travel time over the 22.0 km between Duncan Bar and Strawberry Island ranged from 10.3

Table 4a. Average, minimum and maximum time between release and recovery, by sex and recovery site, for Fraser River pink salmon, 1995.

Sex	Recovery site	Recovered on	Sample size	Mean time: Time (hours)	Mean time: Standard deviation	Minimum time (hours)	Maximum time (hours)
Male	Ridgedale Bar	Day of release	25	6.9	0.92	3.8	8.2
		One day after release	12	17.3	2.37	12.7	21.8
		More than 1-day after release [a]	3	7.3	2.51	5.0	10.0
	Strawberry Island	Day of release	4	10.7	0.75	10.3	11.8
		One day after release	37	22.2	1.97	18.6	29.9
		More than 1-day after release [a]	4	7.5	4.65	2.0	14.0
	Spawning grounds [b]	Day of release	0	-	-	-	-
		One day after release	0	-	-	-	-
		More than 1-day after release [a]	130	22.3	3.54	14.0	31.0
Female	Ridgedale Bar	Day of release	25	7.3	0.78	5.7	9.0
		One day after release	7	17.7	1.8	14.6	19.5
		More than 1-day after release [a]	2	4.0	2.82	2.0	6.0
	Strawberry Island	Day of release	5	10.5	0.83	9.6	11.8
		One day after release	40	21.9	2.25	16.6	26.1
		More than 1-day after release [a]	6	12.2	9.22	2.0	21.0
	Spawning grounds [b]	Day of release	0	-	-	-	-
		One day after release	0	-	-	-	-
		More than 1-day after release [a]	209	22.2	3.95	9.0	32.0

[a] Data reported in days.

[b] Calculated from fresh carcasses recovered above the live recapture sites.

Table 4b. Time of release at Duncan Bar and time of recovery at Ridgedale Bar and Strawberry Island, by sex, for Fraser River pink salmon recovered on the day of release and the day following release, 1995.

Sex	Tags recovered on	Time of release	Recovered on Ridgedale Bar at: 05:30 to 09:59	10:00 to 14:29	14:30 to 19:10	Recovered on Strawberry Island at: 05:30 to 09:59	10:00 to 14:29	14:30 to 19:10
Male	Day of release	05:30 to 09:59	0	4	18	0	0	4
		10:00 to 14:29	0	0	3	0	0	0
		14:30 to 19:00	0	0	0	0	0	0
	Day following release	05:30 to 09:59	0	0	0	5	1	0
		10:00 to 14:29	4	0	0	9	9	0
		14:30 to 19:00	5	3	0	1	9	3
Female	Day of release	05:30 to 09:59	0	3	20	0	0	5
		10:00 to 14:29	0	0	2	0	0	0
		14:30 to 19:00	0	0	0	0	0	0
	Day following release	05:30 to 09:59	0	0	0	7	0	0
		10:00 to 14:29	4	0	0	11	6	0
		14:30 to 19:00	2	1	0	1	12	3

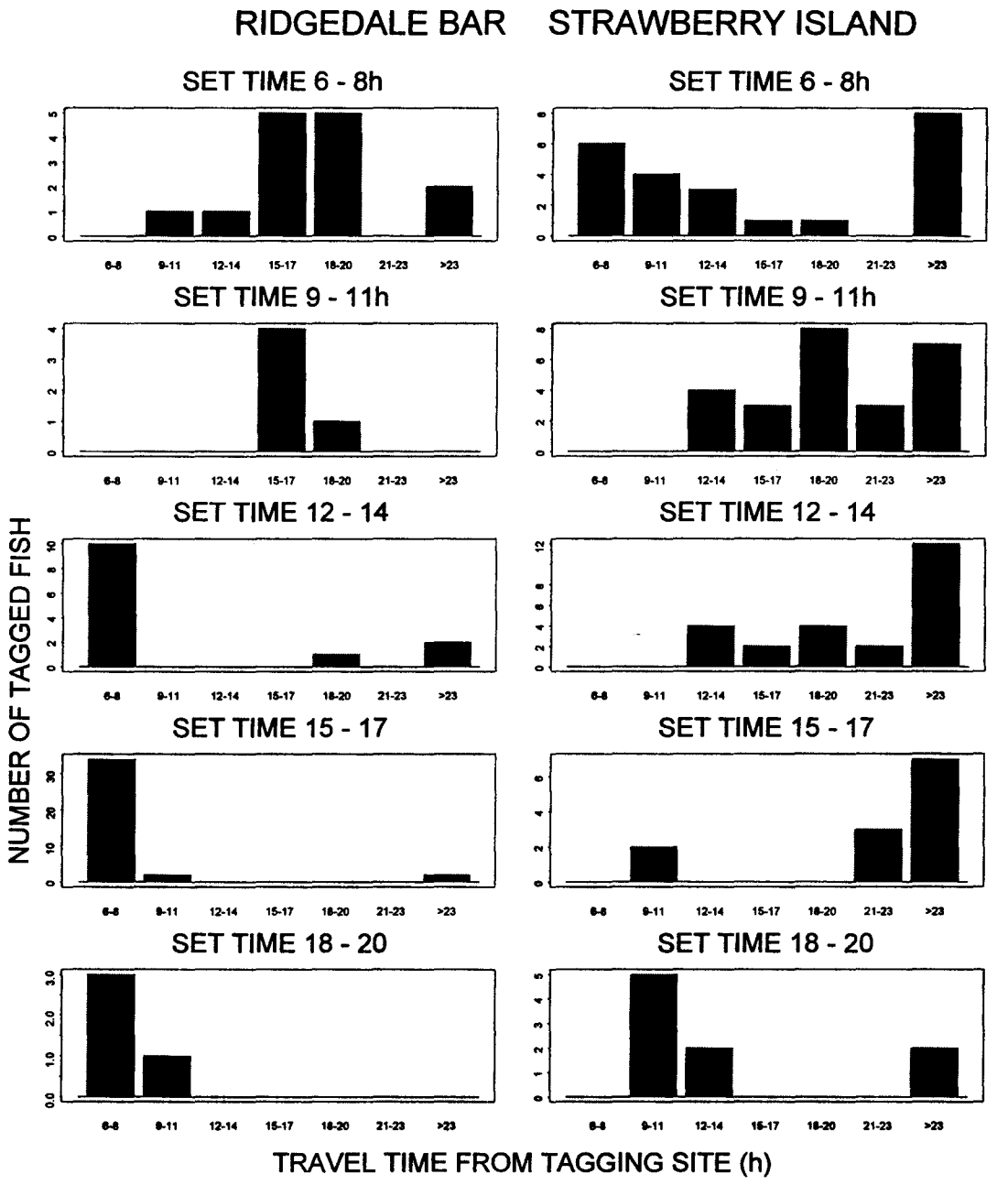


Fig. 3. Frequency of recoveries of tagged fish by migration (travel) time (3 h intervals) from the Duncan Bar tagging site to Ridgedale Bar and Strawberry Island recovery sites stratified by intervals of daily set start time (3 h intervals) at each recovery site.

hours to 14 days among males and 9.6 hours to 21 days among females (Table 4a). Nine percent of the males and 10% of the females were recaptured on the same day they were tagged; all had been tagged before 10:00 h (Table 4b; Fig. 3). Travel time averaged 10.7 hours (2.06 kmh^{-1}) among males and 10.5 hours (2.10 kmh^{-1}) among females. Most of the Strawberry Island recaptures (82% of the males and 78% of the females) occurred on the day after tagging and had been tagged throughout the previous day. Travel time averaged 22.2 hours (0.99 kmh^{-1}) among males and 21.9 hours (1.00 kmh^{-1}) among females. The remaining fish (9% of the males and 12% of the females) were recaptured more than one day after release.

Spawning Grounds

Elapsed time between tagging and recovery as carcasses on the lower Fraser mainstem spawning grounds ranged from 14 days to 31 days among males and 9 days to 32 days among females (Table 4a). Elapsed time averaged 22.3 days and 22.2 days among males and females, respectively. Unlike the live recovery sites, these figures include spawning time and do not represent rates of travel.

SAMPLING SELECTIVITY

Period

Temporal bias in the application sample was examined by comparing tag or mark incidences in recovery periods which were stratified in three ways: by equal periods; equal recovery effort; and equal numbers of total recoveries. At Ridgedale Bar, incidences ranged from 0.0% to 0.7% in males and 0.1% to 2.7% in females. These differences were not significant in males, but were significant in two of three stratifications in females, with higher incidences early and late in the study (Table 5). At Strawberry Island, incidences ranged from 0.0% to 1.4% in males and 0.0% to 5.0% in females. These differences were significant in both sexes in all stratifications, with higher incidences late in the study (Table 6). On the spawning grounds, incidences ranged from 0.1% to 0.7% in males and 0.1% to 0.3% in females. These differences were significant in two of three stratifications in both sexes, with higher incidences early and late in the study (Table 7).

Recovery bias was examined by comparing the proportions recovered from application periods which were stratified in three ways: by equal periods; equal application effort; and equal numbers applied. At Ridgedale Bar, the proportion recovered ranged from 0.00% to 0.65% in males and 0.00% to 0.99% in females. These differences were significant in only one stratification in males (Table 8) but in all three stratifications in females, with higher proportions recovered early in the study (Table 9). At Strawberry Island, the proportion recovered ranged from 0.00% to 0.76% in males and 0.00% to 0.68% in females. These differences were not significant in males (Table 8) and were significant in only one of three stratification in females (Table 9). On the spawning grounds, the proportion recovered ranged from 0.00% to 3.59% in males and 0.00% to 3.97% in females. These differences were highly significant in both males (Table 8) and females (Table 9), with much higher proportions recovered late in the study.

Temporal bias was also examined within days. Bias in the application sample was examined by stratifying the Ridgedale Bar and Strawberry Island live recovery data into three daily periods and comparing the tag or mark incidences in each (Table 10a). At Ridgedale Bar, incidences ranged from 0.13% to 0.49% in males and 0.09% to 0.40% in females. Both differences were significant, with higher incidences during 14:00 h to 19:05 h. At Strawberry Island, incidences ranged from 0.21% to 0.49% in males and 0.19% to 0.51% in females. The differences were significant only in females, with higher incidences during 06:30 h to 09:59 h.

Within day bias in the recovery sample was examined by comparing the proportions recovered in three application periods (Table 10b). At Ridgedale Bar, the proportion recovered ranged from 0.22% to 0.58% in males and 0.07% to 0.54% in females. Both differences were statistically significant, with higher incidences during 05:30 h to 09:59 h. At Strawberry Island, the proportion recovered ranged from 0.32% to 0.47% in males and 0.34% to 0.45% in females. Neither difference was significant. On the spawning grounds, the proportion recovered ranged from 1.29% to 2.04% in males and 1.96% to 2.21% in females. These differences were significant only in males, with higher recovery rates during during 05:30 h to 09:59 h.

Table 5a. Incidence of spaghetti tags and secondary marks in pink salmon recovered at Ridgedale Bar, by recovery period and sex, 1995. Data are stratified by approximately equal recovery periods.

Ridgedale Bar recovery period	Number of sets	Live pinks recovered with tags or secondary marks			Total recovery			Tag or mark incidence		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
02-Sep to 06-Sep	38	4	1	5	588	628	1,216	0.7%	0.2%	0.4%
07-Sep to 11-Sep	45	6	13	19	3,148	3,125	6,273	0.2%	0.4%	0.3%
12-Sep to 16-Sep	48	9	4	13	4,282	5,084	9,366	0.2%	0.1%	0.1%
17-Sep to 21-Sep	52	10	6	16	4,130	5,376	9,506	0.2%	0.1%	0.2%
22-Sep to 26-Sep	44	7	7	14	1,816	1,878	3,694	0.4%	0.4%	0.4%
27-Sep to 01-Oct	47	4	3	7	763	695	1,458	0.5%	0.4%	0.5%
02-Oct to 06-Oct	42	0	1	1	40	37	77	0.0%	2.7%	1.3%
Chi-Square Test Result:		Males:	6.582	Not		Females:	19.958	Highly		
P (df = 6):			0.361	significant [a]			0.003	significant [a]		

[a] Liklihood ratio test used.

Table 5b. Incidence of spaghetti tags and secondary marks in pink salmon recovered at Ridgedale Bar, by recovery period and sex, 1995. Data are stratified by approximately equal recovery effort.

Ridgedale Bar recovery period	Number of sets	Live pinks recovered with tags or secondary marks			Total recovery			Tag or mark incidence		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
02-Sep to 09-Sep	65	10	10	20	2,319	2,300	4,619	0.4%	0.4%	0.4%
10-Sep to 16-Sep	66	9	8	17	5,699	6,537	12,236	0.2%	0.1%	0.1%
17-Sep to 23-Sep	63	10	8	18	4,194	5,470	9,664	0.2%	0.1%	0.2%
24-Sep to 29-Sep	62	11	7	18	2,442	2,417	4,859	0.5%	0.3%	0.4%
30-Sep to 06-Oct	60	0	2	2	113	99	212	0.0%	2.0%	0.9%
Chi-Square Test Result:		Males:	8.284	Not		Females:	25.446	Highly		
P (df = 4):			0.082	significant			0.000	significant		

Table 5c. Incidence of spaghetti tags and secondary marks in pink salmon recovered at Ridgedale Bar, by recovery period and sex, 1995. Data are stratified by approximately equal numbers of total recoveries.

Ridgedale Bar recovery period	Number of sets	Live pinks recovered with tags or secondary marks			Total recovery			Tag or mark incidence		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
02-Sep to 13-Sep	100	11	15	26	5,224	5,416	10,640	0.2%	0.3%	0.2%
14-Sep to 18-Sep	53	12	9	21	4,259	5,227	9,486	0.3%	0.2%	0.2%
19-Sep to 06-Oct	163	17	11	28	5,284	6,180	11,464	0.3%	0.2%	0.2%
Chi-Square Test Result:		Males:	1.228	Not		Females:	1.831	Not		
P (df = 2):			0.541	significant			0.400	significant		

Table 6a. Incidence of spaghetti tags and secondary marks in pink salmon recovered at Strawberry Island, by recovery period and sex, 1995. Data are stratified by approximately equal recovery periods.

Strawberry Island recovery period	Number of sets	Live pinks recovered with tags or secondary marks			Total recovery			Tag or mark incidence		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
02-Sep to 06-Sep	38	1	0	1	108	100	208	0.9%	0.0%	0.5%
07-Sep to 11-Sep	45	2	3	5	920	846	1,766	0.2%	0.4%	0.3%
12-Sep to 16-Sep	59	5	4	9	2,346	2,541	4,887	0.2%	0.2%	0.2%
17-Sep to 21-Sep	49	12	13	25	4,365	6,207	10,572	0.3%	0.2%	0.2%
22-Sep to 26-Sep	56	8	13	21	3,319	4,444	7,763	0.2%	0.3%	0.3%
27-Sep to 01-Oct	49	17	15	32	1,205	1,415	2,620	1.4%	1.1%	1.2%
02-Oct to 06-Oct	32	0	3	3	63	60	123	0.0%	5.0%	2.4%
Chi-Square Test Result:		Males:	27.068	Highly		Females:	32.142	Highly		
P (df = 6):			0.000	significant [a]			0.000	significant [a]		

[a] Liklihood ratio test used.

Table 6b. Incidence of spaghetti tags and secondary marks in pink salmon recovered at Strawberry Island, by recovery period and sex, 1995. Data are stratified by approximately equal recovery effort.

Strawberry Island recovery period	Number of sets	Live pinks recovered with tags or secondary marks			Total recovery			Tag or mark incidence		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
02-Sep to 09-Sep	66	1	3	4	626	585	1,211	0.2%	0.5%	0.3%
10-Sep to 16-Sep	76	8	4	12	2,749	2,902	5,651	0.3%	0.1%	0.2%
17-Sep to 23-Sep	70	14	16	30	5,783	8,274	14,057	0.2%	0.2%	0.2%
24-Sep to 29-Sep	66	20	23	43	2,979	3,628	6,607	0.7%	0.6%	0.7%
30-Sep to 06-Oct	50	2	5	7	189	224	413	1.1%	2.2%	1.7%
Chi-Square Test Result:		Males:	13.724	Significant		Females:	43.818	Highly		
P (df = 4):			0.008	difference			0.000	significant		

Table 6c. Incidence of spaghetti tags and secondary marks in pink salmon recovered at Strawberry Island, by recovery period and sex, 1995. Data are stratified by approximately equal numbers of total recoveries.

Strawberry Island recovery period	Number of sets	Live pinks recovered with tags or secondary marks			Total recovery			Tag or mark incidence		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
02-Sep to 13-Sep	107	10	10	20	3,976	4,278	8,254	0.3%	0.2%	0.2%
14-Sep to 18-Sep	58	10	10	20	3,763	5,416	9,179	0.3%	0.2%	0.2%
19-Sep to 06-Oct	163	25	31	56	4,587	5,919	10,506	0.5%	0.5%	0.5%
Chi-Square Test Result:		Males:	6.514	Significant		Females:	11.550	Highly		
P (df = 2):			0.039	difference			0.003	significant		

Table 7a. Incidence of spaghetti tags and secondary marks in pink salmon recovered on the lower Fraser River study area spawning grounds, by recovery period and sex, 1995. Data are stratified by approximately equal recovery periods.

Spawning ground recovery period	Number of surveys	Carcasses recovered with tags or secondary marks			Total recovery			Disk tag incidence		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
22-Sep to 25-Sep	1.0	7	6	13	2,677	2,467	5,144	0.3%	0.2%	0.3%
26-Sep to 30-Sep	1.3	29	37	66	10,711	14,606	25,317	0.3%	0.3%	0.3%
01-Oct to 05-Oct	0.7	32	33	65	26,200	28,316	54,516	0.1%	0.1%	0.1%
06-Oct to 10-Oct	1.0	52	96	148	37,043	62,157	99,200	0.1%	0.2%	0.1%
11-Oct to 15-Oct	1.3	56	97	153	26,267	51,194	77,461	0.2%	0.2%	0.2%
16-Oct to 20-Oct	1.4	6	15	21	3,017	7,296	10,313	0.2%	0.2%	0.2%
21-Oct to 25-Oct	1.3	4	5	9	609	1,487	2,096	0.7%	0.3%	0.4%
Chi-Square Test Result:		Males:	23.938	Highly		Females:	16.217	Significant		
P (df = 6):			0.001	significant			0.013	difference		

Table7b. Incidence of spaghetti tags and secondary marks in pink salmon recovered on the lower Fraser River study area spawning grounds, by recovery period and sex, 1995. Data are stratified by approximately equal recovery cycles.

Spawning ground recovery period	Number of surveys	Carcasses recovered with tags or secondary marks			Total recovery			Disk tag incidence		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
22-Sep to 28-Sep	2	24	31	55	9,657	10,758	20,415	0.2%	0.3%	0.3%
29-Sep to 10-Oct	2	96	141	237	66,974	96,788	163,762	0.1%	0.1%	0.1%
11-Oct to 17-Oct	2	59	107	166	28,505	56,764	85,269	0.2%	0.2%	0.2%
18-Oct to 25-Oct	2	7	10	17	1,388	3,213	4,601	0.5%	0.3%	0.4%
Chi-Square Test Result:		Males:	17.155	Highly		Females:	16.834	Highly		
P (df = 3):			0.001	significant			0.001	significant		

Table 7c. Incidence of spaghetti tags and secondary marks in pink salmon recovered on the lower Fraser River study area spawning grounds, by recovery period and sex, 1995. Data are stratified by approximately equal number total recoveries.

Spawning ground recovery period	Number of surveys	Carcasses recovered with tags or secondary marks			Total recovery			Disk tag incidence		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
22-Sep to 03-Oct	2.7	50	59	109	28,186	35,364	63,550	0.2%	0.2%	0.2%
04-Oct to 07-Oct	0.7	43	58	101	25,717	35,548	61,265	0.2%	0.2%	0.2%
08-Oct to 10-Oct	0.6	27	55	82	22,728	36,634	59,362	0.1%	0.2%	0.1%
11-Oct to 13-Oct	0.8	47	63	110	20,647	36,628	57,275	0.2%	0.2%	0.2%
14-Oct to 25-Oct	3.3	19	54	73	9,246	23,349	32,595	0.2%	0.2%	0.2%
Chi-Square Test Result:		Males:	7.992	Not		Females:	5.994	Not		
P (df = 4):			0.092	significant			0.200	significant		

Table 8a. Proportion of the male tag application sample recovered in subsequent surveys, by application period and recovery site, 1995. Data are stratified by approximately equal application periods. [a]

Duncan Bar application period	Number of sets	Tags applied	Tags recovered at Ridegedale Bar		Tags recovered at Strawberry Island		Tags recovered on the spawning grounds	
			Number	Percent	Number	Percent	Number	Percent
01-Sep to 05-Sep	34	552	3	0.54%	1	0.18%	15	2.72%
06-Sep to 10-Sep	35	1,226	8	0.65%	3	0.24%	44	3.59%
11-Sep to 15-Sep	38	2,023	9	0.44%	4	0.20%	49	2.42%
16-Sep to 20-Sep	41	3,180	10	0.31%	13	0.41%	46	1.45%
21-Sep to 25-Sep	42	2,311	2	0.09%	9	0.39%	18	0.78%
26-Sep to 30-Sep	48	1,984	8	0.40%	15	0.76%	9	0.45%
01-Oct to 05-Oct	46	85	0	0.00%	0	0.00%	0	0.00%
Chi-Square Test Result:			9.448	Not	10.246	Not	72.483	Highly
P (df = 6):			0.150	significant	0.115	significant	0.000	significant

[a] Corrected for sex identification error; excludes immediate mortalities and recoveries with secondary marks only.

