PORTLAND CANAL CHUM SALMON

CODED-WIRE-TAGGING PROJECT

1988 – 1995

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

A coded-wire-tagging study was conducted at Fish Creek, near Hyder, Alaska, in order to gather much needed data on the migratory characteristics, harvest distribution, total abundance, survival rates, and age structure of Portland Canal chum salmon runs. Over 900,000 wild chum salmon fry were tagged with half-length coded wire tags from 1988 to 1991. From 1991 to 1995, tagged adults were recovered from the commercial fisheries of Alaska and British Columbia, and from the escapement at an adult weir at Fish Creek. The estimated total adult run was quite variable from year to year, and ranged from 35,663 (1991) to 201,989 (1993). The exploitation rate averaged 56.7% (range 38.1% to 67.8%). The total escapement ranged from 9,996 (1991) to 79,169 (1993). Over 90% of the annual harvest was taken in the net fisheries of Dixon Entrance (Alaska District 101 drift gillnet and British Columbia Area 3 gillnet and seine, and Area 4 gillnet) and the outside waters of Alaska District 104. Run timing in the escapement varied annually and progressed earlier over the five years of the study (median date from 3 September 1991 to 31 July 1995). The marine survival rate of tagged fish ranged from 0.08% to 0.96%. Fish Creek chum salmon matured predominantly at age 0.3 (range 65-80%), followed by age 0.4 (20-30%). Age 0.2 and age 0.5 fish composed a small portion of the adult return. Mean lengths of male and female age 0.3 spawners increased annually. Mean annual spawner stream life ranged from 8.5 days to 10.4 days. Straying of tagged fish to nearby streams was documented. An escapement estimator was developed from a comparison of annual foot surveys to weir counts; annual Fish Creek escapements were then reconstructed from historical foot surveys back to 1971. Escapements were highly variable and without trend over the 1971-1999 period. Preliminary spawner-recruit analysis showed that production might be maximized with escapements between 15,000 and 50,000 fish, and may be limited by escapements below 10,000 fish.

KEY WORDS: Chum salmon, coded wire tag, exploitation rate, Fish Creek, migration patterns, *Oncorhynchus keta*, run timing, Southeast Alaska, straying, stream life, survival rate

INTRODUCTION

The 1985 Pacific Salmon Treaty identified chum salmon *Oncorhynchus keta* originating from streams in Portland Canal as stocks that "require rebuilding" (Pacific Salmon Treaty, Annex IV, Chapter 2, 1985 and all subsequent revisions). The treaty annex directed both U.S. and Canadian agencies to undertake assessment of these chum salmon runs to identify possible measures to restore and enhance them, and instructed the fisheries management of both countries to reduce interceptions of these runs to the extent practicable.

This treaty directive was the result of growing concern in the 1970s and 1980s over the status of Portland Canal chum salmon runs. Escapement goals, or "index targets," that had been established for the major chum salmon streams in Portland Canal were not being met on either side of the border. Historical escapement data for Portland Canal chum salmon streams was insufficient to fully evaluate the "depressed" escapements of chum salmon in the area. For example, most of the streams on the Alaska side of the canal have been surveyed annually from the air by Alaska Department of Fish and Game (ADF&G) personnel. Aerial escapement enumeration of chum salmon has generally been conducted secondarily to pink salmon *O. gorbuscha* escapement enumeration. Chum salmon are enumerated early in the season when there are few pink salmon and they are easy to see; however, as pink salmon numbers increase it is often very difficult to see and count chum salmon (Scott B. Walker, Assistant Management Biologist, Alaska Department of Fish and Game, Ketchikan, pers. comm.). Most of the annual peak counts of chum salmon for a given stream have been limited to the period before pink salmon were abundant in that stream. Counts of chum salmon were not possible, or not attempted, later in the season in some years, and high pink salmon escapements may have masked high chum salmon escapements (Van Alen 2000).