Table 8b. Proportion of the male tag application sample recovered in subsequent surveys, by application period and recovery site, 1995. Data are stratified by approximately equal application effort. [a]

Duncan Bar application period	Number of sets	Tags applied	Tags recovered at Ridegedale Bar		Tags recovered at Strawberry Island		Tags recovered on the spawning grounds	
			Number	Percent	Number	Percent	Number	Percent
01-Sep to 10-Sep	69	1,778	11	0.62%	4	0.22%	59	3.32%
11-Sep to 19-Sep	70	4,661	15	0.32%	14	0.30%	88	1.89%
20-Sep to 27-Sep	69	4,016	12	0.30%	22	0.55%	30	0.75%
28-Sep to 05-Oct	76	907	2	0.22%	5	0.55%	4	0.44%
Chi-Square Test Result:			4.495	Not	5.303	Not	62.334	Highly
P (df = 3):			0.213	significant	0.151	significant	0.000	significant

[a] Corrected for sex identification error; excludes immediate mortalities and recoveries with secondary marks only.

Table 8c. Proportion of the male tag application sample recovered in subsequent surveys, by application period and recovery site, 1995. Data are stratified by approximately equal numbers of total tags applied. [a]

Duncan Bar application period	Number of sets	Tags applied	Tags recovered at Ridegedale Bar		Tags recovered at Strawberry Island		Tags recovered on the spawning grounds	
			Number	Percent	Number	Percent	Number	Percent
01-Sep to 12-Sep	85	2,349	11	0.47%	5	0.21%	71	3.02%
13-Sep to 16-Sep	30	2,085	13	0.62%	5	0.24%	50	2.40%
17-Sep to 19-Sep	24	2,005	6	0.30%	11	0.55%	33	1.65%
20-Sep to 24-Sep	43	2,129	2	0.09%	9	0.42%	18	0.85%
25-Sep to 05-Oct	102	2,794	8	0.29%	15	0.54%	9	0.32%
Chi-Square Test Result:			10.307	Significant	9.033	Not	74.885	Highly
P (df = 4):			0.036	difference	0.060	significant	0.000	significant

[a] Corrected for sex identification error; excludes immediate mortalities and recoveries with secondary marks only.

Table 9a. Proportion of the female tag application sample recovered in subsequent surveys, by application period and recovery site, 1995. Data are stratified by approximately equal application periods. [a]

Duncan Bar application period	Number of sets	Tags applied	Tags recovered at Ridegedale Bar		Tags recovered at Strawberry Island		Tags recovered on the spawning grounds	
			Number	Percent	Number	Percent	Number	Percent
01-Sep to 05-Sep	34	557	0	0.00%	0	0.00%	18	3.23%
06-Sep to 10-Sep	35	1,309	13	0.99%	4	0.31%	52	3.97%
11-Sep to 15-Sep	38	2,527	4	0.16%	7	0.28%	76	3.01%
16-Sep to 20-Sep	41	4,037	6	0.15%	12	0.30%	93	2.30%
21-Sep to 25-Sep	42	2,747	6	0.22%	13	0.47%	29	1.06%
26-Sep to 30-Sep	48	2,341	5	0.21%	15	0.64%	19	0.81%
01-Oct to 05-Oct	46	110	0	0.00%	0	0.00%	0	0.00%
Chi-Square Test Result:			33.581	Highly	9.139	Not	72.289	Highly
P (df = 6):			0.000	significant	0.166	significant	0.000	significant

[a] Corrected for sex identification error; excludes immediate mortalities and recoveries with secondary marks only.

Table 9b. Proportion of the female tag application sample recovered in subsequent surveys, by application period and recovery site, 1995. Data are stratified by approximately equal application effort. [a]

Duncan Bar application period	Number of sets	Tags applied	Tags recovered at Ridegedale Bar		Tags recovered at Strawberry Island		Tags recovered on the spawning grounds	
			Number	Percent	Number	Percent	Number	Percent
01-Sep to 10-Sep	69	1,866	13	0.70%	4	0.21%	70	3.75%
11-Sep to 19-Sep	70	5,946	10	0.17%	18	0.30%	154	2.59%
20-Sep to 27-Sep	69	4,847	8	0.17%	23	0.47%	57	1.18%
28-Sep to 05-Oct	76	969	3	0.31%	6	0.62%	6	0.62%
Chi-Square Test Result:			18.106	Highly	4.960	Not	62.003	Highly
P (df = 3):			0.000	significant	0.175	significant	0.000	significant

[a] Corrected for sex identification error; excludes immediate mortalities and recoveries with secondary marks only.

Table 9c. Proportion of the female tag application sample recovered in subsequent surveys, by application period and recovery site, 1995. Data are stratified by approximately equal numbers of total tags applied. [a]

Duncan Bar application period	Number of sets	Tags applied	Tags recovered at Ridegedale Bar		Tags recovered at Strawberry Island		Tags recovered on the spawning grounds	
			Number	Percent	Number	Percent	Number	Percent
01-Sep to 12-Sep	85	2,549	14	0.55%	4	0.16%	96	3.77%
13-Sep to 16-Sep	30	2,687	7	0.26%	9	0.33%	68	2.53%
17-Sep to 19-Sep	24	2,576	2	0.08%	9	0.35%	60	2.33%
20-Sep to 24-Sep	43	2,563	4	0.16%	7	0.27%	36	1.40%
25-Sep to 05-Oct	102	3,253	7	0.22%	22	0.68%	27	0.83%
Chi-Square Test Result:			13.325	Significant	12.049	Significant	68.870	Highly
P (df = 4):			0.010	difference	0.017	difference	0.000	significant

[a] Corrected for sex identification error; excludes immediate mortalities and recoveries with secondary marks only.

Table 10a. Incidence of spaghetti tags and secondary marks in pink salmon recovered at Ridgedale Bar and Strawberry Island, by sex and daily recovery period, 1995.

		Ridgedale Bar			Strawberry Island		
Sex	Recovery period	Tags or secondary marks	Total recovery	Percent with tags or marks	Tags or secondary marks	Total recovery	Percent with tags or marks
Male	06:30 to 09:59	10	3,707	0.27%	15	3,041	0.49%
	10:00 to 14:29	8	5,946	0.13%	23	5,960	0.39%
	14:30 to 19:05	25	5,117	0.49%	7	3,325	0.21%
Female	06:30 to 09:59	6	4,054	0.15%	21	4,090	0.51%
	10:00 to 14:29	6	6,932	0.09%	22	7,361	0.30%
	14:30 to 19:05	23	5,813	0.40%	8	4,162	0.19%
Male Chi-Square Test Result:		8.896	Significant		3.628	Not	
P (df = 2)		0.012	difference		0.163	significant	
Female Chi-Square Test Result:		15.365	Highly		6.868	Significant	
P (df = 2)		0.000	significant		0.032	difference	

Table 10b. Proportion of the application sample recovered at Ridgedale Bar and Strawberry Island and on the lower Fraser River spawning grounds, by sex and daily release time, 1995.

			Tags recovered at Ridegedale Bar		Tags recovered at Strawberry Island		Tags recovered on the spawning grounds	
Sex	Duncan Bar release period	Tags applied	Number	Percent	Number	Percent	Number	Percent
Male	05:30 to 09:59	3,775	22	0.58%	12	0.32%	77	2.04%
	10:00 to 14:29	4,009	10	0.25%	19	0.47%	58	1.45%
	14:30 to 19:00	3,577	8	0.22%	14	0.39%	46	1.29%
Female	05:30 to 09:59	4,477	24	0.54%	15	0.34%	95	2.12%
	10:00 to 14:29	5,114	7	0.14%	18	0.35%	113	2.21%
	14:30 to 19:00	4,038	3	0.07%	18	0.45%	79	1.96%
Male Chi-Square Test Result:			8.612	Significant	1.203	Not	7.503	Significant
P (df = 2):			0.013	difference	0.548	significant	0.023	difference
Female Chi-Square Test Result:			22.363	Highly	0.807	Not	0.710	Not
P (df = 2):			0.000	significant	0.668	significant	0.701	significant

Table 11. Proportion of the lower Fraser River pink salmon spawning ground recovery sample marked with spaghetti tags and secondary marks, by recovery location and sex, 1995.

Recovery location	Carcasses recovered with spaghetti tags or secondary marks			Total carcasses examined			Tag/mark incidence		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
1- 2	40	55	95	12,777	17,181	29,958	0.31%	0.32%	0.32%
3- 8	69	79	148	41,614	45,469	87,083	0.17%	0.17%	0.17%
9-12	42	74	116	31,912	51,455	83,367	0.13%	0.14%	0.14%
13-14	20	45	65	13,435	35,522	48,957	0.15%	0.13%	0.13%
15-17	15	36	51	6,786	17,896	24,682	0.22%	0.20%	0.21%
Male Chi-Square Test Result:		18.972	Highly		Female Chi-Square Test Result:			29.387	Highly
P (df = 4)		0.000	significant		*P* (df = 4)			0.000	significant

Table 12. Nose-fork lengths of pink salmon tagged at Duncan Bar and recovered at Ridgedale Bar and Strawberry Island and on the lower Fraser River spawning grounds, by sex and 3 cm increments of nose-fork length, 1995.

Sex	Nose-fork length (cm)	Tags applied at Duncan Bar		Tags recovered at Ridegedale Bar		Tags recovered at Strawberry Island		Tags recovered on the spawning grounds	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent
Male	38.0 - 40.9	8	0.1%	0	0.0%	0	0.0%	0	0.0%
	41.0 - 43.9	24	0.2%	0	0.0%	0	0.0%	1	0.6%
	44.0 - 46.9	128	1.1%	1	2.5%	1	2.2%	2	1.1%
	47.0 - 49.9	969	8.5%	7	17.5%	3	6.7%	18	9.9%
	50.0 - 52.9	2,981	26.2%	12	30.0%	14	31.1%	42	23.2%
	53.0 - 55.9	3,794	33.4%	13	32.5%	14	31.1%	59	32.6%
	56.0 - 58.9	2,332	20.5%	6	15.0%	10	22.2%	40	22.1%
	59.0 - 61.9	840	7.4%	1	2.5%	1	2.2%	12	6.6%
	62.0 - 64.9	218	1.9%	0	0.0%	0	0.0%	6	3.3%
	65.0 - 67.9	56	0.5%	0	0.0%	2	4.4%	0	0.0%
	68.0 - 70.9	8	0.1%	0	0.0%	0	0.0%	1	0.6%
Female	35.0 - 37.9	1	0.0%	0	0.0%	0	0.0%	0	0.0%
	38.0 - 40.9	12	0.1%	0	0.0%	0	0.0%	0	0.0%
	41.0 - 43.9	49	0.4%	0	0.0%	0	0.0%	1	0.3%
	44.0 - 46.9	345	2.5%	1	2.9%	2	3.9%	7	2.4%
	47.0 - 49.9	2,756	20.2%	10	29.4%	8	15.7%	44	15.4%
	50.0 - 52.9	6,398	47.0%	15	44.1%	23	45.1%	139	48.6%
	53.0 - 55.9	3,322	24.4%	7	20.6%	13	25.5%	83	29.0%
	56.0 - 58.9	624	4.6%	1	2.9%	5	9.8%	9	3.1%
	59.0 - 61.9	90	0.7%	0	0.0%	0	0.0%	2	0.7%
	62.0 - 64.9	15	0.1%	0	0.0%	0	0.0%	1	0.3%

Kolmogorov-Smirnov Test Results:		KS	D	KSa	*P*	Result
Males	Ridgedale	0.008	0.915	0.533	0.939	Not significant
	Strawberry Island	0.002	0.055	0.393	0.998	Not significant
	Spawning grounds	0.003	0.051	0.862	0.448	Not significant
Females:	Ridgedale	0.004	0.139	0.875	0.428	Not significant
	Strawberry Island	0.003	0.039	0.261	0.999	Not significant
	Spawning grounds	0.007	0.022	0.296	0.999	Not significant

Table 13. Sex composition of pink salmon in the tag application and recovery samples, 1995. [a]

		Application sample, by recovery status [b]				Recovery sample, by mark status			
Recovery site	Sex	Sample size	Recovered	Not recovered	Total	Sample size	Marked	Unmarked	Total
Ridgedale Bar	Male	11,362	53.3%	45.4%	45.5%	14,767	53.3%	46.7%	46.7%
	Female	13,628	46.7%	54.6%	54.5%	16,823	46.7%	53.3%	53.3%
Strawberry Island	Male	11,362	46.9%	45.5%	45.5%	12,326	46.9%	44.1%	44.1%
	Female	13,628	53.1%	54.5%	54.5%	15,613	53.1%	78.9%	55.9%
Spawning grounds	Male	11,362	39.9%	45.6%	45.5%	106,524	39.9%	38.9%	38.9%
	Female	13,628	60.1%	54.4%	54.5%	167,523	60.1%	61.1%	61.1%
Ridgedale Bar:		Chi-Square Test Result:			1.584	Chi-Square Test Result:			1.064
		Critical Chi-Square (df = 1; α = 0.05):			3.840	Critical Chi-Square (df = 1; α = 0.05):			3.840
Strawberry Island:		Chi-Square Test Result:			0.031	Chi-Square Test Result:			0.197
		Critical Chi-Square (df = 1; α = 0.05):			3.840	Critical Chi-Square (df = 1; α = 0.05):			3.840
Spawning Grounds:		Chi-Square Test Result:			6.646	Chi-Square Test Result:			0.202
		Critical Chi-Square (df = 1; α = 0.05):			3.840	Critical Chi-Square (df = 1; α = 0.05):			3.840

[a] Data are from Table 1.

[b] Corrected for sex identification error.

Location

Spatial bias could be examined only among spawning ground locations. Bias in the application sample was examined by comparing the tag and mark incidence among five recovery locations. Incidences ranged from 0.13% to 0.31% in males and 0.13% to 0.32% in females, with higher incidences in the lower and upper areas. Both differences were significant (Table 11). Recovery bias could not be examined because only one tagging site was used.

Fish Size

Size bias at tag application could not be assessed because the length of untagged fish was not measured at recovery. Recovery bias was examined by comparing the NF length frequency distributions of tagged fish in the application sample versus the three recovery samples. No difference is length distribution was noted in either sex between application and recovery (Table 12).

Fish Sex

There was no difference ($P > 0.05$; chi-square) in the sex ratio of the marked and unmarked recoveries from either the live recovery sites or the spawning grounds (Table 13). The application sample, therefore, was relatively unbiased with respect to sex. There was no difference in the sex ratios of the live recovered and nonrecovered components of the application sample (Table 13). Further, no difference was noted in the proportion of males and females released with tags and later recovered at either Ridgedale Bar or Strawberry Island (Table 1). The live recovery sample, therefore, was relatively unbiased with respect to sex. A significant difference was noted, however, in the sex ratios of the spawning ground recovered and nonrecovered components of the application sample (Table 13). The proportion of the application sample recovered on the spawning grounds was also significantly different ($P > 0.05$; chi-square) among males (1.83%) and females (2.30%).

Other Tests

Stress: Potential bias resulting from handling and tagging stress was assessed in three ways. First, three tests were used to determine whether specific tags should be excluded from the application sample. The results of these tests were reported on pages 10-11. Second, spawning success was compared between tagged (91.5%) and untagged (99.3%) female carcasses. The data (0%, 50% and 100% spawned) were collapsed into two groups (0-50% and 100%) because of the low number of expected

Table 14. Proportion of the tag application sample recovered at Ridgedale Bar and Strawberry Island and on the lower Fraser River spawning grounds, by sex, application procedure (high or low stress), and tag colour (green or orange), 1995.

Sex	Application group	Tags applied	Tags recovered at Ridegedale Bar		Tags recovered at Strawberry Island		Tags recovered on the spawning grounds	
			Number	Percent	Number	Percent	Number	Percent
Males	High Stress	6,450	27	0.42%	28	0.43%	90	1.40%
	Low Stress	4,911	13	0.26%	17	0.35%	91	1.85%
	Green tags	5,655	20	0.35%	21	0.37%	101	1.79%
	Orange tags	5,106	20	0.39%	24	0.47%	80	1.57%
Females	High Stress	7,280	15	0.21%	33	0.45%	157	2.16%
	Low Stress	6,349	19	0.30%	18	0.28%	130	2.05%
	Green tags	6,760	20	0.30%	18	0.27%	144	2.13%
	Orange tags	6,869	14	0.20%	33	0.48%	143	2.08%

Chi-square test results	df	Male χ^2 value	Male *P*	Male Result	Female χ^2 value	Female *P*	Female Result
Stress, within sites:							
Ridgedale	1	1.882	0.170	Not sig.	1.184	0.277	Not sig.
Strawberry Island	1	0.547	0.460	Not sig.	2.622	0.105	Not sig.
Spawning grounds	1	0.369	0.055	Not sig.	0.196	0.658	Not sig.
Stress, among sites:	3	6.098	0.107	Not sig.	3.997	0.262	Not sig.
Tag colour, within sites:							
Ridgedale	1	0.001	0.977	Not sig.	1.16	0.281	Not sig.
Strawberry Island	1	0.175	0.676	Not sig.	3.636	0.057	Not sig.
Spawning grounds	1	2.671	0.102	Not sig.	0.039	0.844	Not sig.
Tag colour, among sites:	3	2.837	0.417	Not sig.	5.372	0.146	Not sig.

recoveries in the 50% group. The difference was highly significant ($P > 0.005$; chi-square). Third, the application sample was partitioned into fish handled using high and low stress tagging methods and the proportions recovered at the live recovery sites and on the spawning grounds were compared. While the proportions recovered differed, especially at the live recovery sites, the differences were not significant (Table 14). While these results suggest that stress effects were unlikely to have introduced substantial bias to this study, they are not unequivocal because the live recovery sample size was small. The recovery of 27 carcasses near the tagging site on the same day of release suggests that acute stress induced mortality may play a role which warrants further investigation. Although the sample size was small, there is no evidence that size, release condition or tagging method contributed to their mortality. We also found little statistical evidence that fish size was an important determinant in stress effects in the high or low stress release groups. When the data were stratified by NF length (<50 cm, 50-55 cm, and >55 cm), no difference was noted in the proportions released and recovered by stress level (chi-square; $P > 0.05$).

Tag Colour: The application sample was partitioned into fish tagged with green and orange tags and the proportions recovered at the live recovery sites and on the spawning grounds were compared. No significant differences were noted (Table 14). These results indicate that: a) the presence on the spawning grounds of a highly noticeable orange tag did not change the vul-

Table 15. Tags applied and recovered during mark-recapture studies of Fraser River pink salmon in 1995. Stratum intervals are results of pooling release and recovery data first by weekly intervals, then by pooling particular weeks as shown to satisfy model assumptions of stratified (Darroch) population estimates.

Ridgedale Bar
Males

Release date	Tags and marks applied	Tags recovered live at Ridgedale: 01-Sep to 14-Sep	15-Sep to 21-Sep	22-Sep to 05-Oct	Tags not recovered
01-Sep to 07-Sep	621	4	0	0	617
08-Sep to 14-Sep	2,039	7	1	0	2,031
15-Sep to 21-Sep	4,314	0	16	2	4,296
22-Sep to 28-Sep	3,474	0	0	8	3,466
29-Sep to 05-Oct	907	0	0	2	905
Total Tags:	11,355	11	17	12	11,315
Total Sample:	-	5,282	6,519	2,966	-

Ridgedale Bar
Females

Release date	Tags and marks applied	Tags recovered live at Ridgedale: 01-Sep to 14-Sep	15-Sep to 21-Sep	22-Sep to 05-Oct	Tags not recovered
01-Sep to 07-Sep	723	1	0	0	722
08-Sep to 14-Sep	2,270	14	0	0	2,256
15-Sep to 21-Sep	5,423	0	8	0	5,415
28-Sep to 05-Oct	5,188	0	0	10	5,178
Total Tags:	13,604	15	8	10	13,571
Total Sample:	-	5,473	8,357	2,991	-

Ridgedale Bar
Sexes Combined

Release date	Tags and marks applied	Tags recovered live at Ridgedale: 01-Sep to 14-Sep	15-Sep to 21-Sep	22-Sep to 28-Sep	29-Sep to 05-Oct	Tags not recovered
01-Sep to 14-Sep	5,664	26	1	0	0	5,637
15-Sep to 21-Sep	9,769	0	24	2	0	9,743
22-Sep to 05-Oct	9,580	0	0	15	5	9,560
Total Tags:	25,013	26	25	17	5	24,940
Total Sample:	-	10,729	14,851	5,135	800	-

Table 15 continued.

Strawberry Island		Male tags recovered on the spawning grounds				Female tags recovered on the spawning grounds		
Release date	Tags and marks applied to males	01-Sep to 21-Sep	22-Sep to 05-Oct	Male tags not recovered	Tags and marks applied to females	01-Sep to 12-Oct	13-Oct to 26-Oct	Female tags not recovered
01-Sep to 14-Sep	2,600	6	0	2,654	2,993	4	1	2,988
15-Sep to 21-Sep	4,314	11	4	4,299	5,423	14	2	5,407
22-Sep to 05-Oct	4,381	0	24	4,357	5,188	1	27	5,160
Total Tags:	11,295	17	28	11,310	13,604	19	30	13,555
Total Sample:	-	6,553	5,773	-	-	8,018	7,593	-

Strawberry Island Sexes Combined		Male tags recovered on the spawning grounds		
Release date	Tags and marks applied to males	01-Sep to 21-Sep	22-Sep to 05-Oct	Male tags not recovered
01-Sep to 14-Sep	5,664	10	1	5,653
15-Sep to 21-Sep	9,769	25	6	9,738
22-Sep to 05-Oct	9,580	1	51	9,528
Total Tags:	25,013	36	58	24,919
Total Sample:	-	14,571	3,366	-

Spawning grounds		Male tags recovered on the spawning grounds				Female tags recovered on the spawning grounds		
Release date	Tags and marks applied to males	01-Sep to 12-Oct	13-Oct to 26-Oct	Male tags not recovered	Tags and marks applied to females	01-Sep to 12-Oct	13-Oct to 26-Oct	Female tags not recovered
01-Sep to 14-Sep	2,660	90	6	2,564	2,993	108	10	2,875
15-Sep to 21-Sep	4,314	49	29	4,236	5,423	99	43	5,281
22-Sep to 05-Oct	4,381	3	26	4,352	5,188	7	45	5,136
Total Tags:	11,355	142	61	11,152	13,604	214	98	13,292
Total Sample:	-	73,906	23,613	-	-	106,215	48,306	-

Table 16. 1995 escapement estimates and 95% confidence limits, by recovery site and estimator, for male and female Fraser River pink salmon. The symbol * indicates the final study area escapement estimates.

		Pooled Petersen			Maximum Likelihood Darroch			
			95% confidence limits			95% confidence limits		
Recovery stratum	Sex	Estimate (millions)	Lower	Upper	Estimate (millions)	Lower	Upper	Schaefer estimate (millions)
Ridgedale Bar	Male	4.0904	2.8574	5.3234	3.8733	2.6561	5.0905	3.9244
	Female	6.7313	4.5063	8.9563	8.3088	4.2340	12.3836	8.3088
	Total [b]	10.8217	8.2779	13.3655	12.1800	7.9273	16.4327	12.2332
	Total [c]	10.6540	8.2491	13.0589	9.9530	7.6778	12.2282	10.1520
Strawberry Island	Male	3.0431 *	2.1764	3.9098	3.4691	2.2498	4.6884	3.3850
	Female	4.2480 *	3.0861	5.4099	4.8484	3.1910	6.5058	4.6803
	Total [b]	7.2911 *	5.8416	8.7406	8.3200	6.2624	10.3776	8.0653
	Total [c]	7.3562	5.8899	8.8225	8.3160	6.2766	10.3554	8.0670
Spawning grounds	Male	5.4286	4.6930	6.1642	4.7495	3.8630	5.6360	5.1500
	Female	6.7165	5.9829	7.4501	6.7177	5.7133	7.7221	6.7303
	Total [b]	12.1451	11.1062	13.1840	11.4672	10.1275	12.8069	11.8803

[a] All estimates include 93,398 pinks of unknown sex which were harvested in the Native fisheries above Duncan Bar, and exclude 60,815 harvested in Native fisheries below Duncan Bar (B. Ennevor, DFO Native Fisheries Biologist, Pers. Comm.).

[b] Sum of male and female estimates.

[c] Estimated from pooled sex-specific data.

nerability of a fish to recovery relative to one with a less noticeable green tag. The recovery crew, therefore, did not appear to select fish based on tag status; and b) tag colour was unlikely to have influenced the correct identification of a tagged fish during live recovery.

ESTIMATION OF SPAWNER POPULATION

Population estimates, calculated from pooled (Table 1) and stratified (Table 15) data, are presented by sex and recovery stratum in Table 16. Statistical summaries for each recovery stratum are presented in Appendix 8. For the stratified estimators, it was typically necessary to pool the first and last two weeks of the release and recovery data to fit the data to the Darroch maximum likelihood estimator in a statistically significant manner. For Ridgedale Bar and Strawberry Island, the tag sample sizes were too small to assess the effects of pooling on the maximum likelihood estimates. For mainstem carcass samples, the maximum likelihood estimates were reasonably robust to the level of pooling.

We could not test the Ridgedale Bar and Strawberry Island recovery data for equal proportions and complete mixing of tag recoveries among strata due to small sample sizes. Instead, we conducted similar tests using pooled sex data. The results were statistically significant (chi-square; $P < 0.05$) for both sites, indicating that the pooled Petersen estimates may be biased. We note, however, that these results are also suspect due to the small sample sizes in some strata. Tests for equal proportions of tags among recovery strata for female spawning ground recovery data could not be rejected (chi-square; $P > 0.05$). For male carcass recoveries, the test for equal proportions of tagged fish was marginally acceptable ($P = 0.05$). Comparable tests for complete mixing failed ($P < 0.05$) at the pooling level necessary to satisfy the maximum likelihood model fit.

We used the sum of individual sex-specific estimates to compare among the live recapture and carcass recovery sites because sex biases were detected in the latter. Little difference was noted between the maximum likelihood Darroch and the pooled Petersen estimators for each site, nor was there any instance where the 95% confidence intervals did not overlap (Fig. 4). This indicates that, given our level of estimation preci-

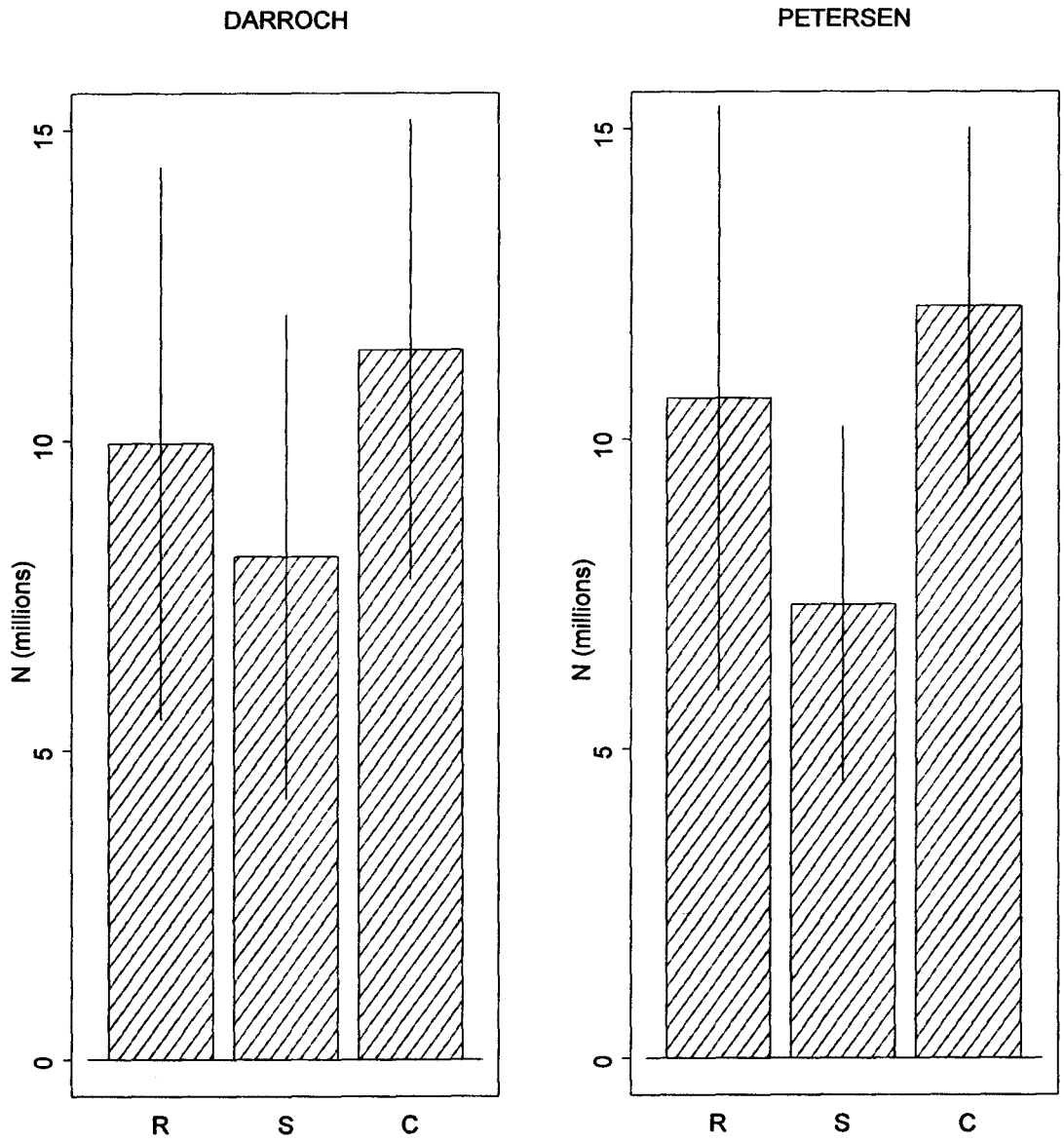


Fig. 4. Population estimates of Fraser River pink salmon based on Darroch (left panel) and pooled Petersen estimators (right panel) by recovery site (R=Ridgedale Bar; S=Strawberry Island; C=main stem carcass recoveries). Bar heights are the point estimate and the lines are the 95% confidence intervals.

sion, we were unable to distinguish among population estimates either among sites or estimators. Biases identified in both the Ridgedale Bar live recovery and Fraser River mainstem carcass recovery samples (discussed later), however, lead us to reject those data sets. Given our established analytic practice to accept the pooled Petersen if its 95% confidence limits overlapped with those of the stratified estimator, we accepted the pooled Petersen estimate, based on Duncan Bar tag application and Strawberry Island live recovery data, as the most appropriate estimator. We chose the sum of sexes estimate (Table 16), despite the slightly higher precision of the pooled sexes estimate, because its use would be consistent with future years when sex-specific biases might well be identified.

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. The accuracy of an escapement estimate, however, 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) Seber (1982) and Arnason *et al.* (1996) 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. In the simplest sense, closure was addressed in the current study by ensuring that tags were applied over the entire period of immigration, the live recapture programs were coincident with the capture and tagging program, and the carcass survey began when the first carcasses were observed and continued until die-off was complete. Within this context, we are confident that closure was addressed and that, with the exception of a very small proportion of the stock which may have immigrated before and after the tagging period, the entire population was vulnerable to either capture or recapture. We note, however, that future studies with a live recapture component must ensure that both application and recovery surveys are coincident with the entire run if underestimation of the population is to be minimize. We recommend that tagging commence within one day of the first report of pink salmon in the PSC test fishery and continue until pinks are not reported in the Duncan Bar catch for several consecutive days.

Within the context of the stratified live recapture studies, closure also requires that tagged fish have a non-zero probability of recovery in one of the recapture strata (Arnason *et al.* 1996). There is evidence, however, that the restriction of tag application to a daily maximum of 12-hours resulted in a contagious migration of tagged fish at least as far upstream as Ridgedale Bar, i.e. a migration of alternate blocks of fish that consist of blocks of tagged and untagged fish which had been sampled at Duncan Bar and blocks that consist primarily of untagged fish that had not been sampled there. Because the average speed of migration permitted pinks which were tagged in the morning to reach Ridgedale Bar seven hours later, the coincidental restriction of live recapture to about the same 12-hour period violated the assumption of a non-zero probability of recapture for an unknown but substantial proportion of the diel migration. Consequently, escapements estimated from the Ridgedale Bar data were likely biased. In contrast, the mixing of tagged and untagged fish likely had occurred by the time they had migrated further upstream to Strawberry Island. Despite a strong shore orientation noted both in the drifted gill net and hydroacoustic (G. Cronkite, DFO hydroacoustic biologist, pers. comm.) samples, tagged fish had been able to move from the south to the north shore, suggesting the possibility of mixing during their extensive lateral movements. Further, most of the Strawberry Island tags were captured one day after release, and the catches were distributed through the day. The latter observation may have resulted from: a) the mixing of tagged and untagged fish as a result of a migratory delay caused by the increased gradient, more restricted channel, and higher water velocity immediately

above the Sumas River; or b) the nocturnal passage of contagiously distributed, healthy fish during the nonfishing period and the recapture of only smaller, stressed fish whose more erratic, slower migration would have permitted more complete mixing. At an average migration speed of 1.9 $km \cdot h^{-1}$, as observed between Duncan and Ridgedale bars, travel time between Ridgedale Bar and Strawberry Island would have averaged 4.5 hours. A substantial component of the previous day's release, therefore, could have migrated undetected past Strawberry Island. This hypothesis is not supported, however, by the similar size of tagged fish at application and live recovery (Table 12) or by the higher tag incidence at Strawberry Island.

Given the above, we view the development of a clear understanding of the diel pattern of migration between Duncan Bar and the live recapture sites to be critical to the design of future studies. We recommend two changes to the study design: a) live recapture should be scheduled over the entire 24-hour per day period; and b) radio telemetry should be used to permit the direct measurement of travel rate and the evaluation of the role of handling and tagging stress.

Identification of Tag Status

The failure to correctly identify the tag status of a recaptured fish is common in mark-recapture studies. It generally results from surveyor inexperience, fatigue, or from assigning a higher priority to speed than to thoroughness. If uncorrected, this type of error results in an underestimate of the proportion of tags in the population and an overestimate of escapement. At the live recapture sites, sample sizes were small and the identification of tag status was continuously monitored by an onsite supervisor. On the spawning grounds, the sample size was relatively large and continuous onsite supervision of all staff was not possible. Instead, the proportion of the tags missed by the initial survey was evaluated by resurveying 33% of the carcasses in previously surveyed areas. A relatively large proportion of the tags, 8.8% or 44 tags, was missed. Although we do not recommend the reimplementation of the carcass survey in future studies (discussed in a later section), three procedural changes are recommended for any similar future surveys: staff training should reemphasize the importance of carefully examining each carcass; the crew chief, through more frequent resurveys, should provide immediate feedback and retraining to staff who are missing tags; and the relationship between the daily number of carcasses processed by an individual and the missed tag rate should be investigated and, if appropriate, a maximum daily carcass processing level should be established.

The resurvey was successful in that a large proportion of the available carcasses were processed and similar proportions of the available carcasses were inspected in each of the main recovery areas. We have three recommendations, however, which would improve the design of the resurvey sample and its analytic treatment. First, resurveys did not begin until a week after the start of the main survey and were relatively infrequent, especially near peak die-off. Unsystematic resurveys can introduce error in the population estimate if the missed tag rate was not uniform, e.g. if the proportion of tags missed was related to the daily number of fish processed, to surveyor fatigue, or to the physical characteristics of the survey area. This issue was not a serious concern in the current study because, given the proportion of carcasses processed during the resurvey period was large, the difference in missed tag rates between periods would have to have been very large to substantially impact the study results. Regardless, the issue should be addressed in future studies by a more representative resurvey. Second, as with the sex identification error correction, there is no variance estimator for the resurvey sampling stage. Consequently, the precision of the population estimate based on the carcass recovery was overstated. This should be addressed in the analytic design of future studies. Third, if variance is to be minimized, simulation studies are required to determine the optimal allocation of effort between the initial and resurvey sampling stages. Recommendations reported by Rajwani (1995) should be incorporated into the design of future studies.

Tag Loss

The undetected loss of tags between tag application and recovery would result in an underestimate of the population tag incidence and an overestimate of escapement. Tag loss can result from poor tag application technique, flawed tag construction, or the fighting which is common among males during spawning. It can be easily

evaluated (although with an incremental labour cost) by applying a secondary tag, or a mark such as an opercular punch or fin clip, in addition to the primary tag. Tag loss in the current study was assessed by applying an opercular punch as a secondary mark to all fish released with a tag. Because the opercular punch was permanent, tag loss had no effect on the pooled population estimators because the true number of recovered fish which had been released with tags was known by summing those with tags and those with secondary marks only. For the stratified estimators, tag loss was assigned proportional to the distribution of initial strata in the marked recoveries that had retained their tags (Arnason *et al.* 1996).

Tag loss between release and the pooled live recovery sites was low, an estimated 0.0% and 1.2% among males and females, respectively. Such low rates were expected because travel time between the sites was generally less than two days. Given the direct supervision of the inspection of live fish, these estimates of tag loss were likely to be relatively unbiased. Tag loss between application and carcass recovery was also low, at 2.7% and 0.7%, respectively. We are concerned, however, that tag loss may have been underestimated among carcasses. We were unable to directly estimate the number of secondary marks missed during the initial survey because tags were removed from all recovered carcasses. Given the high incidence of missed tags and the additional recognition error which likely resulted from fungal infections and carcass decomposition, we believe that tag loss was underestimated and, consequently, the population estimate calculated from carcass recovery data had a positive bias. This bias could be addressed in future studies by changing to a more visible secondary tag. We note, however, that the permanent opercular punch can be applied quickly and at low cost, and is well suited to the assessment of tag loss at the live recapture sites where sample sizes are small and the staff are under direct supervision. Change should be considered only if spawning ground surveys continue to be integral to future 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: although upstream fisheries harvested approximately 93,000 pink salmon (B. Ennevor, Native Fisheries Biologist, pers. comm.), the spaghetti tag was unlikely to have influenced the catchability of a fish; the technicians were trained to recover fish independent of their tag status, and there was no difference in recovery rate among highly visible orange tags and lesser visible green tags; and, although there was no indication that predators differentially removed tagged fish, predator recoveries were excluded from the sample.

The capture, holding and tagging of fish can subject them 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 capture and recapture; 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 trivial, or it may be manifested 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, and others may drift downstream and die outside the study area. The potential impact on the current study of a spectrum of subacute to severe acute stresses is discussed below.

There are a number of stress-related tagging effects which are of potential concern in the current study. First, stress could impair the ability of an affected fish to swim in stronger currents. In a subacute case, the ability of a stressed fish to hold position in faster currents could be impaired, forcing it to spawn in slower flowing water along the river periphery. This could increase the probability that the fish would wash ashore and could result in a higher carcass recovery rate among the stressed group, a violation of the equal probability of recapture assumption. In a more severe case, the ability of the fish to move beyond the tagging site could be impaired, resulting in a lower probability of recovery on the spawning grounds. In an extreme case, such fish could be flushed from the study area, a violation of the closure assumption. Second, stress may impair the ability of a fish to spawn successfully, resulting in a measur-

able reduction in spawning success. Lower spawning success among tagged fish could indicate a subacute stress, while lower success below the tagging site could indicate a more severe, acute stress. By itself, differential spawning success does not violate the basic mark-recapture assumptions; however, it does demonstrate behavioral differences which could violate the assumptions in a way which would be undetectable using current study techniques. Such differential spawning success should be treated as an indicator that the study stock may be highly susceptible to stress; low stress study techniques should be considered. Third, the time span between release and death could be shorter among stressed fish. Shorter time spans among tagged fish in general could indicate a subacute stress which would violate the assumption of random mixing. The detection of such a stress, however, requires an independent estimate of the time between migration past the tagging site and recovery for untagged fish; such an assessment was unavailable in the current study. In contrast, acute stresses should be detectable because behaviour was assessed immediately after release.

In the current study, we attempted to minimize handling stress by ensuring that the capture and tagging processes were as free of stress as possible. This was done by: limiting holding time before tagging to a level (45-minutes) reported by Cass *et al.* (MS 1995) to have had no impact on subsequent recovery rates or distributions; minimizing activity within the net to reduce siltation; removing fish from the water only when a tagger was ready and tagging it as quickly as possible; when removed from the water, cradling the fish in two hands rather than dangling it by the caudal peduncle; and when released over the cork line, gently throwing the fish the minimum necessary distance. We note, however, that the silty substrate at Duncan Bar resulted in poor holding conditions, especially at low tide, and that elevated holding stress was likely.

Our evaluation of stress in the current study focused on the: impact of recapture at Duncan Bar on subsequent recovery rates; comparison of spawning success in tagged and untagged carcasses; recovery of carcasses within five days of release, especially near Duncan Bar; and recovery rates among pink salmon tagged using high and low stress procedures. The evaluation of recapture and release procedure provided no indication of a stress effect in the current study. The difference is spawning success, however, suggested a chronic stress effect. The recovery within one day of release of 27 carcasses at or near Duncan Bar also indicated that at least a component of the population was highly susceptible to acute stress. Although females appeared to be more susceptible, we were unable to relate mortality to attributes such as release condition or fish size, or to directly estimate the number of affected individuals. We addressed the issue by removing the observed recoveries from the application data, a procedure which has been used for several decades. We note, however, that the recovery rate for affected individuals in a river the size of the Fraser would be low despite the daily surveys of the lower river which were first implemented in 1995. Consequently, the impact of undetected mortality on the study results was under estimated, although we note that even a ten-fold difference would result in less than a 10% positive bias in the escapement estimate. Regardless, future studies should develop procedures to directly measure immediate mortality.

In summary, there was equivocal evidence from our tests that stress induced tagging effects were present at a level likely to introduce substantial bias in the population estimates. We acknowledge uncertainty in the estimation of immediate mortality, however, and recommend two design changes to minimize stress and permit its direct assessment: a) operational procedures should be developed to further reduce handling stress. Examples include: the use of a tagging platform to move fish offshore where they could be held in less silty water and their post-release behaviour better observed; the development of holding facilities to permit post-tagging observations for durations of several days; and b) a radio telemetry study to permit the direct measurement of postrelease behaviour and mortality. Further, we support the use of high and low stress tag application techniques for the ongoing evaluation of the stress susceptibility of Fraser River pink salmon.