In addition, no method had been developed to accurately estimate the total escapement to any stream in Portland Canal. Typically, an annual "peak" survey estimate (= largest estimate) was multiplied by some factor (e.g. 2.5) to estimate the total escapement to a stream. Prior adult tagging studies had shown that Portland Canal chum salmon contributed to commercial fisheries in the boundary area of Dixon Entrance in both Alaska and British Columbia (Hoffman et al. 1984, 1985). However, there was no available information that specified the migratory routes, run timing, or exploitation rate for Portland Canal chum salmon.

In order to learn more about Portland Canal chum salmon, ADF&G initiated a coded-wire-tagging project at Fish Creek, a tributary of the Salmon River near Hyder, Alaska, in 1988. The juvenile tagging phase of this project was conducted from 1988 to 1991, and the adult recovery phase was conducted from 1991 to 1995. Fish Creek was chosen as the study stream for Portland Canal chum salmon for several reasons. First, Fish Creek is relatively small (only a few kilometers of spawning habitat), easily accessible (can be accessed by vehicle from Hyder), and is one of the major chum producing streams in Portland Canal. Other major chum producing streams in Portland Canal are located in remote wilderness, and are long systems that stretch for many kilometers. Adult chum salmon returning to Fish Creek must migrate through all of the commercial fisheries of Dixon Entrance, and also navigate the entire length of Portland Canal. Another reason for choosing Fish Creek was the historical escapement database that exists for that system; one or more foot surveys of the creek have been conducted annually by Dr. John H. Helle (National Marine Fisheries Service Auke Bay Laboratory, in lit.) since 1972 in association with other work there (Helle 1984; Helle and Hoffman 1995, 1998). This database of foot surveys, conducted by the same person, forms one of the best escapement records for any chum salmon system in southern Southeast Alaska, and provided an immediate advantage in using Fish Creek as an index stream for Portland Canal chum salmon.

The primary objectives of this study were to obtain baseline assessment information on the adult run of Fish Creek chum salmon by: (1) estimating the abundance, age-sex-size composition, stream life, and migratory timing of the 1991-1995 escapements; (2) estimating the fishery contribution, exploitation rate, harvest distribution, timing, and marine survival of the 1991-1995 runs; (3) developing a standardized conversion between foot survey counts and the weir-based estimates of total escapement in 1991-1995, and use that conversion to estimate escapements for the years 1971-1999; and (4) reconstructing returns from the 1986-1991 brood years and use this information to assess escapement objectives.

STUDY SITE

Portland Canal is a narrow fjord, approximately 112 km long, that forms the southeastern-most boundary between Alaska and British Columbia (Figure 1). The southern end of Portland Canal forks into Pearse Canal and Portland Inlet, both of which open into Dixon Entrance. Fish Creek (ADF&G stream number 101-15-10500-2028; Figure 2) flows south from the Coast Mountains for approximately 7.2 km and into the east side of the Salmon River at $55^{o}57'$ N, $130^{o}03'$ W, approximately 5 km north of the Salmon River mouth, near Hyder, Alaska (Orth 1967). Nearby Marx Creek (ADF&G stream number 101-15-10500-2036; Figure 2) is a 1.8 km long spawning channel that flows into the east side of the Salmon River, approximately 7 km north of the Salmon River mouth, near Hyder, Alaska.

METHODS

Fry Tagging

Migrant chum salmon fry were captured for tagging at Fish Creek from 1988 to 1991, downstream of the major chum salmon spawning areas, and approximately 2.4 km upstream from its confluence with the Salmon River as described by Koerner (1988, 1989, 1990; Figure 2). Project dates were: 11 Mar-17 May, 1988; 1 Mar-23 May, 1989; 18 Feb-27 May, 1990; and 16 Feb-15 May, 1991. The project start up date was advanced each season because migrant fry were captured on the first day that nets were fished. Fry were captured with two 0.45 m x 0.9 m fyke nets spaced 4.0 m apart in the center of the stream. Early in the season, 1.0 m high leads of plastic netting (3.2 mm mesh vexar) were placed from the fyke nets to the stream banks, effectively capturing all migrant salmon fry. Those leads were removed annually in mid-April because of extended high water events (from snow melt) leaving only the fyke nets to capture fry. In 1988, the vexar leads were removed on 15 April and not replaced. In other years, the leads were replaced again in early May after the water depth subsided.

The fyke nets were fished for 5 or 6 days per week. The entire night's outmigration of fry, from sunset to sunrise, was enumerated biweekly by gravimetric method, where a subsample of known weight was enumerated by species, and the total weight was then expanded to estimate the total number of fry by species. On other nights the nets were fished for less than 9 hours, or only long enough to catch fry for tagging the following day in which case numbers were estimated visually. In 1988 and 1989, a total of 5,000 to 8,000 chum salmon fry were held for coded-wire-tagging the next day. In 1990 and 1991, a total of 10,000 to 30,000 fry were held for tagging. A total of 200 chum salmon fry were sampled for length (to the nearest 0.5mm) and weight (to the nearest 0.01g) each week.

A minimum total fry population (above the fyke net site only) was estimated from the biweekly overnight counts using the area-under-the-curve (AUC) method (English et al. 1992):

$$auc = 0.5\sum_{i=2}^{n}(t_i - t_{i-1})(p_i + p_{i-1}); \quad (1)$$

where t_i is the number of days measured from the first day nets are fished to the *i*th sampling day, p_i is the number of fry captured on the *i*th sampling day, and n-2 is the number of surveys when fish were captured (i.e. p=0 on day one and day n). English et al. (1992) estimated the total escapement of adult salmon to a stream by dividing the AUC (the total number of fish-days) by the residence time. Assuming that all fry outmigrate at night and because fry were released downstream of the nets, the residence time is assumed to be one. Thus, the estimate of the total fry population is the AUC.

Only counts that used the vexar leads to the stream banks were incorporated into the AUC population estimates. This resulted in a 17 to 19 day gap in biweekly counts in 1989, 1990, and 1991. As noted above, in 1988 the vexar leads from the fyke nets to the stream banks were removed in mid-April (at the peak of fry migration) and not replaced. The 1988 AUC population estimate was calculated through 15 April, and then multiplied by 2.

Coded-wire-tagging operations were conducted in a 7 m tagging trailer parked adjacent to the fyke net site at Fish Creek. Chum salmon fry were anesthetized with MS-222 (tricaine methanesulfonate) at a concentration of 40 $mg \cdot L^{-1}$. Because MS-222 lowers the pH of the water, the solution was buffered with sodium carbonate (Na_2CO_3) to maintain the pH of Fish Creek water (7.5). Non-iodized salt was added to the solution at a concentration of 0.5% to stimulate mucus flow and to replace salts lost through handling. Fry were not left in the anesthetic solution for more than five minutes. Only fry that had completely absorbed their yolk sacs were selected for tagging. The adipose fins of the chum salmon fry were removed with surgical grade micro-scissors prior to tagging with half-length coded wire tags. The tagging equipment consisted of a Northwest Marine Technology[2] model MK-IV tag injector and quality control device (QCD). Tagged fry were routed through the QCD and out a 63.5mm diameter pipe to a holding pen in Fish Creek. If the quality control device did not detect a tag, the device routed the fry into a bucket. Those fry were passed through the device a second time, and were retagged if no tag was detected. Fry were tagged at a maximum rate of $3{,}000 \cdot day^{-1}$ in 1988, $3{,}500 \cdot day^{-1}$ in 1989, and $5{,}000 \cdot day^{-1}$ in 1990 and 1991.

Tagged fry were released during the late evening hours on the day of tagging. Tagged fish mortalities were recorded at the time of release and subtracted from the total number of tags released. A random sample of 200 fry were passed through the QCD each night and the number of fry without tags was recorded and used to calculate the tag retention percentage at time of release.