Sampling Selectivity

The assumption of equal probability of capture and recapture and simple random sampling is violated in virtually all mark-recapture studies and is generally considered to be an unattainable

Table 17a. Application sample bias profile for the 1995 Fraser River pink salmon escapement estimation study. [a]

Sample site	Application sample bias type	Test of	Between	Test result
Ridgedale Bar	Temporal, among days	Tag incidence	Equal recovery periods	High early and late in study, females
			Equal recovery effort	High early and late in study, females
			Equal numbers of recoveries	No bias
	Temporal, within days	Tag incidence	Three daily recovery periods	High late in day, both sexes
	Fish sex	Sex ratio:	Marked/unmarked recoveries	No bias
Strawberry Island	Temporal, among days	Tag incidence	Equal recovery periods	High early and late in study, both sexes
			Equal recovery effort	High early and late in study, both sexes
			Equal numbers of recoveries	High late in study, both sexes
	Temporal, within day	Tag incidence	Three daily recovery periods	High early in day, females
	Fish sex	Sex ratio:	Marked/unmarked recoveries	No bias
Spawning grounds	Temporal, among days	Tag incidence	Equal recovery periods	High early and late, both sexes
			Equal recovery effort	High early and late, both sexes
			Equal numbers of recoveries	No bias
	Spatial	Tag incidence:	Five spawning ground areas	High lower and upper, both sexes
	Fish sex	Sex ratio:	Marked/unmarked recoveries	No bias
All sites	Stress	Recovery rate:	Ventilated/nonventilated releases	No bias
		Recovery of a tag within 5-days of rel:	-	Removed 27 tags
		Recovery rate:	Duncan recaptured/not recaptured	No bias
		Spawning success:	Tagged/untagged recoveries	Higher in untagged females

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

ideal (Otis *et al.* 1978). This condition can be relaxed to some extent, however, without introducing bias in the population estimate. Junge (1963) showed that selectivity can exist in both 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 this assumption by making both tag application and recovery as representative as possible. Daily tagging and live recovery effort was standardized as much as possible, and the fish were captured using a gear (beach seine net) known to minimize selectivity. Standardized effort can still fail to provide a representative sample of migrating pink salmon, however, due to variability in: river conditions; the proportion of the fish which migrate at night or by tidal cycle; daily set times; the technique used during each set; and the daily size of the fish migration (large migrations may exceed the tagging capacity of the crew). The spawning ground surveys were also planned to be as representative as possible. Standardized effort can be compromised, however, by variable river conditions or staff levels.

We could not definitively test sample representativeness because the true population parameters were not known. Instead, we constructed bias profiles for the application (Table 17a) and recovery (Table 17b) components of the study by examining the samples for four potential biases, temporal, spatial, fish size, and fish sex, as indicators of weaknesses in the study design. The results are presented by recovery site below.

Table 17b. Recovery sample bias profile for the 1995 Fraser River pink salmon escapement estimation study. [a]

Sample site	Recovery sample bias type	Test of	Between	Test result
Ridgedale Bar	Temporal among days	Recovery rate	Equal application periods	High early in study, females
			Equal application effort	High early in study, females
			Equal numbers applied	High early in study, both sexes
	Temporal, within day	Recovery rate	Three daily application periods	High early in day, both sexes
	Fish size	Size-frequency distrib:	Recovered/nonrecovered tags	No bias
	Fish sex	Sex ratio:	Recovered/nonrecovered tags	No bias
Strawberry Island	Temporal among days	Recovery rate	Equal application periods	No bias
			Equal application effort	No bias
			Equal numbers applied	High late in study, females
	Temporal, within day	Recovery rate	Three daily application periods	No bias
	Fish size	Size-frequency distrib:	Recovered/nonrecovered tags	No bias
	Fish sex	Sex ratio:	Recovered/nonrecovered tags	No bias
Spawning grounds	Temporal among days	Recovery rate	Equal application periods	High early in study, both sexes
			Equal application effort	High early in study, both sexes
			Equal numbers applied	High early in study, both sexes
	Temporal, within day	Recovery rate	Three daily application periods	High early in day, males
	Fish size	Size-frequency distrib:	Recovered/nonrecovered tags	No bias
	Fish sex	Sex ratio:	Recovered/nonrecovered tags	Bias to females

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

Ridgedale Bar: Four biases were detected in the application and recovery samples: a) a temporal application bias which resulted in a high tag incidence among females recaptured early and late in the study; b) a temporal recovery bias which resulted in a high recovery rate among females tagged early in the study; c) a temporal application bias for both sexes which resulted in a high tag incidence among fish recaptured late in the day; and d) a temporal recovery bias for both sexes which resulted in a high recovery rate among fish tagged early in the day.

The temporal application bias toward the early and late parts of the study period likely reflected the large daily migrations which occurred during the peak of the run. Although capture effort remained relatively constant at 8-10 sets per day, the number of fish captured was often controlled by setting the net closer to shore and using only part of the net. Further, the catch in some sets exceeded the crew's tagging capacity and required the release of untagged fish. The temporal recovery bias toward higher recovery rates for fish tagged early in the study is more difficult to explain. Recovery effort early in the study tended to be low at this site; therefore, this bias may have been an artifact of the low number of tags recovered at Ridgedale Bar.

The within day temporal application and recovery biases detected at Ridgedale Bar clearly reflect the contagious migration of tags between Duncan and Ridgedale bars (discussed in the Population Closure section). Because tagged fish apparently required an average of 7 hours to migrate to Ridgedale Bar, only fish tagged early in the 12-hour Duncan Bar shift would have been vulnerable to recapture, and only late in the 12-hour Ridgedale Bar shift. Consequently, Ridgedale Bar recovery rates were high for fish tagged

early in the day, and tag incidences were high for fish recaptured late in the day. Because none of the fish tagged after 14:30 h were recovered on the same day at Ridgedale Bar, a component of the tagged population was unlikely to have been vulnerable to recovery. This would result in an underestimate of the population tag incidence and an overestimate of the escapement.

Strawberry Island: Two biases and one potential bias was detected in the application and recovery samples, respectively: a) a temporal application bias for both sexes which resulted in a high tag incidence among fish recaptured early and late in the study; b) a temporal application bias which resulted in a high tag incidence among females recaptured early in the day; and c) a potential temporal recovery bias in one of three stratifications which resulted in a high recovery rate for females tagged late in the study.

As noted at Ridgedale Bar, the temporal application bias through the study period likely reflected the large daily migrations which occurred during the peak of the run. The temporal recovery bias was noted in only one stratification and, given the small tag sample sizes at this site, may have been a sample size artifact.

The temporal application bias among females is potentially more serious because the diel mixing of tagged and untagged fish is a necessary prerequisite for an unbiased population estimate. A higher tag incidence among females recovered early in the shift may indicate that contagious migrations of tagged fish continued to some extent as far upstream as Strawberry Island. Conversely, it may also indicate that the mixing among the previous day's migration had occurred as the fish held at night below the Sumas River, and that their migration resumed the following day during daylight hours, thus depleting the tag incidence as the day progressed (Table 10a). Our uncertain interpretation of these results provides further support for the need to develop a thorough understanding of the diel migratory characteristics of this stock aggregate.

Spawning Grounds: Five biases were detected in the application and recovery samples: a) a temporal application bias for both sexes which resulted in a high tag incidence among fish recaptured early and late in the study; b) a temporal recovery bias for both sexes which resulted in a high recovery rate among fish tagged early in the study; c) a temporal recovery bias which resulted in a high recovery rate among males tagged early in the day; d) a spatial application bias for both sexes which resulted in a high tag incidence among fish recovered in the lower and upper spawning areas; and d) a general recovery bias toward females.

We consider the latter three biases to be relatively unimportant with respect to the accurate esti-mation of the 1995 escapement. The sex bias was easily treated by stratifying the data set and calculating sex-specific population estimates. The spatial and within-day temporal biases suggest that this stock exhibits unique behaviours in the lower river. Their potential impact on the study results was likely small, however, in comparison to that of the coincidental temporal biases in the application and recovery samples. These biases have important implications regarding the utility of the mainstem recovery data to the estimation of current and future escapements. Both can be related directly to specific aspects of the study design or the behaviour of the stock aggregate. The application bias likely reflected disproportionately low capture and tag application during the peak of the run (discussed in previous sections). The recovery bias toward fish tagged early in the study reflected: a) the early timing of the mainstem stock through the lower Fraser River. Previous tagging studies have shown that this stock migrates through the lower river before late run stocks such as the Harrison and Vedder-Chilliwack (Anon. 1995). Mainstem pinks, therefore would not comprise a large proportion of the later migrants at Duncan Bar; and b) high water in mid October which limited the recovery rate of the later migrants by flushing most of the remaining carcasses out of the system. The late migrants, which had a higher tag incidence, were not vulnerable to recovery on the Fraser River mainstem because they either spawned elsewhere or were flushed out of the recovery area. This would result in an underestimate of the population tag incidence and an overestimate of the escapement.

Because these biases are inherent sample characteristics resulting from stock timing, prevailing environmental conditions and operational limitations imposed by the size of the Fraser River pink escapement, they cannot be easily addres-

sed and, consequently, they limit the utility of the mainstem carcass survey to the estimation of the system-wide escapement.

INTERSITE MIGRATION

The behaviour of tagged pink salmon between release and live recapture could not be directly assessed in 1995 because neither sample was obtained over a complete diel cycle. Instead, behaviour and rate of travel were inferred from the time of release and the elapsed time to recovery. At Ridgedale Bar, we noted three patterns: a) most of the recaptured fish had been released on the morning of the same day and had required less than 7.5 hours (0.8 kmh^{-1}) to migrate the 13.5 km between the sites; b) none of the fish released on the afternoon or evening were recaptured on the same day. Some of these fish, however, were recaptured on the following morning or early afternoon and had required an average of 17 hours to migrate between the sites; and c) a small number of fish were recaptured several days after release and may have delayed between sites, perhaps as a result of stress, or may have migrated past Ridgedale Bar before dropping downstream. We inferred from these results that the predominant behaviour between Duncan and Ridgedale bars was a contagious migration, i.e. because tagging was restricted to specific daily periods, the migration past Ridgedale Bar consisted of alternating blocks of fish which had and had not been vulnerable to tagging. Clearly, however, the migration was not completely contagious (depicted in Fig. 5) because apparent travel rates varied, and tagged fish were recaptured both in the morning (Table 4b) and several days after release. Regardless, the assumption of equal probability of recapture was violated at Ridgedale Bar because the mixing of tagged fish with the study population was incomplete and the recapture shifts were scheduled to investigate the diel pattern of tag incidence rather than to obtain either a representative or consistent sample. For example, recapture shifts continued until 15:00 h, 16:00 h and 18:00 h on 94%, 56% and 24% of the days, respectively. Because tagged fish did not begin to arrive at Ridgedale Bar until the early afternoon, daily tag incidences would have been highest on the shifts which extended later in the day. This violates the fundamental mark-recapture assumption of equal probability of recapture of tagged fish and, if these data were used in population estimation, would result in an overestimate of the study population. We could not quantify the size of the bias; however, we note that 67% of the tagged fish were released after 10:00 h and, on average, would not have reached Ridgedale Bar until after 17:00 h.

Three patterns were noted among the Strawberry Island recaptures: a) some of the fish had been released on the morning of the same day and had required 10.5 hours to migrate the 22 km between the sites. The average speed (2.1 kmh^{-1}) was similar to that of fish recaptured on the day of release at Ridgedale Bar (1.9 kmh^{-1}); b) most fish were recaptured the day after release and had required an average of 22 hours (1.0 kmh^{-1}) to migrate between the sites. Recapture was independent of the time of release; and c) some fish were recaptured several days after release. These observations were not consistent with the hypothesis of a largely contagious migration of tagged fish. Had the majority of the fish migrated at a constant speed (Fig. 5), tagged fish would have been recaptured at Strawberry Island only at the end of the latest shifts and, because they would have cleared the area overnight, the daily tag incidence would have been low. Instead, tags were observed throughout the day, and the tag incidence (0.34%) was higher than at Ridgedale (0.24%). These observations suggest two processes were in effect. First, a component of the population which had actively migrated between Duncan and Ridgedale bars had continued to do so at Strawberry Island. These fish had migrated between Duncan Bar and Strawberry Island in just under 11 hours and arrived near the end of the work shift. They may then have either delayed above the site or continued their active migration upstream. If the latter, then an unknown component of the release was likely not vulnerable to sampling at Strawberry Island. Second, most of the tagged population delayed at Strawberry Island and, based on the declining tag incidence through the day (Table 10a), resumed their migration the next day and had largely cleared the area before the arrival of that day's tags. This apparent delay may have reflected a behavioural response to changes in river hydrology which occur above Strawberry Island. The river has a relatively low gradient and is tidal as far upstream as Ridgedale Bar; however, near Strawberry Island, the gradient increases and the river braids into a number of high velocity gravel-bed channels. The velocity change may have induced a reduced migration speed or a

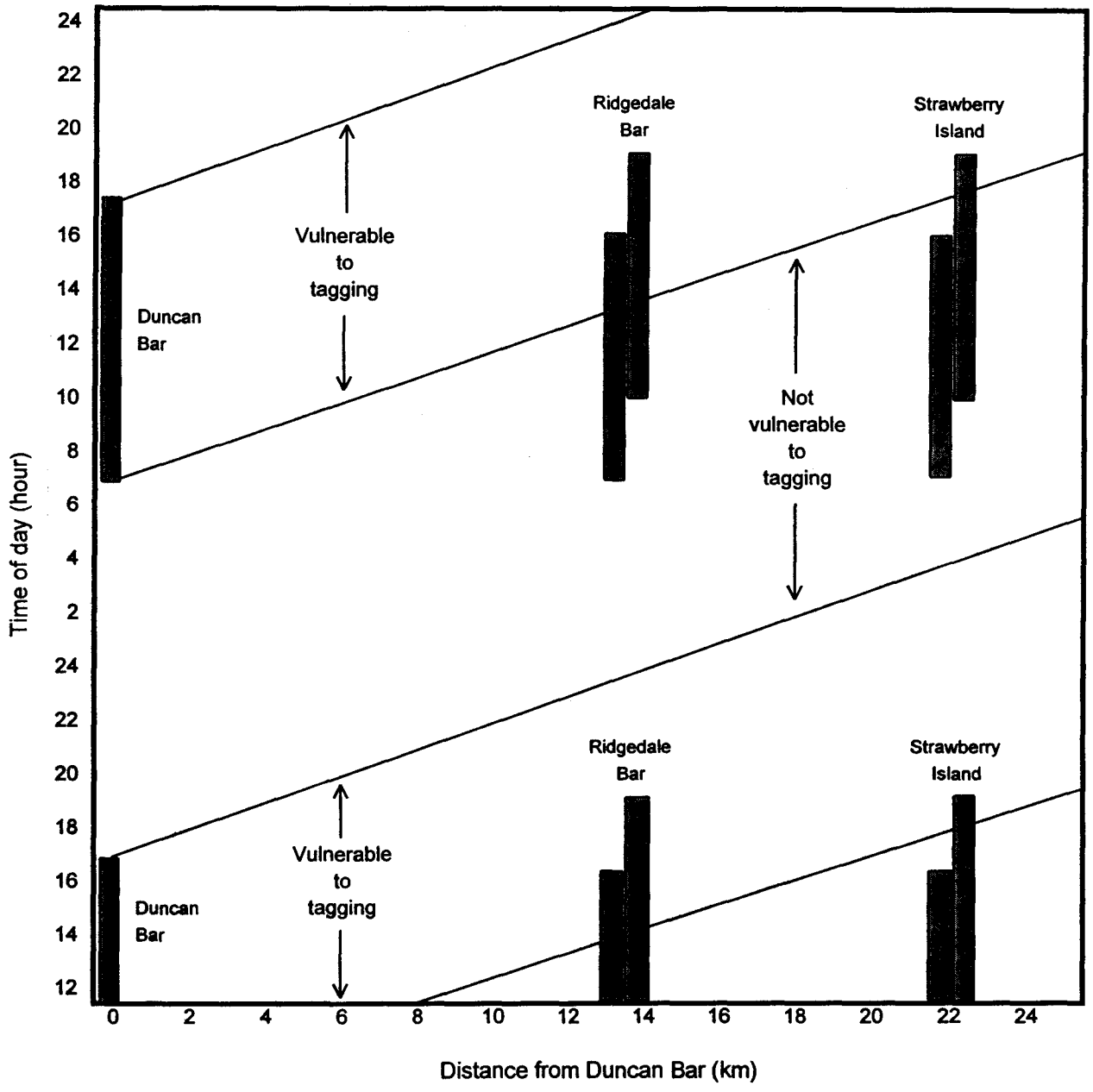


Fig. 5. Conceptual illustration of the pattern of migration of contagiously distributed tagged pink salmon migrating between the tagging site at Duncan Bar and the live recapture sites at Ridgedale Bar and Strawberry Island at an assumed fixed migration speed of 2 km/hr. Vertical bars show the average shift times (two shifts were worked at Ridgedale Bar and Strawberry Island) during the peak at each site. Diagonal lines represent blocks of comigrating tagged fish.

period of holding or resting. Regardless of the reason underlying the observed tag distributions, the defensibility of the 1993 and 1995 population estimates depends entirely on whether complete mixing of tagged and untagged fish had occurred at Strawberry Island. While the Strawberry Island data ultimately satisfied the conditions for a valid pooled or stratified mark-recapture estimate, they were inadequate to evaluate this assumption. We recommend, therefore, the extension of the daily sampling period to 24 hours per day as a necessary element to the defensibility of future studies and for the validation of the 1993 and 1995 estimates.

CONCLUSIONS

1. Severe within-day temporal biases were noted at the Ridgedale Bar live recovery site. These biases resulted from a failure to representatively resample contagiously distributed tagged fish as they migrated up the Fraser River and are symptomatic of the failure of the 1995 study to address the assumption of population closure at this site. We conclude, therefore, that the Ridgedale Bar live recovery data should not be used to estimate the 1995 Fraser river pink salmon escapement.

2. The lower Fraser River mainstem spawning ground survey has limited utility in the ongoing estimation of the Fraser River system pink salmon escapement because: a) both application and recovery are nonrepresentative, the former because capture and tagging are limited during the arrival peak of the large recent returns, the latter because mainstem pinks are an early run stock which is not present later in the run; and b) the mainstem bars are highly susceptibility to relatively small increases in river stage which result from frequent fall rainfall events. This occurred in 1995, and limits the effectiveness of the study even if tags could be representatively applied over the entire Fraser River population. Spawning ground data, therefore, should not be used in 1995 and should be avoided in future studies intended to estimate the aggregate Fraser River pink salmon escapement.

3. We conclude that the 1995 Fraser River system pink salmon escapement should be estimated from the Duncan Bar tag application and the Strawberry Island live recovery data. The pooled Petersen estimator should be used because, given the level of estimation precision generated by the study data, it was indistinguishable from the maximum likelihood Darroch estimator and its precision was higher. Total escapement should be estimated from the sum of the male and female estimates to ensure that it will be consistent with future years when sex-specific biases might be present.

4. The utility of the live recovery data collected by the 1995 study was limited for two reasons. First, although the Strawberry Island tag recovery total exceeded the 1993 total (96 versus 81) and the overall tag recovery at the live recapture sites was over double the 1993 total, the number of tags recovered was insufficient to permit adequate testing for equal proportions and complete mixing of tag recoveries among strata. Second, the failure to recover live fish over a 24-hour period hindered our development of a thorough understanding of the diel migratory characteristics of this stock aggregate and limited our ability to evaluate biases.

5. Our evaluation of the role of stress in the current study can be divided into chronic and acute impacts. We detected evidence of chronic stress only in the difference in spawning success between tagged and untagged females. We failed to detect evidence of chronic stress-related impacts, however, in two other areas: a) there was no difference in recovery rates among fish tagged using normal and low stress procedures; and b) there was no difference in recovery rates among small and large fish, nor was there any evidence of a disproportionate impact of stress on smaller fish. In contrast, acute stress-related mortality was unequivocally detected in 1995 with the recovery in the lower river within one day of release of 27 tagged carcasses. We were unable to relate immediate mortality to condition at release, fish size (as has been suggested by the PSC (Anon. 1994a)), or to any other factor. We note that, despite the daily survey of the lower river, 81% of the carcasses were recovered in subsequent beach seine sets at Duncan Bar. Visual observation in the lower river, therefore, may be a relatively ineffective method to assess immediate mortality. Our evaluation of acute stress-related mortality will remain equivocal until a direct assessment can be completed.

RECOMMENDATIONS

1. We recommend that the pooled Petersen estimate generated from the Strawberry island live recovery site be accepted as the most appropriate estimate for 1995. The estimated escapement was 7.3 million, with 95% confidence limits of 5.8 million to 8.7 million. The escapement of males and females was 3.0 million (2.2 million to 3.9 million) and 4.2 million (3.1 million to 5.4 million), respectively.

2. The objective of the 1997 study should again be to estimate the abundance of the aggregate Fraser River pink salmon escapement. The study should have the following components:

- Live capture and tagging conducted at Duncan Bar, with shifts scheduled over a fixed daily 12-hour period;
- Live recapture conducted at both Ridgedale Bar and Strawberry Island, with shifts scheduled 24-hours per day. This recommendation addresses the need to increase the number of tags recovered and to investigate diel migratory characteristics. We recommend the increased sampling period at live recovery rather than at application or on the spawning grounds because several attributes make proportional sampling feasible: a) pinks appear almost entirely shore oriented; b) sets are inspected visually and can be processed quickly; and c) the recovery sites can operate over a wide range of water levels and are, therefore, largely independent of weather;
- A study to directly measure the immediate mortality resulting from acute stress.

3. The lower Fraser River mainstem spawning ground survey is unlikely to provide a representative sample of the system-wide escapement and provides other information which is of only peripheral importance to this study. We recommend the cancellation of this survey in 1997.