Commercial Catch Sampling

Coded-wire-tagged adult Fish Creek chum salmon were recovered from the commercial fisheries from 1991 to 1995. Coded-wire-tag recovery was conducted in nearly all marine fisheries in Southeast Alaska and northern British Columbia. Sampling of the Alaska commercial catch was conducted by the ADF&G Commercial Fisheries Division Port Sampling Program (briefly described in Oliver 1990, and Clark and Bernard 1987). The heads of all fish missing adipose fins were sent to the ADF&G Coded Wire Tag Laboratory for tag removal and decoding. The Canadian Department of Fisheries and Oceans conducted sampling of British Columbia commercial fisheries and provided data on coded-wire-tag recoveries (Fisheries and Oceans Canada, Mark Recovery Program, Pacific Biological Station, Nanaimo, B. C.). Commercial fisheries tag-recovery data were stratified by fishing district (Figure 1), gear, and statistical week (designated by mid-week date, Appendix 1). Only randomly recovered tags from discrete strata

[2] Mention of trade names does not constitute endorsement by ADF&G.

were used for evaluation – i.e., we did not include tags recovered from mixed gear or mixed district landings. In a few cases, recoveries from mixed landings were the *only* recoveries for a given stratum. Thus, by not including those recoveries, our estimates are biased, but this bias should be very small.

Adult Escapement Sampling

Coded-wire-tagged adult chum salmon were recovered at Fish Creek, from 1991 to 1995, at a salmon counting weir located in Fish Creek 0.1 km upstream of its confluence with the Salmon River (Figure 2). The weir was an aluminum bipod, channel and picket design, that incorporated an upstream trap for capturing fish. The entire chum salmon escapement was enumerated at the weir, and nearly all fish were examined for missing adipose fins. The heads of all chum salmon missing adipose fins were sent to the ADF&G Coded Wire Tag Lab where coded wire tags were removed and decoded. The annual weir counts were considered reliable estimates of the total annual escapement to Fish Creek, though the accuracy of the weir counts was not tested.

The age composition of the escapement was determined from a set of random scale samples taken daily from adult chum salmon at the Fish Creek weir. Fish were sampled throughout the run in proportion to abundance, and between 900 and 2,700 scale samples were collected each season. The sex of each fish was determined from external sexual maturation characteristics. Lengths were measured from mid eye to tail fork to the nearest millimeter. One scale was taken from the preferred area of each fish (INPFC 1963), and prepared for analysis as described by Clutter and Whitesel (1956). Scale samples were aged at the ADF&G Salmon Aging Lab, Douglas, Alaska. In addition to the random sample, a select sample of scales was collected from every adipose-clipped fish that was recovered at the weir.

The age distribution, by sex, was calculated from the random scale sample for each week of escapement:

$$\hat{p}_{hj} = n_{hj} / n_h \; ; \qquad (2)$$

where: h = index of the stratum (week),
j = index of the age-sex class,
p_{hj} = proportion of the sample taken during stratum h that is age j,
n_h = number of fish sampled in week h, and
n_{hj} = number observed in class j, week h.

Standard errors of the weekly age class proportions were calculated as (Cochran 1977, page 52):

$$SE(\hat{p}_{hj}) = \sqrt{\left[\frac{(\hat{p}_{hj})(1-\hat{p}_{hj})}{n_h - 1}\right][1 - n_h / N_h]} \; ; \qquad (3)$$

Where N_h = the number of fish in the escapement in week h. The age-sex distributions for the total escapement were estimated as a weighted (by stratum size) sum of the weekly proportions.

$$\hat{p}_j = \sum_h p_{hj} (N_h / N); \qquad (4)$$

where N = the total escapement. The standard error of a seasonal proportion is the square root of the weighted sum of the weekly variances (Cochran 1977, pages 107-108):

$$SE(\hat{p}_j) = \sqrt{\sum_j^h [SE(\hat{p}_{hj})]^2 (N_h/N)^2} \;. \tag{5}$$

The mean length, by sex and age class (weighted by week of escapement), and the variance of the weighted mean length, were calculated using the following equations from Cochran (1977, pages 142-144) for estimating means over subpopulations:

$$\hat{\bar{Y}}_j = \frac{\sum_h (N_h/n_h) \sum_i y_{hij}}{\sum_h (N_h/n_h) n_{hj}}, \text{ and} \tag{6}$$

$$\hat{V}\left(\hat{\bar{Y}}_j\right) = \frac{1}{\hat{N}_j^2} \sum_h \frac{N_h^2 (1 - n_h/N_h)}{n_h (n_h - 1)} \left[\sum_i \left(y_{hij} - \bar{y}_{hj}\right)^2 + n_{hj} \left(1 - \frac{n_{hj}}{n_h}\right) \left(\bar{y}_{hj} - \hat{\bar{Y}}_j\right)^2 \right]; \tag{7}$$

where: i = index of the individual fish in the age-sex class j, and
y_{hij} = length of the ith fish in class j, week h.

Fish Creek Stream-Life

Stream-life studies were conducted at Fish Creek in 1991, 1992, and 1995, to determine the average life expectancy of adult salmon after passing upstream of the weir. In 1991, fish were tagged just below the dorsal fin with numbered, bright red, Peterson disc tags (Hoffman et al. 1984). In 1992 and 1995, we switched to dull-colored, numbered aluminum jaw tags (National Band & Tag Co., style 893), in an effort to cut down on the tag loss experienced with Peterson disc tags, and to reduce the possibility of selective predation by bears. Up to 300 fish were tagged per week. Stream surveys were conducted every other day to recover tags from fresh carcasses. The tag number, sex, and carcass condition were recorded for each tag recovery. The stream life was calculated for each week of tagging, by averaging the number of days between tagging and recovery.

Marx Creek and Adjacent Salmon River Escapements

Weekly foot surveys of Marx Creek were conducted from 1992 to 1995 to estimate the chum salmon spawning population, and to recover tagged chum salmon straying from Fish Creek. (Unfortunately, no effort was made to recover stray tags from Marx Creek in 1991, and only a few foot surveys were conducted). The total escapement was calculated using an area-under-the-curve method (Helle 1970), where total fish days (sum of weekly foot surveys times 7 days) were divided by the mean stream life (derived from Fish Creek in 1992 and 1995). Other studies have shown that stream life can differ significantly from year to year in the same system, and can also differ in adjacent systems during the same year (Helle 1970; Dangel and Jones 1988; Perrin and Irvine 1990, English et al. 1992). Thus, our estimates of the spawning escapement at Marx Creek and the Salmon River are, at best, rough approximations.

In 1993 and 1994, chum salmon spawned in the adjacent Salmon River within 5 km of the mouth of Fish Creek. Foot surveys were conducted to estimate the spawning population and to recover tagged chum salmon straying from Fish Creek. In 1993, the number of fish spawning in the Salmon River was estimated from a single foot survey conducted in mid-September. In 1994, the number of chum salmon spawning in the adjacent Salmon River was estimated from weekly foot surveys using an area-under-the-curve method (Helle 1970).

Foot-to-Weir Escapement Estimate

A standardized method of estimating the annual escapement to Fish Creek was developed by comparing an index of foot surveys to the weir counts. For this analysis, foot survey data from all observers were pooled. Foot surveys were conducted on a regular basis (weekly) only in 1995. From 1991 to 1994 only 4 to 6 escapement surveys were conducted each year, and not on established dates. For that reason, survey periods were chosen for comparison to the weir counts, rather than comparing escapement surveys that were conducted on a specific day or week of the season.

The average run timing at the Fish Creek weir was determined for the five years 1991 to 1995. Three survey periods were then established about the mean 25^{th}, 50^{th}, and 75^{th} percentile run dates for those five years: Survey period one from 23 July to 5 August (mean 25^{th} percentile run date 30 July), survey period 2 from 6 August to 22 August (mean 50^{th} percentile run date 14 August), and survey period 3 from 23 August to 8 September (mean 75^{th} percentile run date 1 September). Each survey period was assigned a peak foot survey count. The first foot survey included both live and dead counts, but only live counts were used for the final two surveys.