4. The control of stress and the evaluation of its impact on the study results continues to be an issue of central importance to this study. We recommend the following:

- Handling procedures implemented in 1995 to reduce stress should continue in 1997;
- Alternate handling procedures should be developed which address the need to capture and hold fish in a silt-rich environment and to evaluate their condition at release;
- Installation of holding facilities to permit the direct observation of tagged and untagged fish for several days after release;
- The impact of holding time on subsequent recovery rates, first investigated in 1993, should be repeated in 1997;
- Continued evaluation of stress-susceptibility should continue through the use of high and low stress tagging procedures; and
- A radio telemetry study to monitor post release behaviour and directly measure immediate stress induced mortality.

5. The following operational procedures are recommended for future programs:

- The combination of spaghetti tags and opercular punches should be retained as the primary tag and secondary mark, respectively;
- Sex identification error should be evaluated at all sampling sites by sacrificing a random sample of previously identified fish.

PSARC RECOMMENDATIONS

This report was reviewed by the Salmon Subcommittee of the Pacific Stock Assessment Review Committee on April 30, 1997. The following recommendations were extracted from the Subcommittee's report:

1. The pooled Petersen estimate generated from the Strawberry Island live recovery site is recommended as the most appropriate estimate for 1995. The estimated escapement was 7.3 million, with 95% confidence limits of 5.8 million to 8.7 million.

2. Previous Subcommittee advice recognized that complete mixing of tagged and untagged fish was critical to the unbiased estimation of escapement. The 1995 study results demonstrated that mixing did not occur at Ridgedale Bar and that the results were equivocal at Strawberry Island. Because mixing at Strawberry Island is critical to the validation of the 1993 and 1995 escapement estimates, the Subcommittee acknowledges the uncertainty in the assumption of complete mixing and supports the authors' recommendation for further investigation.

3. The Subcommittee recognized in its evaluation of Working Papers S93-4 (Cass and Whitehouse MS 1993) and S94-19 (Cass *et al.* MS 1995) that stress-induced immediate mortality could bias the study results. The 1995 study demonstrated that immediate mortality does occur but was unable to quantify its impact on the escapement estimate. The Subcommittee reiterates its concerns and supports the authors' recommendations for further investigation.

4. The lower Fraser River mainstem spawning ground survey is unlikely to provide a representative sample of the system-wide escapement and should be dropped as part of the pink escapement estimation program.

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APPENDICES

Appendix 1a. Daily application of spahgetti tags and secondary marks, by tag colour (green or orange) and application method (high or low stress), for male pink salmon in the lower Fraser River at Duncan Bar, 1995. Both field totals and estimates corrected for sex identification error at time of tagging are included. [a]

				Original field estimate of males					Males corrected for sex identification error				
	Set start time			Green tags		Orange tags			Green tags		Orange tags		
Date	First	Last	Number of sets	High stress	Low stress	High stress	Low stress	Total	High stress	Low stress	High stress	Low stress	Total
1-Sep	9:20	15:05	5	0	7	10	1	18	0	7	10	1	18
2-Sep	8:10	15:00	8	0	17	14	0	31	0	17	14	0	31
3-Sep	8:00	15:20	8	0	54	57	0	111	0	54	57	0	111
4-Sep	8:15	14:35	6	0	117	121	0	238	0	117	121	0	238
5-Sep	8:05	14:35	7	0	84	70	0	154	0	84	70	0	154
6-Sep	8:05	15:05	8	0	63	61	0	124	0	63	61	0	124
7-Sep	8:00	15:20	7	0	190	198	0	388	0	161	172	0	333
8-Sep	8:15	14:50	6	62	123	120	50	355	51	110	108	39	308
9-Sep	8:10	15:05	7	70	26	28	59	183	67	23	25	55	170
10-Sep	8:05	15:10	7	46	102	114	29	291	46	102	114	29	291
11-Sep	7:10	15:15	6	123	61	58	128	370	118	58	54	124	354
12-Sep	7:10	16:20	10	50	59	61	48	218	49 [b]	59	61	48	217
13-Sep	7:05	16:05	8	91	93	97	81	362	84	83 [b]	89	73	329
14-Sep	7:05	16:05	7	183	125	173	118	599	180	120 [c]	169	114	583
15-Sep	7:25	16:05	7	194	108	137	119	558	188 [b]	105	132 [b]	115	540
16-Sep	9:10	18:05	8	92	218	263	75	648	88	214	259	71	632
17-Sep	7:05	16:10	8	264	143	214	183	804	254	131	202	173	760
18-Sep	9:20	17:55	8	121	156	212	62	551	117	151	208	60	536
19-Sep	7:15	17:57	8	152	195	253	127	727	148	191	247 [b]	123	709
20-Sep	7:20	17:35	9	103	173	189	79	544	101 [c]	173	189	80	543
21-Sep	7:25	17:40	5	31	91	114	42	278	31	91	114	42	278
22-Sep	7:10	17:35	10	140	68	107	68	383	140	68	107	68	383
23-Sep	7:20	17:25	10	115	118	132	96	461	115	118	132	96	461
24-Sep	7:20	17:10	9	114	135	142	73	464	114	135	142	73	464
25-Sep	7:20	17:35	8	104	207	314	100	725	104	207	314	100	725
26-Sep	7:25	17:35	9	174	122	149	127	572	167	115	144	121	547
27-Sep	7:20	18:05	9	181	116	216	102	615	181	116	216	102	615
28-Sep	7:20	17:35	10	88	108	203	44	443	88	108	203	44	443
29-Sep	7:20	17:40	10	103	30	56	64	253	103	30	56	64	253
30-Sep	7:15	16:40	10	42	28	27	29	126	42	28	27	29	126
1-Oct	7:20	17:45	11	7	18	25	3	53	7	18	25	3	53
2-Oct	7:15	18:00	10	5	8	14	1	28	5	8	14	1	28
3-Oct	7:15	14:10	8	3	0	0	0	3	3	0	0	0	3
4-Oct	7:15	15:30	9	0	1	0	0	1	0	1	0	0	1
5-Oct	7:15	14:20	8	0	0	0	0	0	0	0	0	0	0
Total	-	-	284	2,658	3,164	3,949	1,908	11,679	2,591	3,066	3,856	1,848	11,361

[a] See methods for sex identification error correction procedure.

[b] Excludes 1 carcass recovered within 1-day of release at the tagging site or by the roving survey.

[c] Excludes 2 carcasses recovered within 1-day of release at the tagging site or by the roving survey.

Appendix 1b. Daily application of spahgetti tags and secondary marks, by tag colour (green or orange) and application method (high or low stress), for female pink salmon in the lower Fraser River at Duncan Bar, 1995. Both field totals and estimates corrected for sex identification error at time of tagging are included. [a]

				Original field estimate of males					Males corrected for sex identification error				
	Set start time			Green tags		Orange tags			Green tags		Orange tags		
Date	First	Last	Number of sets	High stress	Low stress	High stress	Low stress	Total	High stress	Low stress	High stress	Low stress	Total
1-Sep	9:20	15:05	5	0	20	6	0	26	0	20	6	0	26
2-Sep	8:10	15:00	8	0	16	24	0	40	0	16	24	0	40
3-Sep	8:00	15:20	8	0	44	40	0	84	0	44	40	0	84
4-Sep	8:15	14:35	6	0	140	111	0	251	0	140	111	0	251
5-Sep	8:05	14:35	7	0	96	60	0	156	0	96	60	0	156
6-Sep	8:05	15:05	8	0	65	46	0	111	0	65	46	0	111
7-Sep	8:00	15:20	7	0	192	152	0	344	0	221	178	0	399
8-Sep	8:15	14:50	6	26	123	99	26	274	37	136	111	37	321
9-Sep	8:10	15:05	7	52	30	42	51	175	55	33	45	55	188
10-Sep	8:05	15:10	7	36	114	102	38	290	36	114	102	38	290
11-Sep	7:10	15:15	6	133	54	92	90	369	138	57	96	94	385
12-Sep	7:10	16:20	10	52	102	91	53	298	52	102	91	53	298
13-Sep	7:05	16:05	8	92	88	113	110	403	99	95	121	118	433
14-Sep	7:05	16:05	7	160	96	142	141	539	163	98 [b]	146	145	552
15-Sep	7:25	16:05	7	286	131	187	245	849	289 [c]	133 [b]	190 [b]	248 [b]	860
16-Sep	9:10	18:05	8	109	284	330	104	827	113	288	334	108	843
17-Sep	7:05	16:10	8	270	201	212	241	924	280	212 [b]	223 [b]	251	966
18-Sep	9:20	17:55	8	136	161	228	94	619	139 [b]	166	232	96	633
19-Sep	7:15	17:57	8	183	279	311	187	960	187	283	316	191	977
20-Sep	7:20	17:35	9	111	181	219	109	620	111	180 [b]	219	108	618
21-Sep	7:25	17:40	5	41	97	109	46	293	41	97	109	45 [b]	292
22-Sep	7:10	17:35	10	142	89	117	134	482	142	88 [b]	117	134	481
23-Sep	7:20	17:25	10	181	130	127	132	570	181	130	127	131 [b]	569
24-Sep	7:20	17:10	9	132	165	198	108	603	132	165	198	108	603
25-Sep	7:20	17:35	8	112	255	331	105	803	112	255	330 [b]	105	802
26-Sep	7:25	17:35	9	225	150	192	164	731	232	157	197	170	756
27-Sep	7:20	18:05	9	174	172	224	158	728	174	171 [b]	223 [b]	158	726
28-Sep	7:20	17:35	10	84	121	169	47	421	84	121	169	47	421
29-Sep	7:20	17:40	10	116	35	61	77	289	116	35	61	77	289
30-Sep	7:15	16:40	10	43	26	38	42	149	43	26	38	42	149
1-Oct	7:20	17:45	11	8	28	24	4	64	8	28	24	4	64
2-Oct	7:15	18:00	10	4	5	16	2	27	4	5	16	2	27
3-Oct	7:15	14:10	8	5	0	0	2	7	5	0	0	2	7
4-Oct	7:15	15:30	9	0	2	4	0	6	0	2	4	0	6
5-Oct	7:15	14:20	8	6	0	0	0	6	6	0	0	0	6
Total	-	-	284	2,919	3,692	4,217	2,510	13,338	2,979	3,779	4,304	2,567	13,629

[a] See methods for sex identification error correction procedure.

[b] Excludes 1 carcass recovered within 1-day of release at the tagging site or by the roving survey.

[c] Excludes 2 carcasses recovered within 1-day of release at the tagging site or by the roving survey.

Appendix 1c. Daily catch of other species by beach seine in the lower Fraser River at Duncan Bar, 1995.

Date	Chinook		Coho		Sock-eye	Chum	Steel-head	Cut-throat	Dolly Varden	Stur-geon
	Adults	Jacks	Adults	Jacks						
1-Sep	0	0	1	0	1	0	0	0	0	0
2-Sep	0	0	1	0	2	0	0	0	0	0
3-Sep	1	0	4	0	0	0	0	0	0	0
4-Sep	0	1	2	0	5	0	0	0	0	0
5-Sep	0	0	1	0	2	0	0	0	0	0
6-Sep	0	0	1	0	4	0	0	0	0	0
7-Sep	0	1	1	0	4	0	0	0	0	0
8-Sep	0	0	1	0	0	0	0	0	0	0
9-Sep	0	1	1	0	2	0	0	0	0	0
10-Sep	0	0	0	0	0	0	0	0	0	0
11-Sep	0	0	5	0	2	0	0	0	0	0
12-Sep	0	0	7	0	2	0	0	0	0	0
13-Sep	0	0	11	0	4	0	0	0	0	0
14-Sep	1	0	2	0	6	0	0	0	0	0
15-Sep	0	0	10	0	18	0	0	0	0	0
16-Sep	1	0	7	0	6	1	0	0	0	0
17-Sep	1	3	14	0	5	1	0	0	0	0
18-Sep	0	0	8	0	1	0	0	0	0	0
19-Sep	0	0	12	0	17	0	0	0	0	0
20-Sep	0	0	3	0	23	1	0	0	0	0
21-Sep	0	1	4	0	3	0	0	0	0	0
22-Sep	0	1	10	0	5	0	0	0	0	0
23-Sep	0	0	14	0	13	0	0	0	0	0
24-Sep	0	0	20	0	7	4	0	0	0	0
25-Sep	1	1	54	0	33	8	0	0	0	0
26-Sep	0	1	35	0	6	5	0	0	0	0
27-Sep	6	1	38	0	17	20	0	0	0	0
28-Sep	4	0	76	0	8	13	0	0	0	0
29-Sep	3	0	71	0	1	16	0	0	0	0
30-Sep	2	0	36	0	3	13	0	0	0	0
1-Oct	0	0	22	0	1	10	1	0	0	0
2-Oct	2	0	45	0	0	19	0	0	0	0
3-Oct	3	0	34	0	0	2	0	0	0	0
4-Oct	0	1	16	0	0	2	0	0	0	0
5-Oct	1	1	27	0	0	0	0	0	0	0
Total	26	13	594	0	201	115	1	0	0	0

Appendix 1d. Incidence of net, lamprey and hook marks and of *Flexibacter columnaris* lesions among male pink salmon captured by beach seine in the lower Fraser River at Duncan Bar, 1995.

Date	Number of males examined	Net marks		Lamprey marks		Hook marks		*F. columnaris*	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent
1-Sep	18	1	5.6%	0	0.0%	0	0.0%	0	0.0%
2-Sep	31	2	6.5%	0	0.0%	0	0.0%	0	0.0%
3-Sep	111	1	0.9%	0	0.0%	2	1.8%	0	0.0%
4-Sep	238	3	1.3%	0	0.0%	9	3.8%	0	0.0%
5-Sep	154	6	3.9%	1	0.6%	6	3.9%	0	0.0%
6-Sep	124	2	1.6%	0	0.0%	1	0.8%	0	0.0%
7-Sep	388	8	2.1%	0	0.0%	10	2.6%	0	0.0%
8-Sep	355	4	1.1%	0	0.0%	8	2.3%	0	0.0%
9-Sep	183	2	1.1%	0	0.0%	2	1.1%	0	0.0%
10-Sep	291	4	1.4%	0	0.0%	5	1.7%	0	0.0%
11-Sep	370	2	0.5%	0	0.0%	4	1.1%	0	0.0%
12-Sep	218	0	0.0%	0	0.0%	2	0.9%	0	0.0%
13-Sep	362	1	0.3%	0	0.0%	5	1.4%	0	0.0%
14-Sep	599	3	0.5%	0	0.0%	7	1.2%	0	0.0%
15-Sep	558	0	0.0%	0	0.0%	10	1.8%	0	0.0%
16-Sep	648	3	0.5%	0	0.0%	12	1.9%	0	0.0%
17-Sep	804	3	0.4%	0	0.0%	13	1.6%	0	0.0%
18-Sep	551	3	0.5%	0	0.0%	12	2.2%	0	0.0%
19-Sep	727	4	0.6%	0	0.0%	5	0.7%	0	0.0%
20-Sep	544	4	0.7%	0	0.0%	3	0.6%	0	0.0%
21-Sep	278	0	0.0%	0	0.0%	2	0.7%	0	0.0%
22-Sep	383	3	0.8%	0	0.0%	5	1.3%	0	0.0%
23-Sep	461	4	0.9%	0	0.0%	2	0.4%	0	0.0%
24-Sep	464	0	0.0%	0	0.0%	2	0.4%	0	0.0%
25-Sep	725	6	0.8%	0	0.0%	6	0.8%	0	0.0%
26-Sep	572	3	0.5%	0	0.0%	5	0.9%	0	0.0%
27-Sep	615	3	0.5%	0	0.0%	1	0.2%	0	0.0%
28-Sep	443	0	0.0%	0	0.0%	3	0.7%	0	0.0%
29-Sep	253	0	0.0%	0	0.0%	2	0.8%	0	0.0%
30-Sep	126	0	0.0%	0	0.0%	0	0.0%	0	0.0%
1-Oct	53	0	0.0%	0	0.0%	0	0.0%	0	0.0%
2-Oct	28	0	0.0%	0	0.0%	0	0.0%	0	0.0%
3-Oct	3	0	0.0%	0	0.0%	0	0.0%	0	0.0%
4-Oct	1	0	0.0%	0	0.0%	0	0.0%	0	0.0%
5-Oct	0	0	-	0	-	0	-	0	-
Total	11,679	75	0.6%	1	0.0%	144	1.2%	0	0.0%

[a] Not corrected for sex identification error.

Appendix 1e. Incidence of net, lamprey and hook marks and of *Flexibacter columnaris* lesions among female pink salmon captured by beach seine in the lower Fraser River at Duncan Bar, 1995. [a]

Date	Number of females examined	Net marks		Lamprey marks		Hook marks		*F. columnaris*	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent
1-Sep	26	1	3.8%	0	0.0%	0	0.0%	0	0.0%
2-Sep	40	1	2.5%	0	0.0%	0	0.0%	0	0.0%
3-Sep	84	5	6.0%	0	0.0%	2	2.4%	0	0.0%
4-Sep	251	8	3.2%	0	0.0%	6	2.4%	0	0.0%
5-Sep	156	8	5.1%	0	0.0%	2	1.3%	0	0.0%
6-Sep	111	3	2.7%	0	0.0%	1	0.9%	0	0.0%
7-Sep	344	8	2.3%	0	0.0%	11	3.2%	0	0.0%
8-Sep	274	8	2.9%	0	0.0%	7	2.6%	0	0.0%
9-Sep	175	3	1.7%	0	0.0%	4	2.3%	0	0.0%
10-Sep	290	8	2.8%	0	0.0%	8	2.8%	0	0.0%
11-Sep	369	3	0.8%	0	0.0%	4	1.1%	0	0.0%
12-Sep	298	6	2.0%	0	0.0%	3	1.0%	0	0.0%
13-Sep	403	4	1.0%	0	0.0%	5	1.2%	0	0.0%
14-Sep	539	5	0.9%	0	0.0%	5	0.9%	0	0.0%
15-Sep	849	11	1.3%	0	0.0%	10	1.2%	0	0.0%
16-Sep	827	16	1.9%	0	0.0%	9	1.1%	0	0.0%
17-Sep	924	14	1.5%	0	0.0%	8	0.9%	0	0.0%
18-Sep	619	3	0.5%	0	0.0%	8	1.3%	0	0.0%
19-Sep	960	8	0.8%	0	0.0%	8	0.8%	0	0.0%
20-Sep	620	11	1.8%	0	0.0%	0	0.0%	0	0.0%
21-Sep	293	3	1.0%	0	0.0%	1	0.3%	0	0.0%
22-Sep	482	2	0.4%	0	0.0%	1	0.2%	0	0.0%
23-Sep	570	4	0.7%	0	0.0%	6	1.1%	0	0.0%
24-Sep	603	3	0.5%	0	0.0%	3	0.5%	0	0.0%
25-Sep	803	11	1.4%	0	0.0%	2	0.2%	0	0.0%
26-Sep	731	2	0.3%	0	0.0%	3	0.4%	0	0.0%
27-Sep	728	4	0.5%	0	0.0%	3	0.4%	0	0.0%
28-Sep	421	1	0.2%	1	0.2%	2	0.5%	0	0.0%
29-Sep	289	3	1.0%	0	0.0%	0	0.0%	0	0.0%
30-Sep	149	1	0.7%	0	0.0%	0	0.0%	0	0.0%
1-Oct	64	0	0.0%	0	0.0%	0	0.0%	0	0.0%
2-Oct	27	0	0.0%	0	0.0%	1	3.7%	0	0.0%
3-Oct	7	1	14.3%	0	0.0%	0	0.0%	0	0.0%
4-Oct	6	0	0.0%	0	0.0%	0	0.0%	0	0.0%
5-Oct	6	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total	13,338	169	1.3%	1	0.0%	123	0.9%	0	0.0%

[a] Not corrected for sex identification error.

Appendix 2a. Daily effort and catch of live pink salmon, by sex, tag status and tag colour, by beach seine in the lower Fraser River at Ridgedale Bar, 1995.