A foot-to-weir conversion was obtained by dividing the weir count by the sum of the three foot surveys (index count). The geometric mean of the five conversion factors was then used as an estimator. A more general estimator of the form: $weir = a*index^b$, was also investigated using PROC REG in SAS (SAS Institute 1989). Ninety-five percent prediction intervals were calculated as:

$$\exp\left[\log_e(\hat{E}) \pm t_{.025,4}\sqrt{s^2\left(\frac{n+1}{n}\right)}\right]; \tag{8}$$

where E is the estimated escapement, s^2 is the sample variance of the natural logarithms of the five weir-to-index ratios, and n=5 (see Hahn and Meeker 1991, for a discussion of prediction intervals).

Estimates of total escapements to Fish Creek were then extrapolated from past foot surveys back to 1971. Foot survey counts were not available for every specified “survey period” for most years, and had to be interpolated from the existing data. Foot survey data were arranged in a matrix table with years in columns, and designated surveys in rows. Missing surveys were interpolated as in other studies (e.g. Shaul 1998) by assuming that the expected count for a given period in a given year is equal to the sum of all counts in that period, times the sum of all counts for the year, divided by the sum of all counts over all periods and years (i.e. row total times column total divided by grand total). This assumes a multiplicative effect between year and period with no interaction. We used an iterative procedure described by Brown (1974), because there was more than one missing value, and the sums change as missing values are filled in at each step.

Analysis of Coded-Wire-Tag Data

Analysis of tag recoveries was somewhat problematic, because chum salmon fry tagged from one brood year return as adults over a four-year period, and chum salmon fry tagged in this study, from 1988 to 1991, would return as adults over a seven-year period. For some years of this study only one or two age classes, and not the entire run, were represented by tagged adults. As a result, we evaluated tag data by two methods: (1) Tag data were analyzed for the run as a whole, all age classes combined. This method allowed annual estimates of the total fishery contribution, total adult run, and the overall exploitation rate on the run.

(2) Tag data were also analyzed for each individual ocean age class to provide estimates of the exploitation rate on each age class and survival rate of each brood year.

Equations for calculating the exploitation rate, fishery contribution, total run, survival rate, and their variances, are derived in Appendix 2, and are based on standard sampling survey theory such as in Cochran (1977). Exploitation rates of the 0.2 and 0.3 age classes were compared by computing the mean difference for 1991-1993. An approximate 95% confidence interval was computed assuming that all exploitation rate estimates are independent and that the mean difference is normally distributed. Although exploitation rate estimates are independent across years, they are dependent within years. However, Kish (1965, p. 135, 138) points out that the covariance term for the means (or proportions) of subpopulations is negligible. The 95% confidence interval is the mean difference +/- 1.96-times the standard error of the mean difference, where the standard error of the mean difference is the mean (across years) of the square root of the sum of the individual age-class standard errors.

For simplicity, we assumed that catches and escapements are known without variance; however this is not strictly true, particularly for the estimates of the escapement to Marx Creek and the Salmon River as noted above. Fishing effort (boat-days) and chum salmon catches for Alaska fisheries were extracted from the ADF&G Integrated Fisheries Data Base. Fishing effort and chum salmon catches for British Columbia fisheries were obtained from the Pacific Salmon Commission Northern Boundary Technical Committee Report (1999).

Stray tagged Fish Creek chum salmon recovered in Marx Creek from 1992 to 1995, and in the adjacent Salmon River in 1993 and 1994, were expanded by the same method as fishery recoveries. The sum of those estimates and the weir counts provided the total escapement of Fish Creek chum salmon.

Spawner-Recruit Analysis

We conducted spawner-recruit analysis using two data sets of Fish Creek chum salmon returns. In the first data set we simply paired the 1987-1990 escapements (estimated from an index of foot surveys) with the total brood-year returns from those escapements (estimated from coded-wire tag recoveries). Adjustments for variation in marine survival were made for the second data set following the method described by Clark et al. (1994). The total return of each brood year was divided by the fry-to-adult survival rate of that brood year (estimated from coded-wire tag recoveries), and multiplied by the geometric mean survival rate over all years. This second set of return estimates was used with the assumption that marine survivals were independent of parental abundance and that removing the random variability in marine survival would improve the fit of the spawner-recruit relationship (Clark et al. 1994).