				Male					Female				
	Set start time			Spaghetti tag and secondary mark present			Second-ary mark only	No tag or secondary mark	Spaghetti tag and secondary mark present			Second-ary mark only	No tag or secondary mark
Date	First	Last	Number of sets	Green	Orange	Total			Green	Orange	Total		
2-Sep	10:15	15:00	5	0	0	0	0	5	0	0	0	0	4
3-Sep	8:30	15:40	9	0	0	0	0	7	0	0	0	0	12
4-Sep	8:40	15:25	8	0	0	0	0	47	0	0	0	0	55
5-Sep	8:30	15:20	8	0	3	3	0	399	0	0	0	0	416
6-Sep	8:15	15:15	8	1	0	1	0	126	1	0	1	0	140
7-Sep	10:25	17:35	10	0	3	3	0	717	4	0	4	0	705
8-Sep	10:15	17:15	8	1	1	2	0	681	3	2	5	0	661
9-Sep	10:30	17:40	9	1	0	1	0	327	0	0	0	0	297
10-Sep	10:30	17:15	9	0	0	0	0	496	2	1	3	0	464
11-Sep	6:30	15:30	9	0	0	0	0	921	0	1	1	0	985
12-Sep	6:50	15:30	9	0	0	0	0	701	0	0	0	0	742
13-Sep	7:00	15:00	8	1	0	1	0	786	1	0	1	0	920
14-Sep	7:00	16:00	10	1	1	2	0	1,263	0	0	0	0	1,473
15-Sep	7:00	16:10	11	1	4	5	0	913	0	2	2	1	1,191
16-Sep	7:00	16:05	10	0	1	1	0	610	0	0	0	0	754
17-Sep	6:45	16:00	11	1	3	4	0	973	3	2	5	0	1,196
18-Sep	9:45	18:30	11	0	0	0	0	488	0	1	1	0	604
19-Sep	10:05	18:50	11	1	1	2	0	1,940	0	0	0	0	2,744
20-Sep	13:30	19:00	8	3	0	3	0	315	0	0	0	0	387
21-Sep	10:00	19:00	11	1	0	1	0	404	0	0	0	0	439
22-Sep	-	-	0	0	0	0	0	0	0	0	0	0	0
23-Sep	10:00	19:00	11	0	0	0	0	64	0	2	2	0	92
24-Sep	9:45	19:00	11	0	0	0	0	23	0	0	0	0	20
25-Sep	6:45	16:00	11	1	0	1	0	1,025	2	0	2	0	1,108
26-Sep	6:45	16:00	11	4	2	6	0	697	1	2	3	0	651
27-Sep	7:00	15:50	10	0	1	1	0	308	1	0	1	0	304
28-Sep	7:00	15:00	10	3	0	3	0	203	1	0	1	0	213
29-Sep	7:00	15:30	9	0	0	0	0	175	0	0	0	0	114
30-Sep	7:00	16:00	10	0	0	0	0	55	1	0	1	0	40
1-Oct	7:20	14:45	8	0	0	0	0	18	0	0	0	0	21
2-Oct	10:00	18:30	8	0	0	0	0	25	0	0	0	0	21
3-Oct	9:45	18:30	10	0	0	0	0	11	0	0	0	0	7
4-Oct	8:30	15:30	8	0	0	0	0	1	0	0	0	0	2
5-Oct	8:30	15:30	8	0	0	0	0	2	0	1	1	0	2
6-Oct	8:45	15:20	8	0	0	0	0	1	0	0	0	0	4
Total	-	-	316	20	20	40	0	14,727	20	14	34	1	16,788

Appendix 2b. Incidence of net, lamprey and hook marks and of *Flexibacter columnaris* lesions among pink salmon captured by beach seine in the lower Fraser River at Ridgedale Bar, 1995.

Date	Number of pinks examined	Net marks		Lamprey marks		Hook marks		*F. columnaris*	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent
2-Sep	9	0	0.0%	0	0.0%	0	0.0%	0	0.0%
3-Sep	19	0	0.0%	0	0.0%	0	0.0%	0	0.0%
4-Sep	102	2	2.0%	1	1.0%	3	2.9%	0	0.0%
5-Sep	818	16	2.0%	6	0.7%	16	2.0%	0	0.0%
6-Sep	268	8	3.0%	3	1.1%	1	0.4%	0	0.0%
7-Sep	1,429	41	2.9%	6	0.4%	23	1.6%	0	0.0%
8-Sep	1,349	42	3.1%	3	0.2%	26	1.9%	0	0.0%
9-Sep	625	16	2.6%	0	0.0%	7	1.1%	0	0.0%
10-Sep	963	43	4.5%	3	0.3%	23	2.4%	0	0.0%
11-Sep	1,907	83	4.4%	6	0.3%	44	2.3%	0	0.0%
12-Sep	1,443	60	4.2%	6	0.4%	19	1.3%	0	0.0%
13-Sep	1,708	82	4.8%	4	0.2%	27	1.6%	0	0.0%
14-Sep	2,738	125	4.6%	5	0.2%	62	2.3%	0	0.0%
15-Sep	2,112	104	4.9%	3	0.1%	38	1.8%	0	0.0%
16-Sep	1,365	60	4.4%	3	0.2%	21	1.5%	0	0.0%
17-Sep	2,178	118	5.4%	9	0.4%	45	2.1%	0	0.0%
18-Sep	1,093	84	7.7%	1	0.1%	11	1.0%	0	0.0%
19-Sep	4,686	221	4.7%	7	0.1%	68	1.5%	0	0.0%
20-Sep	705	43	6.1%	1	0.1%	15	2.1%	0	0.0%
21-Sep	844	34	4.0%	1	0.1%	21	2.5%	0	0.0%
22-Sep	0	0	-	0	-	0	-	0	-
23-Sep	158	6	3.8%	0	0.0%	1	0.6%	0	0.0%
24-Sep	43	0	0.0%	1	2.3%	0	0.0%	0	0.0%
25-Sep	2,136	105	4.9%	4	0.2%	20	0.9%	0	0.0%
26-Sep	1,357	53	3.9%	5	0.4%	12	0.9%	0	0.0%
27-Sep	614	34	5.5%	0	0.0%	11	1.8%	0	0.0%
28-Sep	420	21	5.0%	0	0.0%	9	2.1%	0	0.0%
29-Sep	289	3	1.0%	0	0.0%	0	0.0%	0	0.0%
30-Sep	96	2	2.1%	0	0.0%	1	1.0%	0	0.0%
1-Oct	39	0	0.0%	0	0.0%	0	0.0%	0	0.0%
2-Oct	46	2	4.3%	0	0.0%	0	0.0%	0	0.0%
3-Oct	18	0	0.0%	0	0.0%	0	0.0%	0	0.0%
4-Oct	3	0	0.0%	0	0.0%	0	0.0%	0	0.0%
5-Oct	5	0	0.0%	0	0.0%	0	0.0%	0	0.0%
6-Sep	5	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total	31,590	1,408	4.5%	78	0.2%	524	1.7%	0	0.0%

Appendix 2c. Daily catch of other species by beach seine in the lower Fraser River at Ridgedale Bar, 1995.

Date	Chinook		Coho		Sock-eye	Chum	Steel-head	Cut-throat	Dolly Varden	Stur-geon
	Adults	Jacks	Adults	Jacks						
2-Sep	0	0	0	0	0	0	0	0	0	0
3-Sep	0	0	0	0	0	0	0	0	0	0
4-Sep	0	0	2	0	1	0	0	0	0	0
5-Sep	0	0	6	2	1	0	0	0	0	0
6-Sep	0	0	4	3	1	0	0	0	0	0
7-Sep	1	0	10	0	1	0	0	0	0	0
8-Sep	1	0	5	0	0	1	0	2	0	0
9-Sep	0	0	5	0	0	0	0	1	0	0
10-Sep	0	4	3	1	0	0	0	4	0	0
11-Sep	0	1	2	5	2	0	1 [a]	6	0	0
12-Sep	0	0	17	4	2	0	0	1	0	0
13-Sep	1	0	19	2	9	0	0	1	0	0
14-Sep	1	2	20	2	4	0	0	8	0	0
15-Sep	1	0	24	2	6	0	0	10	0	0
16-Sep	1	0	17	3	1	0	0	5	0	0
17-Sep	2	0	32	0	2	0	0	3	0	0
18-Sep	0	0	5	0	0	0	0	7	0	0
19-Sep	0	0	19	0	0	2	0	3	0	0
20-Sep	0	0	13	0	0	0	0	2	0	0
21-Sep	1	1	20	0	2	1	1 [b]	5	0	0
22-Sep	0	0	0	0	0	0	0	0	0	0
23-Sep	0	0	14	0	0	3	0	6	0	0
24-Sep	0	0	8	0	1	0	0	12	0	0
25-Sep	3	0	59	0	5	0	0	2	0	0
26-Sep	1	0	58	0	9	3	0	1	0	0
27-Sep	3	0	34	0	6	3	0	2	0	0
28-Sep	3	0	44	0	2	2	0	2	0	0
29-Sep	5	0	67	0	3	4	0	2	0	0
30-Sep	1	0	55	0	0	7	0	5	0	0
1-Oct	1	0	22	0	4	13	0	6	0	0
2-Oct	5	0	46	0	1	8	0	4	0	0
3-Oct	8 [c]	0	38	0	0	12	0	3	0	0
4-Oct	2	0	69	0	0	7	0	15	0	0
5-Oct	2	0	42	0	0	2	0	10	0	0
6-Oct	2	0	20	0	0	5	0	12	0	0
Total	45	8	799	24	63	73	2	140	0	0

[a] Net marked female tagged with Tag No. E16803.

[b] Net marked female tagged with Tag No. E16812.

[c] Female tagged with red anchor Tag. No. S94 02081.

Appendix 3a. Daily effort and catch of live pink salmon, by sex, tag status and tag colour, by beach seine in the lower Fraser River at Strawberry Island, 1995.

				Male					Female				
	Set start time			Spaghetti tag and secondary mark present			Second-ary mark only	No tag or secondary mark	Spaghetti tag and secondary mark present			Second-ary mark only	No tag or secondary mark
Date	First	Last	Number of sets	Green	Orange	Total			Green	Orange	Total		
2-Sep	10:10	14:33	7	0	0	0	0	1	0	0	0	0	2
3-Sep	7:05	13:45	10	0	0	0	0	14	0	0	0	0	7
4-Sep	7:00	7:00	1	0	0	0	0	6	0	0	0	0	7
5-Sep	7:22	14:10	9	0	1	1	0	50	0	0	0	0	55
6-Sep	7:00	13:45	11	0	0	0	0	36	0	0	0	0	29
7-Sep	7:30	14:00	8	0	0	0	0	122	0	0	0	0	140
8-Sep	7:00	13:40	10	0	0	0	0	187	1	0	1	0	153
9-Sep	6:50	13:53	10	0	0	0	0	209	0	2	2	0	189
10-Sep	6:59	9:38	5	0	2	2	0	104	0	0	0	0	83
11-Sep	10:30	19:05	12	0	0	0	0	296	0	0	0	0	278
12-Sep	10:30	18:40	12	0	1	1	0	311	0	0	0	0	327
13-Sep	10:30	18:54	12	1	1	2	0	302	1	0	1	0	406
14-Sep	10:30	18:45	12	0	0	0	0	553	0	1	1	0	613
15-Sep	10:20	18:35	11	2	0	2	0	663	1	0	1	0	666
16-Sep	10:10	18:40	12	1	0	1	0	512	0	1	1	0	525
17-Sep	10:17	18:36	12	2	1	3	0	600	3	0	3	0	788
18-Sep	6:30	15:20	11	1	1	2	0	900	1	3	4	0	1,310
19-Sep	7:15	16:10	9	1	1	2	0	718	0	4	4	0	1,158
20-Sep	6:50	15:05	9	0	1	1	0	841	0	0	0	0	1,139
21-Sep	7:00	15:15	8	0	3	3	0	1,294	1	1	2	0	1,799
22-Sep	7:00	15:00	9	0	2	2	0	1,050	1	1	2	0	1,465
23-Sep	7:00	15:20	12	1	0	1	0	366	0	1	1	0	599
24-Sep	7:00	15:20	12	1	0	1	0	364	0	0	0	0	503
25-Sep	10:00	18:30	12	2	0	2	0	777	0	3	3	0	997
26-Sep	9:30	17:35	11	0	2	2	0	754	1	6	7	0	867
27-Sep	9:30	16:50	10	3	3	6	0	284	1	3	4	0	372
28-Sep	9:20	17:35	12	3	3	6	0	433	5	3	8	0	473
29-Sep	7:00	15:20	9	2	1	3	0	347	0	1	1	0	393
30-Sep	9:30	13:00	5	0	0	0	0	76	0	2	2	0	95
1-Oct	9:30	17:48	13	1	1	2	0	48	0	0	0	0	67
2-Oct			0	0	0	0	0	0	0	0	0	0	0
3-Oct	7:00	9:40	4	0	0	0	0	13	0	0	0	0	7
4-Oct	7:20	15:15	10	0	0	0	0	27	1	0	1	0	26
5-Oct	7:30	15:05	9	0	0	0	0	19	1	0	1	0	21
6-Oct	7:50	13:51	9	0	0	0	0	4	0	1	1	0	3
Total	-	-	328	21	24	45	0	12,281	18	33	51	0	15,562

Appendix 3b. Incidence of net, lamprey and hook marks and of *Flexibacter columnaris* lesions among pink salmon captured by beach seine in the lower Fraser River at Strawberry Island, 1995.

Date	Number of pinks examined	Net marks		Lamprey marks		Hook marks		*F. columnaris*	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent
2-Sep	3	0	0.0%	0	0.0%	0	0.0%	0	0.0%
3-Sep	21	0	0.0%	0	0.0%	0	0.0%	0	0.0%
4-Sep	13	0	0.0%	0	0.0%	0	0.0%	0	0.0%
5-Sep	106	1	0.9%	0	0.0%	1	0.9%	0	0.0%
6-Sep	65	0	0.0%	0	0.0%	1	1.5%	0	0.0%
7-Sep	262	3	1.1%	1	0.4%	2	0.8%	0	0.0%
8-Sep	341	0	0.0%	0	0.0%	0	0.0%	0	0.0%
9-Sep	400	3	0.8%	0	0.0%	3	0.8%	0	0.0%
10-Sep	189	0	0.0%	0	0.0%	4	2.1%	0	0.0%
11-Sep	574	2	0.3%	0	0.0%	18	3.1%	0	0.0%
12-Sep	639	7	1.1%	0	0.0%	15	2.3%	0	0.0%
13-Sep	711	2	0.3%	0	0.0%	14	2.0%	0	0.0%
14-Sep	1,167	2	0.2%	0	0.0%	5	0.4%	0	0.0%
15-Sep	1,332	3	0.2%	0	0.0%	19	1.4%	0	0.0%
16-Sep	1,039	1	0.1%	0	0.0%	14	1.3%	0	0.0%
17-Sep	1,394	4	0.3%	0	0.0%	7	0.5%	0	0.0%
18-Sep	2,216	8	0.4%	0	0.0%	22	1.0%	0	0.0%
19-Sep	1,882	20	1.1%	0	0.0%	8	0.4%	0	0.0%
20-Sep	1,981	0	0.0%	0	0.0%	0	0.0%	0	0.0%
21-Sep	3,098	34	1.1%	0	0.0%	23	0.7%	0	0.0%
22-Sep	2,519	13	0.5%	0	0.0%	14	0.6%	0	0.0%
23-Sep	967	2	0.2%	0	0.0%	4	0.4%	0	0.0%
24-Sep	868	9	1.0%	0	0.0%	9	1.0%	0	0.0%
25-Sep	1,779	18	1.0%	0	0.0%	8	0.4%	0	0.0%
26-Sep	1,630	12	0.7%	0	0.0%	12	0.7%	0	0.0%
27-Sep	666	6	0.9%	0	0.0%	4	0.6%	0	0.0%
28-Sep	920	14	1.5%	0	0.0%	5	0.5%	0	0.0%
29-Sep	744	2	0.3%	0	0.0%	0	0.0%	0	0.0%
30-Sep	173	3	1.7%	0	0.0%	0	0.0%	0	0.0%
1-Oct	117	4	3.4%	0	0.0%	2	1.7%	0	0.0%
2-Oct	0	0	-	0	-	0	-	0	-
3-Oct	20	0	0.0%	0	0.0%	0	0.0%	0	0.0%
4-Oct	54	0	0.0%	0	0.0%	0	0.0%	0	0.0%
5-Oct	41	0	0.0%	0	0.0%	0	0.0%	0	0.0%
6-Sep	8	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total	27,939	173	0.6%	1	0.0%	214	0.8%	0	0.0%

Appendix 3c. Daily catch of other species by beach seine in the lower Fraser River at Strawberry Island, 1995.

	Chinook		Coho							
Date	Adults	Jacks	Adults	Jacks	Sock-eye	Chum	Steel-head	Cut-throat	Dolly Varden	Stur-geon
2-Sep	0	0	1	0	0	0	0	15	0	0
3-Sep	0	0	0	0	0	0	0	12	0	0
4-Sep	0	0	0	0	0	0	0	0	0	0
5-Sep	0	0	3	0	0	0	0	7	0	0
6-Sep	0	0	0	0	1	0	0	10	0	0
7-Sep	7	0	1	0	0	0	0	11	0	0
8-Sep	2	0	2	0	3	0	0	4	0	0
9-Sep	0	0	0	0	3	0	0	18	0	0
10-Sep	0	0	0	0	0	0	0	2	0	0
11-Sep	2	0	2	0	0	0	0	10	0	0
12-Sep	4	0	4	0	1	0	0	2	0	0
13-Sep	10	0	10	0	7	0	0	6	0	0
14-Sep	2	0	2	0	2	0	0	6	1	0
15-Sep	5	0	5	0	6	1	0	7	0	1
16-Sep	8	0	8	0	6	0	0	4	0	0
17-Sep	5	0	5	0	7	2	0	10	0	1
18-Sep	7	0	6	0	0	0	0	3	1	0
19-Sep	3	0	3	0	0	0	0	0	0	0
20-Sep	6	0	6	0	3	3	0	3	0	0
21-Sep	2	0	2	0	8	1	0	2	0	0
22-Sep	3	0	3	0	16	0	0	1	0	0
23-Sep	3	0	3	0	6	0	0	0	0	0
24-Sep	10	0	10	0	25	6	0	6	0	0
25-Sep	10	0	25	0	10	2	0	0	0	0
26-Sep	7	0	19	0	2	5	0	4	0	0
27-Sep	2	0	0	0	0	0	0	0	0	0
28-Sep	8	0	10	0	5	4	0	3	0	0
29-Sep	8	0	11	0	2	8	0	3	0	0
30-Sep	3	0	5	0	0	5	0	2	0	0
1-Oct	8	0	3	0	0	10	0	3	0	0
2-Oct	0	0	0	0	0	0	0	0	0	0
3-Oct	0	0	0	0	0	0	0	0	0	0
4-Oct	13	0	42	0	0	17	0	1	0	0
5-Oct	17	0	65	0	1	34	0	0	0	0
6-Oct	7	0	10	0	0	15	0	0	0	0
Total	162	0	266	0	114	113	0	155	2	2

Appendix 4a. Daily effort and catch of live pink salmon, by sex and tag status, and of other species by drifted gill net in the lower Fraser River at Ridgedale Bar, 1995.

		Male Pink Salmon		Female Pink Salmon						
Date	Number of sets	Tag and/or secondary present	No tag or secondary mark	Tag and/or secondary present	No tag or secondary mark	Chinook	Coho	Sockeye	Chum	Sturgeon
2-Sep	4	0	0	0	1	0	0	1	0	0
3-Sep	6	0	2	0	3	0	0	12	0	0
4-Sep	7	0	6	0	2	2	1	8	0	0
5-Sep	6	0	11	0	4	0	0	3	0	0
6-Sep	2	0	0	0	0	0	0	3	0	0
7-Sep	10	0	0	0	0	0	0	12	0	0
8-Sep	0	0	0	0	0	0	0	0	0	0
9-Sep	8	0	0	0	0	0	0	4	0	0
10-Sep	0	0	0	0	0	0	0	0	0	0
11-Sep	0	0	0	0	0	0	0	0	0	0
12-Sep	0	0	0	0	0	0	0	0	0	0
13-Sep	12	0	0	0	0	0	0	7	1	0
14-Sep	0	0	0	0	0	0	0	0	0	0
15-Sep	10	0	3	0	2	0	1	20	0	0
16-Sep	0	0	0	0	0	0	0	0	0	0
17-Sep	11	0	1	0	3	2	0	9	1	1
18-Sep	0	0	0	0	0	0	0	0	0	0
19-Sep	12	0	1	0	2	2	0	2	1	1
Total	88	0	24	0	17	6	2	81	3	2

Appendix 4b. Daily effort and catch of live pink salmon, by sex and tag status, and of other species by drifted gill net in the lower Fraser River at Strawberry Island, 1995.

		Male Pink Salmon		Female Pink Salmon						
Date	Number of sets	Tag and/or secondary present	No tag or secondary mark	Tag and/or secondary present	No tag or secondary mark	Chinook	Coho	Sockeye	Chum	Sturgeon
2-Sep	3	0	5	0	2	0	0	6	0	0
3-Sep	5	0	2	0	3	0	0	4	0	0
4-Sep	2	0	1	0	0	0	0	1	0	0
5-Sep	4	0	5	0	1	0	0	0	0	0
6-Sep	8	0	2	0	0	0	0	3	0	0
7-Sep	0	0	0	0	0	0	0	0	0	0
8-Sep	9	0	2	0	4	0	0	2	0	0
9-Sep	0	0	0	0	0	0	0	0	0	0
10-Sep	0	0	0	0	0	0	0	0	0	0
11-Sep	0	0	0	0	0	0	0	0	0	0
12-Sep	13	0	1	0	1	0	0	1	0	0
13-Sep	0	0	0	0	0	0	0	0	0	0
14-Sep	11	0	3	0	5	0	0	5	0	0
15-Sep	0	0	0	0	0	0	0	0	0	0
16-Sep	12	0	1	0	6	0	0	8	1	0
17-Sep	0	0	0	0	0	0	0	0	0	0
18-Sep	12	0	9	0	4	0	1	3	0	0
Total	79	0	31	0	26	0	1	33	1	0

Appendix 5. Daily pink carcass recoveries, by sex, area, tag and mark status, and tag colour, in the lower Fraser River mainstem spawning areas, 1995. [a]

			Male					Female				
			Spaghetti tag and secondary mark present			Second-ary mark only	No tag or secondary mark	Spaghetti tag and secondary mark present			Second-ary mark only	No tag or secondary mark
Date	Area	Number of surveys	Green	Orange	Total			Green	Orange	Total		
22-Sep	10	-	0	0	0	0	72	0	0	0	0	78
	16	-	0	0	0	0	32	0	0	0	0	42
	17	-	0	0	0	0	68	1	0	1	0	95
23-Sep	10	-	0	0	0	0	27	0	0	0	0	29
	11	-	1	0	1	0	101	0	0	0	0	142
	12	-	0	0	0	0	92	1	0	1	0	109
	13	-	0	0	0	0	145	0	0	0	0	236
	14	-	0	0	0	0	43	0	0	0	0	54
	15	-	1	0	1	0	99	0	0	0	0	108
	16	-	0	0	0	0	26	0	0	0	0	26
24-Sep	3	-	0	0	0	0	18	0	0	0	0	12
	4	-	0	0	0	0	131	0	0	0	0	112
	5	-	0	0	0	0	149	0	0	0	0	87
	6	-	0	0	0	0	65	0	1	1	0	34
	7	-	0	0	0	0	95	0	0	0	0	72
	8	-	0	0	0	0	282	0	0	0	0	212
	9	-	2	0	2	0	598	0	1	1	0	474
25-Sep	1	-	0	0	0	0	15	0	0	0	0	9
	2	-	1	1	2	0	578	1	1	2	0	487
	3	-	1	0	1	0	34	0	0	0	0	43
26-Sep	12	-	0	0	0	0	145	0	0	0	0	151
	13	-	1	1	2	0	399	1	0	1	0	598
	14	-	0	0	0	0	415	0	0	0	0	729
	15	-	0	0	0	0	240	1	1	2	0	474
	16	-	0	0	0	0	121	1	0	1	0	305
	17	-	0	0	0	0	44	0	1	1	0	101
27-Sep	5	-	0	0	0	0	81	0	0	0	0	88
	6	-	1	1	2	0	621	1	0	1	0	539
	7	-	2	1	3	0	816	0	2	2	0	735
	8	-	0	0	0	0	249	0	1	1	0	215
	9	-	3	0	3	0	1,402	5	0	5	0	1,575
	10	-	0	2	2	0	784	2	0	2	0	931
	11	-	0	0	0	0	394	2	2	4	0	533
	12	-	0	1	1	0	243	0	2	2	0	321
28-Sep	1	-	0	0	0	0	46	0	0	0	0	34
	2	-	1	1	2	0	418	0	1	1	0	409
	3	-	0	0	0	0	169	2	0	2	0	188
	4	-	1	1	2	0	376	0	0	0	0	340
29-Sep	13	-	3	2	5	1	1,544	3	3	6	0	2,762
	14	-	0	1	1	0	317	1	0	1	0	351
	15	-	1	0	1	0	358	0	1	1	0	720
	16	-	0	0	0	0	283	0	0	0	0	592
	17	-	0	0	0	0	52	1	0	1	0	175
30-Sep	11	-	2	0	2	0	349	0	0	0	0	544
	12	-	0	0	0	0	412	0	2	2	0	575
	15	-	2	0	2	0	404	0	1	1	0	584
1-Oct	10	-	1	0	1	0	2,325	2	1	3	0	2,818
	11	-	1	0	1	0	454	1	0	1	0	720

Continued

Appendix 5. Daily pink carcass recoveries, by sex, area, tag and mark status, and tag colour, in the lower Fraser River mainstem spawning areas, 1995. [a]

			Male					Female				
			Spaghetti tag and secondary mark present			Second-ary mark only	No tag or secondary mark	Spaghetti tag and secondary mark present			Second-ary mark only	No tag or secondary mark
Date	Area	Number of surveys	Green	Orange	Total			Green	Orange	Total		
2-Oct	8	-	3	1	4	0	4,491	3	2	5	0	4,512
	9	-	0	2	2	0	2,109	1	0	1	0	3,270
3-Oct	7	-	0	2	2	0	757	1	1	2	0	729
	8	-	1	0	1	0	1,997	0	0	0	0	2,017
	9	-	2	1	3	0	2,651	3	1	4	0	4,209
4-Oct	4	-	0	1	1	0	1,696	2	0	2	0	1,504
	5	-	1	1	2	0	517	0	0	0	0	303
	6	-	1	2	3	0	1,513	4	0	4	0	1,241
5-Oct	2	-	1	1	2	0	556	1	1	2	0	724
	3	-	1	3	4	0	1,888	1	1	2	0	1,920
	4	-	0	0	0	1	753	0	0	0	0	555
	5	-	2	0	2	0	1,252	1	3	4	0	1,465
	6	-	3	0	3	0	3,209	2	1	3	0	2,296
6-Oct	2	-	1	4	5	0	1,597	6	5	11	1	2,579
	5	-	2	0	2	0	3,635	0	3	3	0	3,565
	13	-	1	1	2	0	585	1	0	1	0	2,269
	14	-	0	1	1	0	366	0	1	1	0	703
	15	-	1	1	2	0	384	0	0	0	0	1,034
7-Oct	2	-	3	1	4	1	582	2	2	4	0	1,324
	6	-	1	1	2	0	1,249	0	0	0	0	1,138
	9	-	2	3	5	0	3,314	2	5	7	0	3,650
	13	-	0	0	0	0	1,495	4	3	7	0	5,982
	15	-	0	1	1	0	1,083	1	5	6	0	3,238
8-Oct	2	-	3	2	5	1	2,090	1	0	1	0	1,715
	6	-	0	0	0	0	1,269	0	1	1	0	1,504
	7	-	1	1	2	0	1,398	0	4	4	0	1,591
	8	-	0	0	0	0	911	0	0	0	0	890
	13	-	0	0	0	0	2,455	3	2	5	0	5,221
	15	-	0	1	1	1	783	2	0	2	0	1,775
	16	-	1	1	2	0	414	3	1	4	0	1,329
9-Oct	1	-	1	0	1	0	1,999	3	4	7	0	1,377
	9	-	2	2	4	0	2,912	3	3	6	0	4,932
	13	-	2	4	6	0	3,498	4	5	9	0	8,018
	16	-	0	1	1	0	487	2	1	3	0	1,957
10-Oct	10	-	1	1	2	0	2,631	4	4	8	0	4,096
	11	-	0	1	1	0	1,143	3	1	4	0	1,450
	12	-	0	0	0	0	711	0	1	1	0	724
11-Oct	3	-	2	2	4	0	1,356	6	4	10	0	2,120
	4	-	0	2	2	0	1,725	1	2	3	0	1,344
	8	-	3	1	4	0	1,823	2	1	3	0	2,414
	13	-	1	0	1	0	939	1	5	6	0	4,399
	15	-	0	0	0	0	271	1	2	3	0	930
	17	-	0	0	0	0	155	0	0	0	0	438
12-Oct	2	-	4	1	5	0	1,647	3	2	5	0	3,385
	4	-	1	1	2	0	674	0	1	1	0	444
	5	-	1	2	3	0	955	1	1	2	0	1,664
	6	-	2	2	4	0	1,035	0	1	1	0	1,108
	7	-	1	1	2	0	492	0	1	1	0	838
	12	-	0	0	0	0	1,515	3	2	5	0	3,547

Continued

Appendix 5. Daily pink carcass recoveries, by sex, area, tag and mark status, and tag colour, in the lower Fraser River mainstem spawning areas, 1995. [a]

			Male					Female				
			Spaghetti tag and secondary mark present			Second-ary mark only	No tag or secondary mark	Spaghetti tag and secondary mark present			Second-ary mark only	No tag or secondary mark
Date	Area	Number of surveys	Green	Orange	Total			Green	Orange	Total		
12-Oct	13	-	0	0	0	0	234	0	0	0	0	945
	14	-	1	0	1	0	542	2	1	3	0	1,095
	15	-	1	1	2	0	553	1	4	5	0	1,344
13-Oct	1	-	3	2	5	0	1,050	1	4	5	1	1,103
	2	-	2	1	3	0	983	3	3	6	0	1,519
	9	-	4	1	5	0	2,516	0	0	0	0	4,081
	11	-	4	0	4	0	2,135	0	3	3	0	3,847
14-Oct	3	-	0	0	0	0	460	0	1	1	0	1,105
	4	-	1	1	2	0	832	2	3	5	0	1,114
	8	-	0	0	0	0	162	1	2	3	0	398
	9	-	0	0	0	0	815	2	1	3	0	1,298
	10	-	0	2	2	0	1,118	5	3	8	0	4,046
	16	-	0	0	0	0	171	0	1	1	0	1,189
	17	-	0	0	0	0	71	0	0	0	0	172
15-Oct	1	-	0	1	1	0	128	1	0	1	0	286
	2	-	1	0	1	0	373	3	1	4	0	1,113
	6	-	2	1	3	0	286	2	0	2	0	424
	7	-	0	0	0	0	130	0	0	0	0	466
	8	-	0	0	0	0	115	1	0	1	0	291
	10	-	0	0	0	0	297	1	0	1	0	940
	13	-	0	0	0	0	183	0	1	1	0	852
	14	-	0	0	0	0	59	1	0	1	0	234
	15	-	0	0	0	0	411	1	1	2	0	604
16-Oct	5	-	0	0	0	0	685	0	2	2	0	1,160
	8	-	0	0	0	0	37	0	0	0	0	74
	9	-	1	0	1	0	180	0	1	1	0	675
	11	-	0	0	0	0	86	0	0	0	0	395
	12	-	0	0	0	0	37	0	0	0	0	186
	13	-	0	0	0	0	154	2	1	3	0	744
17-Oct	2	-	0	0	0	0	58	0	0	0	0	84
	3	-	0	1	1	0	338	0	0	0	0	614
	4	-	0	0	0	0	120	0	1	1	0	291
	5	-	0	0	0	0	22	0	0	0	0	80
	6	-	0	0	0	0	138	0	0	0	0	154
	7	-	0	0	0	0	7	0	0	0	0	39
	8	-	0	0	0	0	142	0	0	0	0	375
	10	-	0	0	0	0	83	1	0	1	0	279
	15	-	0	0	0	0	41	0	0	0	0	190
	16	-	0	0	0	0	60	2	0	2	0	141
	17	-	1	0	1	0	47	0	0	0	0	79
18-Oct	1	-	1	1	2	0	338	1	2	3	0	333
	2	-	0	0	0	0	143	1	0	1	0	336
	9	-	0	0	0	0	78	0	0	0	0	251
	11	-	0	0	0	0	31	0	0	0	0	120
	12	-	0	0	0	0	28	0	0	0	0	87
	13	-	0	0	0	0	23	0	0	0	0	200
	14	-	0	0	0	0	12	0	0	0	0	34
19-Oct	7	-	0	0	0	0	13	0	0	0	0	46
	8	-	1	0	1	0	57	1	0	1	0	156

Continued

Appendix 5. Daily pink carcass recoveries, by sex, area, tag and mark status, and tag colour, in the lower Fraser River mainstem spawning areas, 1995. [a]

			Male					Female				
			Spaghetti tag and secondary mark present			Second-ary mark only	No tag or secondary mark	Spaghetti tag and secondary mark present			Second-ary mark only	No tag or secondary mark
Date	Area	Number of surveys	Green	Orange	Total			Green	Orange	Total		
19-Oct	10	-	0	0	0	0	19	0	0	0	0	74
	11	-	0	0	0	0	8	0	0	0	0	12
	15	-	0	0	0	0	7	0	0	0	0	34
20-Oct	16	-	0	0	0	0	3	0	0	0	0	9
	17	-	0	0	0	0	16	0	0	0	0	29
21-Oct	14	-	0	0	0	0	2	0	0	0	0	8
	15	-	0	0	0	0	62	0	0	0	0	72
	16	-	0	0	0	0	25	0	0	0	0	74
22-Oct	10	-	0	0	0	0	5	0	0	0	0	23
	11	-	0	0	0	0	7	0	0	0	0	58
	12	-	0	0	0	0	8	0	0	0	0	23
	13	-	0	0	0	0	5	0	0	0	0	43
23-Oct	8	-	0	0	0	0	58	0	0	0	0	227
	9	-	0	0	0	0	19	0	0	0	0	74
	10	-	0	0	0	0	16	0	0	0	0	34
24-Oct	4	-	1	3	4	0	88	1	1	2	0	177
	5	-	0	0	0	0	16	0	1	1	0	111
	6	-	0	0	0	0	12	0	0	0	0	41
	7	-	0	0	0	0	3	0	0	0	0	6
25-Oct	1	-	0	0	0	0	21	0	0	0	0	50
	2	-	0	0	0	0	115	0	0	0	0	259
	3	-	0	0	0	0	143	1	1	2	0	202
Total	1	7	5	4	9	0	3,597	6	10	16	1	3,192
	2	12	17	12	29	2	9,140	21	16	37	1	13,934
	3	8	4	6	10	0	4,406	10	7	17	0	6,204
	4	9	4	9	13	1	6,395	6	8	14	0	5,881
	5	9	6	3	9	0	7,312	2	10	12	0	8,523
	6	10	10	7	17	0	9,397	9	4	13	0	8,479
	7	9	4	5	9	0	3,711	1	8	9	0	4,522
	8	12	8	2	10	0	10,324	8	6	14	0	11,781
	9	11	16	9	25	0	16,594	16	12	28	0	24,489
	10	11	2	5	7	0	7,377	15	8	23	0	13,348
	11	10	8	1	9	0	4,708	6	6	12	0	7,821
	12	9	0	1	1	0	3,191	4	7	11	0	5,723
	13	13	8	8	16	1	11,659	19	20	39	0	32,269
	14	8	1	2	3	0	1,756	4	2	6	0	3,208
	15	13	6	4	10	1	4,696	7	15	22	0	11,107
	16	10	1	2	3	0	1,622	8	3	11	0	5,664
	17	7	1	0	1	0	453	2	1	3	0	1,089
	Total	-	101	80	181	5	106,338	144	143	287	2	167,234

[a] Recovery areas were:

Appendix 6. Daily number of pink carcasses examined and spaghetti tags recovered, by area and sex, during the re-survey of the lower Fraser River mainstem spawning areas, 1995.

Date	Area	Number of surveys	Spaghetti tag present			Total examined			Sapghetti tag incidence		
			Male	Female	Total	Male	Female	Total	Male	Female	Total
29-Sep	10	-	0	0	0	595	678	1,273	0.000	0.000	0.000
	11	-	0	0	0	379	526	905	0.000	0.000	0.000
	12	-	0	0	0	176	213	389	0.000	0.000	0.000
	13	-	2	0	2	882	1365	2,247	0.002	0.000	0.001
30-Sep	6	-	0	0	0	292	252	544	0.000	0.000	0.000
	7	-	0	0	0	56	50	106	0.000	0.000	0.000
	8	-	0	0	0	181	103	284	0.000	0.000	0.000
	9	-	0	0	0	712	712	1,424	0.000	0.000	0.000
1-Oct	1	-	0	0	0	18	7	25	0.000	0.000	0.000
	2	-	0	0	0	314	436	750	0.000	0.000	0.000
	3	-	0	0	0	82	108	190	0.000	0.000	0.000
	4	-	0	1	1	220	171	391	0.000	0.006	0.003
	5	-	0	0	0	40	83	123	0.000	0.000	0.000
2-Oct	14	-	0	0	0	67	88	155	0.000	0.000	0.000
	15	-	0	0	0	427	665	1,092	0.000	0.000	0.000
	16	-	0	0	0	218	315	533	0.000	0.000	0.000
3-Oct	12	-	0	1	1	298	361	659	0.000	0.003	0.002
	13	-	0	0	0	499	910	1,409	0.000	0.000	0.000
	14	-	0	0	0	124	205	329	0.000	0.000	0.000
4-Oct	10	-	0	0	0	864	1470	2,334	0.000	0.000	0.000
	11	-	0	0	0	389	779	1,168	0.000	0.000	0.000
5-Oct	9	-	0	1	1	2282	3655	5,937	0.000	0.000	0.000
6-Oct	7	-	0	0	0	427	466	893	0.000	0.000	0.000
	8	-	1	2	3	2323	3007	5,330	0.000	0.001	0.001
7-Oct	5	-	0	0	0	2265	2479	4,744	0.000	0.000	0.000
	6	-	0	1	1	2519	2256	4,775	0.000	0.000	0.000
8-Oct	3	-	0	0	0	803	810	1,613	0.000	0.000	0.000
	4	-	0	0	0	2610	2222	4,832	0.000	0.000	0.000
	5	-	0	0	0	210	232	442	0.000	0.000	0.000
9-Oct	2	-	0	0	0	3165	4450	7,615	0.000	0.000	0.000
	3	-	0	0	0	568	601	1,169	0.000	0.000	0.000
16-Oct	13	-	0	0	0	1578	5752	7,330	0.000	0.000	0.000
	15	-	1	0	1	213	765	978	0.005	0.000	0.001
	16	-	0	0	0	323	1122	1,445	0.000	0.000	0.000
	17	-	0	0	0	73	168	241	0.000	0.000	0.000
17-Oct	10	-	0	0	0	528	1343	1,871	0.000	0.000	0.000
	11	-	2	0	2	1024	2406	3,430	0.002	0.000	0.001
	12	-	0	0	0	517	814	1,331	0.000	0.000	0.000
	14	-	0	0	0	288	931	1,219	0.000	0.000	0.000
	15	-	0	0	0	131	427	558	0.000	0.000	0.000
18-Oct	9	-	0	1	1	684	2041	2,725	0.000	0.000	0.000
	10	-	0	0	0	805	1894	2,699	0.000	0.000	0.000
19-Oct	4	-	0	0	0	768	1006	1,774	0.000	0.000	0.000
	5	-	0	0	0	501	691	1,192	0.000	0.000	0.000
	8	-	1	0	1	694	1772	2,466	0.001	0.000	0.000
	9	-	0	1	1	605	1216	1,821	0.000	0.001	0.001
20-Oct	6	-	0	0	0	152	395	547	0.000	0.000	0.000
	7	-	0	0	0	32	162	194	0.000	0.000	0.000
	8	-	0	0	0	46	146	192	0.000	0.000	0.000
21-Oct	16	-	0	0	0	216	875	1,091	0.000	0.000	0.000
	17	-	0	0	0	8	36	44	0.000	0.000	0.000
22-Oct	14	-	0	0	0	62	324	386	0.000	0.000	0.000
	15	-	0	0	0	169	726	895	0.000	0.000	0.000

Continued

Appendix 6. Daily number of pink carcasses examined and spaghetti tags recovered, by area and sex, during the re-survey of the lower Fraser River mainstem spawning areas, 1995 continued.

Date	Area	Number of surveys	Spaghetti tag present			Total examined			Sapghetti tag incidence		
			Male	Female	Total	Male	Female	Total	Male	Female	Total
23-Oct	8	-	0	0	0	1	9	10	0.000	0.000	0.000
	9	-	0	0	0	17	68	85	0.000	0.000	0.000
	10	-	0	0	0	6	40	46	0.000	0.000	0.000
	11	-	0	0	0	13	44	57	0.000	0.000	0.000
	12	-	0	0	0	21	54	75	0.000	0.000	0.000
	13	-	0	0	0	48	241	289	0.000	0.000	0.000
24-Oct	4	-	0	0	0	56	101	157	0.000	0.000	0.000
	5	-	0	0	0	11	34	45	0.000	0.000	0.000
	6	-	0	0	0	21	35	56	0.000	0.000	0.000
	7	-	0	0	0	1	21	22	0.000	0.000	0.000
	8	-	0	0	0	21	83	104	0.000	0.000	0.000
25-Oct	1	-	0	0	0	23	52	75	0.000	0.000	0.000
	2	-	0	0	0	125	271	396	0.000	0.000	0.000
	3	-	0	0	0	128	170	298	0.000	0.000	0.000
Total	1	2	0	0	0	41	59	100	0.000	0.000	0.000
	2	3	0	0	0	3,604	5,157	8,761	0.000	0.000	0.000
	3	4	0	0	0	1,581	1,689	3,270	0.000	0.000	0.000
	4	4	0	1	1	3,654	3,500	7,154	0.000	0.000	0.000
	5	5	0	0	0	3,027	3,519	6,546	0.000	0.000	0.000
	6	4	0	1	1	2,984	2,938	5,922	0.000	0.000	0.000
	7	4	0	0	0	516	699	1,215	0.000	0.000	0.000
	8	6	2	2	4	3,266	5,120	8,386	0.001	0.000	0.000
	9	5	0	3	3	4,300	7,692	11,992	0.000	0.000	0.000
	10	5	0	0	0	2,798	5,425	8,223	0.000	0.000	0.000
	11	4	2	0	2	1,805	3,755	5,560	0.001	0.000	0.000
	12	4	0	1	1	1,012	1,442	2,454	0.000	0.001	0.000
	13	4	2	0	2	3,007	8,268	11,275	0.001	0.000	0.000
	14	4	0	0	0	541	1,548	2,089	0.000	0.000	0.000
	15	3	1	0	1	940	2,583	3,523	0.001	0.000	0.000
	16	3	0	0	0	757	2,312	3,069	0.000	0.000	0.000
	17	2	0	0	0	81	204	285	0.000	0.000	0.000
	Total		7	8	15	33,914	55,910	89,824	0.000	0.000	0.000

Appendix 7. Daily pink carcass recoveries, by sex, area, tag and mark status, and tag colour, from the roving survey of the lower Fraser River mainstem between McMillan and Matsqui islands, 1995. [a]