We did not recover age 0.2 coded-wire tagged fish from the 1987 brood year, or age 0.5 coded-wire tagged fish from the 1990 brood year. Therefore we interpolated those values by using the same fill-in method described above in the “Foot-to-Weir Escapement Estimate” section. The filled-in numbers represented only 5% and 1% of the total returns in those brood years. Ricker recruitment curves (Ricker 1975) were fit to the two spawner-recruit data sets. We multiplied the estimated number of spawners that produced the maximum harvestable surplus by 0.8 and 1.6 to produce the ranges of escapement predicted to provide 90% or more of the maximum sustained yield (after Eggers 1993).

RESULTS

Fry Tagging

The estimated number of outmigrant fry ranged from 4.5 million (1988) to 11.0 million (1989; Table 1). The AUC estimates are considered minimum population estimates because, while the fyke nets were placed below the main chum salmon spawning areas, they were still 2.4 km upstream of the mouth of Fish Creek, and could not capture all migrant fry. Also, fry were migrating before and after the period that fry were captured. Fry were captured annually on the very first night that fyke nets were fished (earliest, 305 fry on 16 February 1991), and were still being captured when the project ended each season (latest, 9,779 fry on 24 May 1990). The seasonal migration generally peaked from late March to early April. (Figure 3). The nightly migration of chum salmon fry commenced after sunset between 1700 and 1900 hours, peaked between 2000 and 2400 hours, and ceased by 0600 hours. An occasional smaller peak took place between 0200 and 0600 hours.

The mean length of Fish Creek chum salmon fry ranged from 38.7 mm (1990) to 40.1 mm (1991), and individuals ranged in length from 37.5 to 40.6 mm. The mean weight of fry ranged from 0.38 g (1990) to 0.39 g (1988, 1989, and 1991), and individuals ranged in weight from 0.34 to 0.42 g.

A total of 965,280 fry were tagged and released during the five years of tagging (Table 1). Tag mortality prior to release was very low and ranged from 0.2% (1988, 1989, and 1990) to 0.4% (1991). Tag retention at time of release (up to 12 hours after tagging) ranged from 91.9% (1988) to 95.5% (1989) for a total season, but ranged from 82.4% to 99.6% for individual tag codes (Appendix 3). The frequency of adipose-clipped adult fish in the escapement that lacked tags indicated additional post-release shedding of tags: 0.12% (1991), 0.09% (1992), 0.26% (1993), 0.36% (1994), and 0.57% (1995). The resulting estimated total rate of tag loss for each year of tagging was considerable: 20.1% (1988), 14.6% (1989), 23.6% (1990), and 35.5% (1991).

Escapement, Harvest Contribution, and Exploitation Rate

Summaries of all coded-wire tag recoveries and associated statistics are presented in Appendices 4-8. Annual escapements of chum salmon through the Fish Creek weir ranged from 9,742 (1995) to 60,447 (1993; Table 2). Fish Creek tags were recovered in Marx Creek from 1992 to 1995, and in the adjacent Salmon River in 1993 and 1994. Stray recoveries represented a mean 20.9% of the escapement (range 17.5% to 23.6%). No attempt was made to recover stray coded-wire-tagged fish in 1991. Therefore, we estimated that portion using the 1992-1995 mean, added it to the 1991 escapement, and accordingly adjusted the exploitation rate and the estimated total adult run for that year. Area-under-the-curve escapement estimates at Marx Creek ranged from 1,054 (1995) to 36,303 (1993), and spawning escapement to the Salmon River was estimated to be 18,485 (1993) and 2,453 (1994; Appendix 9).