			Male					Female				
			Spaghetti tag and secondary mark present					Spaghetti tag and secondary mark present				
Date	Area [b]	Number of surveys	Green	Orange	Total	Secondary mark only	No tag or secondary mark	Green	Orange	Total	Secondary mark only	No tag or secondary mark
8-Sep	F	-	0	0	0	0	1	0	0	0	0	0
9-Sep	B	-	0	0	0	0	1	0	0	0	0	0
	E	-	0	0	0	0	1	0	0	0	0	0
11-Sep	B	-	0	0	0	0	1	0	0	0	0	0
	C	-	0	0	0	0	2	0	0	0	0	0
12-Sep	B	-	0	0	0	0	1	0	0	0	0	0
	C	-	0	0	0	0	0	0	0	0	0	1
	D	-	0	0	0	0	1	0	0	0	0	1
14-Sep	C	-	0	0	0	0	2	0	0	0	0	0
	D	-	1	0	1	0	49	0	0	0	0	17
	E	-	0	0	0	0	2	0	0	0	0	2
15-Sep	B	-	0	0	0	0	2	0	0	0	0	0
	D	-	1	1	2	0	16	2	0	2	0	2
	E	-	0	0	0	0	2	0	0	0	0	1
	F	-	0	0	0	0	2	0	0	0	0	1
18-Sep	A	-	0	0	0	0	1	0	0	0	0	0
	B	-	0	0	0	0	4	0	0	0	0	1
	C	-	0	0	0	0	3	0	0	0	0	0
	D	-	0	0	0	0	3	0	0	0	0	1
	E	-	0	0	0	0	3	0	0	0	0	3
	F	-	0	0	0	0	6	0	0	0	0	1
19-Sep	A	-	0	0	0	0	1	0	0	0	0	0
	B	-	0	0	0	0	3	0	0	0	0	1
	C	-	0	0	0	0	1	0	0	0	0	0
	D	-	0	0	0	0	2	0	0	0	0	1
	E	-	0	0	0	0	5	0	0	0	0	2
	F	-	0	0	0	0	1	0	0	0	0	0
20-Sep	B	-	0	0	0	0	5	0	0	0	0	0
	D	-	0	0	0	0	1	0	0	0	0	0
	E	-	0	0	0	0	2	0	0	0	0	1
	F	-	0	0	0	0	1	0	0	0	0	0
21-Sep	B	-	0	0	0	0	1	0	0	0	0	2
	C	-	0	0	0	0	0	0	0	0	0	1
	D	-	0	0	0	0	0	0	0	0	0	1
	E	-	1	0	1	0	2	0	0	0	0	1
	F	-	0	0	0	0	10	0	0	0	0	0
22-Sep	A	-	0	0	0	0	1	0	0	0	0	0
	B	-	0	0	0	0	2	0	0	0	0	3
	D	-	0	0	0	0	1	0	0	0	0	2
	E	-	0	0	0	0	4	0	0	0	0	1
25-Sep	B	-	0	0	0	0	2	0	0	0	0	1
	C	-	0	0	0	0	2	0	0	0	0	0
	D	-	0	0	0	0	15	0	0	0	0	2
	E	-	0	0	0	0	11	0	0	0	0	3
	F	-	0	0	0	0	3	0	0	0	0	1
26-Sep	A	-	0	0	0	0	1	0	0	0	0	0
	B	-	0	0	0	0	2	0	0	0	0	0
	C	-	0	0	0	0	3	0	0	0	0	1
	D	-	0	0	0	0	18	0	0	0	0	3
	E	-	0	0	0	0	14	0	0	0	0	3
	F	-	0	0	0	0	8	0	0	0	0	0

Continued

Appendix 7. Daily pink carcass recoveries, by sex, area, tag and mark status, and tag colour, from the roving survey of the lower Fraser River mainstem between McMillan Island and the Mission Bridge, 1995, continued. [a]

			Male					Female				
			Spaghetti tag and secondary mark present			Second-ary mark only	No tag or secondary mark	Spaghetti tag and secondary mark present			Second-ary mark only	No tag or secondary mark
Date	Area [b]	Number of surveys	Green	Orange	Total			Green	Orange	Total		
27-Sep	B	-	0	0	0	0	1	0	0	0	0	0
	C	-	0	0	0	0	1	0	0	0	0	0
	D	-	0	0	0	0	8	0	0	0	0	0
	E	-	0	0	0	0	4	0	0	0	0	1
	F	-	0	0	0	0	3	0	0	0	0	0
28-Sep	A	-	0	0	0	0	4	0	0	0	0	0
	C	-	0	0	0	0	5	0	0	0	0	1
	D	-	0	0	0	0	9	0	0	0	0	2
	E	-	0	0	0	0	7	0	0	0	0	1
	F	-	0	0	0	0	11	0	0	0	0	4
29-Sep	B	-	0	0	0	0	1	0	0	0	0	1
	C	-	0	0	0	0	6	0	0	0	0	3
	D	-	0	0	0	0	3	0	0	0	0	1
	E	-	0	0	0	0	7	0	0	0	0	3
	F	-	0	0	0	0	4	0	0	0	0	0
2-Oct	A	-	0	0	0	0	1	0	0	0	0	0
	B	-	0	0	0	0	8	0	0	0	0	2
	C	-	0	0	0	0	3	0	0	0	0	0
	D	-	0	0	0	0	4	0	0	0	0	1
	E	-	1	0	1	0	8	0	0	0	0	6
	F	-	0	0	0	0	2	0	0	0	0	0
3-Oct	A	-	0	0	0	0	1	0	0	0	0	0
	B	-	0	0	0	0	5	0	0	0	0	1
	D	-	0	0	0	0	3	0	0	0	0	0
	E	-	0	0	0	0	4	0	0	0	0	2
	F	-	0	0	0	0	4	0	0	0	0	1
4-Oct	A	-	0	0	0	0	1	0	0	0	0	0
	B	-	0	0	0	0	15	0	1	1	0	3
	C	-	0	0	0	0	7	0	0	0	0	2
	E	-	0	0	0	0	6	0	0	0	0	2
4-Oct	F	-	0	0	0	0	2	0	0	0	0	0
5-Oct [c]	A	-	0	0	0	0	1	0	0	0	0	0
	B	-	0	0	0	0	13	0	0	0	0	12
	C	-	0	0	0	0	2	0	0	0	0	1
	D	-	0	0	0	0	1	0	0	0	0	1
	E	-	0	0	0	0	13	0	0	0	0	11
	F	-	0	0	0	0	18	0	0	0	0	16
6-Oct	A	-	0	0	0	0	5	0	0	0	0	2
	B	-	0	0	0	0	19	0	0	0	0	7
	C	-	0	0	0	0	2	0	0	0	0	3
	D	-	0	0	0	0	2	0	0	0	0	2
	E	-	0	0	0	0	7	0	0	0	0	5
	F	-	0	0	0	0	19	0	0	0	0	13
9-Oct	E	-	0	0	0	0	73	0	1	1	0	141
	F	-	1	0	1	0	101	0	0	0	0	212
10-Oct	A	-	0	0	0	0	4	0	0	0	0	12
	B	-	0	0	0	0	14	0	0	0	0	17
	C	-	0	0	0	0	35	0	0	0	0	39
	D	-	0	0	0	0	7	0	0	0	0	9
	E	-	0	0	0	0	19	0	0	0	0	20
	F	-	0	0	0	0	9	0	0	0	0	10

Continued

Appendix 7. Daily pink carcass recoveries, by sex, area, tag and mark status, and tag colour, from the roving survey of the lower Fraser River mainstem between McMillan Island and the Mission Bridge, 1995, continued. [a]

			Male					Female				
			Spaghetti tag and secondary mark present					Spaghetti tag and secondary mark present				
Date	Area [b]	Number of surveys	Green	Orange	Total	Secondary mark only	No tag or secondary mark	Green	Orange	Total	Secondary mark only	No tag or secondary mark
11-Oct	E	-	0	0	0	0	14	0	0	0	0	8
	F	-	0	0	0	0	104	0	0	0	0	86
Total	A	24	0	0	0	0	21	0	0	0	0	14
	B	24	0	0	0	0	100	0	1	1	0	51
	C	24	0	0	0	0	74	0	0	0	0	52
	D	24	2	1	3	0	143	2	0	2	0	46
	E	24	2	0	2	0	208	0	1	1	0	217
	F	24	1	0	1	0	309	0	0	0	0	345
	Total	24	5	1	6	0	855	2	2	4	0	725

[a] Data are reported only if carcasses were recovered; all areas were surveyed each survey day.

[b] Areas were: A - South shore of Matsqui Island;
B - North shore of Matsqui Island;
C - South shore of Fraser River from the west end of Matsqui Island to the Duncan Bar tagging site;
D - South shore of the Fraser River from the Duncan Bar tagging site to the east end of Crescent Island;
E - North and south shores of Crescent Island and the south shore of the Fraser River adjacent to Crescent Island;
F - South shore of the Fraser River from the west end of Crescent Island to the east end on McMillan Island.

[c] Last day of tag application.

Appendix 8. Mark-recapture statistics for Fraser River pink salmon by recapture site. Stratum intervals are results of pooling release and recovery data first by weekly intervals (i.e. week 1 = Sept 1-7) then by pooling particular weeks as shown to satisfy model assumptions stratified (Darroch) population estimates.

RIDGEDALE MALES

Pooling Tests

-Chi-square Test Statistics

Complete Mixing : 4.04 (4 df)
Significance... 0.40
Equal Proportions: 2.75 (2 df)
Significance... 0.25

ML Darroch Estimate

Estimate (std. err) : 3873287 (620965)
Log likelihood : 78510

95 % normal C I :(2656195,5090379)
G-square : 0.63 (2 df)
Significance : 0.73
Chi-square : 0.67 (2 df)
Significance... 0.71

Table of Stratum Estimates & Predicted counts N(recap), m(cap,rec), u(rec)

	1-2	3	4-5	Unseen
1	2.84	0.00	0.00	618
2	8.16	1.17	0.00	2030
3	0.00	15.83	1.96	4296
4	0.00	0.00	7.96	3466
5	0.00	0.00	2.08	905

Stratum Size	1155063	1424113	1294111
S.E.(Size)	366671	449407	407902
P(Recapture)	0.0046	0.0046	0.0023
S.E.(P(Rec	0.0015	0.0014	0.0007

APPENDIX 8 (cont'd)

Schaefer Estimate

Estimate : 3924429

Table of Stratum Estimates: N(cap), N(cap,rec), N(rec)

Stratum	Size	P(Capture)	1-2	3	4-5
1	298192	0.0021	298193	0.00	0.00
2	954441	0.0021	856704	97737	0.00
3	1588957	0.0027	0.00	1470482	118475
4	858657	0.0040	0.00	0.00	858657
5	224180	0.0040	0.00	0.00	224180
Stratum Size)			1154897	1568219	1201312
P(Recapture)			0.0046	0.0042	0.0025

Pooled Petersen Estimate

Estimate (std. err) : 4090375 (629143)

95 % normal C I :(2857254,5323495)
95 % transform C I :(3069059,5620106)

RIDGEDALE FEMALE

Pooling Tests

- Chi-square Test Statistics

Complete Mixing : 16.01 (3 df)
Significance... 0.00
Equal Proportions: 8.92 (2 df)
Significance... 0.01

ML Darroch Estimate

Estimate (std. err) : 8308778 (2078506)
Log likelihood : 99478

95 % normal C I :(4234907,12382649)
G-square : 3.25 (1 df)
Significance : 0.07
Chi-square : 2.52 (1 df)
Significance... 0.11

APPENDIX 8 (cont'd)

Table of Stratum Estimates & Predicted counts N(recap), m(cap,rec), u(rec)

	1-2	3	4-5	Unseen
1	3.62	0.00	0.00	719
2	11.38	0.00	0.00	2259
3	0.00	8.00	0.00	5415
4-5	0.00	0.00	10.00	5178

Stratum Si	1092046	5665001	155173
S.E.(Size)	281258	2001401	490227
P(Recapture)	0.0050	0.0015	0.0019
S.E.(P(Rec))	0.0013	0.0005	0.0006

Schaefer Estimate

Estimate : 8308778

Table of Stratum Estimates: N(cap), N(cap,rec), N(rec)

	Stratum Si	P(Capture)	1-2	3	4-5
1	263799	0.0027	263799	0.00	0.00
2	828247	0.0027	828247	0.00	0.00
3	5665001	0.0010	0.00	5665001	0.00
4-5	1551731	0.0033	0.00	0.00	1551731

Stratum Size)	1092046	5665001	1551731
P(Recapture)	0.0050	0.0015	0.0019

Pooled Petersen Estimate

Estimate (std. err) : 6731272 (1135221)

95 % normal C I :(4506239,8956307)
95 % transform C I :(4919402,9554245)

APPENDIX 8 (cont'd)

RIDGEDALE SEXES COMBINED

Pooling Tests

- Chi-square Test Statistics

Complete Mixing : 9.14 (2 df)
Significance... 0.01
Equal Proportions: 10.18 (3 df)
Significance... 0.02

ML Darroch Estimate

Estimate (std. err) : 10441939 (1348115)
Log likelihood : 259412

95 % normal C I :(7799635,13084244)
G-square : 0.69 (1 df)
Significance : 0.41
Chi-square : 0.72 (1 df)
Significance : 0.39

Table of Stratum Estimates & Predicted counts N(cap), m(cap,rec), u(rec)

	Stratum Si	S.E.(Size)	P(Capture)	S.E.(P(Cap))	1-2	3	4	5
1-2	2335809	457413	0.0024	0.0005	26.02	0.98	0.00	0.00
3	6025276	1240442	0.0016	0.0003	0.00	23.42	2.58	0.00
4-5	2080854	643369	0.0046	0.0014	0.00	0.00	16.32	3.68
Unmarked					10703	14827	5117	796

Schaefer Estimate

Estimate : 10512579

Table of Stratum Estimates: N(cap), N(cap,rec), N(rec)

	Stratum Si	P(Capture)	1-2	3	4	5
1-2	2375322	0.0024	2250706	124616	0	0
3	5583764	0.0017	0	5356779	226986	0
4-5	2553493	0.0038	0	0	2170293	383200
Stratum Size)			2250706	5481395	2397278	383200
P(Recapture)			0.0048	0.0027	0.0021	0.0021

APPENDIX 8 (cont'd)

Pooled Petersen Estimate

Estimate (std. err) : 10653259 (1226869)
95 % normal C I :(8248596,13057921)
95 % transform C I :(8569704,13470872)

STRAWBERRY MALES

Pooling Tests

- Chi-square Test Statistics

Complete Mixing : 4.77 (2 df)
Significance... 0.09
Equal Proportions: 4.29 (1 df)
Significance... 0.04

ML Darroch Estimate

Estimate (std. err) : 3469059 (622083)
Log likelihood : 82163

95 % normal C I :(2249775,4688342)
G-square : 0.36 (1 df)
Significance : 0.55
Chi-square : 0.36 (1 df)
Significance... 0.55

Table of Stratum Estimates & Predicted counts N(recap), m(cap,rec), u(rec)

	1-3	4-5	Unseen
1-2	7.19	0.00	2653
3	9.81	3.78	4300
4-5	0.00	24.22	4357
Stratum Size)	2424941	1044117	
S.E.(Size)	604299	210937	
P(Recaptur	0.0027	0.0055	
S.E.(P(Rec	0.0007	0.0011	

APPENDIX 8 (cont'd)

Schaefer Estimate

Estimate : 3385283

Table of Stratum Estimates: N(cap), N(cap,rec), N(rec)

	Stratum Size	P(Capture)	1-3	4-5
1-2	1025352	0.0026	1025352	0.00
3	1456663	0.0030	1219475	237188
4-5	903268	0.0049	0.00	903268
Stratum Size)			2244827	1140456
P(Recapture)			0.0029	0.0051

Pooled Petersen Estimate

Estimate (std. err) : 3043160 (442163)

95 % normal C I :(2176520,3909800)
95 % transform C I :(2318293,4104638)

STRAWBERRY FEMALES

Pooling Tests

- Chi-square Test Statistics

Complete Mixing : 8.41 (2 df)
Significance... 0.01
Equal Proportions: 3.12 (1 df)
Significance... 0.08

ML Darroch Estimate

Estimate (std. err) : 4848361 (845631)
Log likelihood : 101026

95 % normal C I :(3190923,6505798)
G-square : 1.50 (1 df)
Significance : 0.22
Chi-square : 1.40 (1 df)
Significance... 0.24

APPENDIX 8 (cont'd)

Table of Stratum Estimates & Predicted counts N(recap), m(cap,rec), u(rec)

	1-3	4-5	Unseen
1-2	6.36	1.18	2985
3	11.64	1.85	5410
4-5	1.00	26.97	5160
Stratum Size)	3510890	1337470	
S.E.(Size)	844280	288114	
P(Recapture)	0.0023	0.0057	
S.E.(P(Rec))	0.0005	0.0012	

Schaefer Estimate

Estimate : 4680333

Table of Stratum Estimates: N(cap), N(cap,rec), N(rec)

	Stratum Size	P(Capture)	1-3	4-5
1-2	1161942	0.0026	1010437	151506
3	2174013	0.0025	2002443	171570
4-5	1344378	0.0039	78191	1266187
Stratum Size)			3091070	1589263
P(Recapture)			0.0026	0.0048

Pooled Petersen Estimate

Estimate (std. err) : 4248024 (592797)

95 % normal C I :(3086142,5409906)
95 % transform C I :(3269710,5658997)

STRAWBERRY ISLAND (sexes combined)

Pooling Tests
- Chi-square Test

Complete Mixing : 13.02 (2 df)
Significance... 0.00
Equal Proportions: 7.26 (1 df)
Significance... 0.01

APPENDIX 8 (cont'd)

ML Darroch Estimate

Estimate (std. err) : 8316021 (1040488)
Log likelihood : 200870

95 % normal C I :(6276665,10355377)
G-square : 1.53 (1 df)
Significance : 0.22
Chi-square : 1.47 (1 df)
Significance... 0.22

Table of Stratum Estimates & Predicted counts N(recap), m(cap,rec), u(rec)

	1-3	4-5	Unseen
1-2	13.43	1.13	5649
3	21.56	5.61	9742
4-5	1.01	51.27	9528
Stratum Size	5925636	2390385	
S.E.(Size)	1025278	351172	
P(Recapture)	0.0025	0.0056	
S.E.(P(Rec))	0.0004	0.0008	

Schaefer Estimate

Estimate : 8066998

Table of Stratum Estimates: N(cap), N(cap,rec), N(rec)

	Stratum Si	P(Capture)	1-3	4-5
1-2	2202754	0.0026	2084096	118660
3	3624438	0.0027	3188712	435726
4-5	2239806	0.0043	74567	2165239
Stratum Size			5347374	2719624
P(Recapture)			0.0027	0.0049

Pooled Petersen Estimate

Estimate (std. err) : 7356221 (748089)

95 % normal C I :(5889967, 8822476)
95 % transform C I :(6065195, 9041257)

APPENDIX 8 (cont'd)

MAINSTEM (carcass) MALES

Pooling Tests

- Chi-square Test Statistics

Complete Mixing : 81.89 (2 df)
Significance... 0.00
Equal Proportions: 3.77 (1 df)
Significance... 0.05

ML Darroch Estimate

Estimate (std. err) : 4749477 (452271)
Log likelihood : 81401

95 % normal C I :(3863026,5635928)
G-square : 1.77 (1 df)
Significance : 0.18
Chi-square : 1.80 (1 df)
Significance... 0.18

APPENDIX 8 (cont'd)

Table of Stratum Estimates & Predicted counts N(recap), m(cap,rec), u(rec)

	4-6	7-8	Unseen
1-2	91.19	6.70	2562
3	47.75	23.99	4242
4-5	3.05	30.31	4348
Stratum Size	1381395	3368083	
S.E.(Size)	360445	499455	
P(Recapture)	0.0535	0.0070	
S.E.(P(Rec))	0.0140	0.0010	

Schaefer Estimate

Estimate : 5149960

Table of Stratum Estimates: N(cap), N(cap,rec), N(rec)

	Stratum Si	P(Capture)	4-6	7-8
1-2	1362264	0.0020	1297909	64355
3	2031376	0.0021	1410500	620876
4-5	1756321	0.0025	235878	1520442
Stratum Size			2944287	2205673
P(Recapture)			0.0251	0.0107

Pooled Petersen Estimate

Estimate (std. err) : 5428612 (375337)

95 % normal C I :(4692952.55,6164272.12)
95 % transform C I :(4754729.03,6236098.77)

MAINSTEM (CARCASS) FEMALES

Pooling Tests
- Chi-square Test Statistics

Complete Mixing : 77.47 (2 df)
Significance... 0.00
Equal Proportions: 0.00 (1 df)
Significance... 0.95

APPENDIX 8 (cont'd)

ML Darroch Estimate

Estimate (std. err) : 6717665 (512471)
Log likelihood : 99772

95 % normal C I :(5713221,7722109)
G-square : 1.55 (1 df)
Significance : 0.21
Chi-square : 1.57 (1 df)
Significance : 0.21

Table of Stratum Estimates & Predicted counts N(recap), m(cap,rec), u(rec)

	1-3	4-5	Unseen
1-2	110.17	11.49	2871
3	96.74	37.24	5289
4-5	7.09	49.27	5132
Stratum Size	1745441	4972225	
S.E.(Size)	405105	631223	
P(Recapture)	0.0609	0.0097	
S.E.(P(Rec))	0.0141	0.0012	

Schaefer Estimate

Estimate : 6730301

Table of Stratum Estimates: N(cap), N(cap,rec), N(rec)

	Stratum Size	P(Capture)	1-3	4-5
1-2	1484655	0.0020	1359629	125026
3	2686002	0.0020	1876543	809459
4-5	2559644	0.0020	346630	2213014
Stratum Size			3582803	3147498
P(Recapture)			0.0296	0.0153

Pooled Petersen Estimate

Estimate (std. err) : 6716522 (374270)
95 % normal C I :(5982953, 7450092)
95 % transform C I :(6033292, 7506931)