The estimated commercial harvest of Fish Creek chum salmon ranged from 23,026 (1991) to 122,819 (1993). The total adult run ranged from 35,663 (1991) to 201,989 (1993). The exploitation rate over all age classes combined ranged from 38.1% (1992) to 67.8% (1995; Table 3). Age 0.2 fish experienced a 14.7% (SE = 4.7%; 95% CI ± 9.3%) higher harvest rate than age 0.3 fish from 1991 to 1993.

Harvest Distribution

The Alaska fisheries landed an estimated 77.9% and 72.9% of the Fish Creek chum salmon harvested in 1991 and 1992 (Table 4). Approximately 60% of the estimated catch was harvested in British Columbia fisheries in 1993, 1994, and 1995. Fish Creek chum salmon were primarily harvested in the major net fisheries of Dixon Entrance (Alaska District 101 drift gillnet, and British Columbia Area 3 gillnet and seine, and Area 4 gillnet) and in the outside waters of the Alaska District 104 purse seine fishery. Those combined areas accounted for 95.8% (5-year mean) of the annual tag recoveries (100.0% in 1991). Very small numbers of coded-wire-tagged Fish Creek chum salmon were recovered in other Alaska fisheries: From 1992 to 1995 the *combined* fishing areas of District 106 drift gillnet, Districts 101, 102, 103, and 105 purse seine, and District 104 troll, accounted for only 2.1% to 5.3% of the annual harvest. The District 105 and 106 landings represented the northernmost recoveries of Fish Creek coded wire tags. Incidental catches of Fish Creek chum salmon were also recorded in the British Columbia Area 2 West and Area 5 net fisheries. The Area 5 landings represented the southernmost recoveries of Fish Creek coded wire tags.

Run Timing – Commercial Fisheries

The migration timing of the Fish Creek run through the major intercepting fisheries are outlined below, for years with at least 15 randomly recovered tags.

Alaska District 104 Purse Seine: In 1992, 1993, and 1994, tagged Fish Creek chum salmon were recovered in the District 104 purse seine fishery from early July (when the fishery opened) to mid-August (Figure 4). One tag was recovered during the first week of September in 1991; otherwise there were no District 104 tag recoveries after the week of 20 August (1993). Fish Creek chum salmon did not contribute to late season peak catches of fall chum salmon that occurred from late August to early September. The annual abundance of Fish creek chum salmon in District 104, as indicated by the catch per unit effort, was highest during the first three weeks of the fishery.

Alaska District 101 Drift Gillnet: Coded-wire-tagged Fish Creek chum salmon were harvested in the District 101 drift gillnet fishery when the fishery opened in mid to late June in 1992, 1993, 1994, and 1995 (Figure 5). Tags were recovered through late August and early September in 1992, 1993, and 1994. Run timing was much earlier in 1995 when coded wire tags were only recovered through the end of July. The run timing also appeared to be earlier in 1994 than in 1993 and 1992. Both the proportion of tags recovered, and the catch per unit of effort, were highest during the first five weeks of the fishery in 1994. Fish Creek chum salmon contributed little, or not at all, to late season peak catches of fall chum salmon that occurred annually from late-August to late-September.

British Columbia Area 3 Gillnet: The proportion of tags recovered generally coincided with the overall catch of chum salmon in the Area 3 gillnet fishery in 1993 and 1994 (Figure 6). Coded-wire-tagged Fish Creek chum salmon were harvested from mid-June to late August. Peak catches occurred in early July of both years, when the fishing effort was highest. However, in 1993 Fish Creek chum salmon were clearly most abundant in this fishery at the end of August as indicated by the catch per unit effort. Late season tag recoveries in 1994 were sporadic, but also extended into late August.

British Columbia Area 3 Seine: The proportion of tags recovered generally coincided with the overall catch of chum salmon in the Area 3 seine fishery in 1993 and 1994 (Figure 7). Recoveries of coded-wire-tagged Fish Creek chum salmon peaked sharply in late July: single week catches represented over 50% of the Fish Creek chum salmon harvested in the Area 3 seine fishery. In 1993 the catch per unit effort peaked during the last half of August, indicating the abundance of Fish Creek chum salmon was highest through the end of August despite an overall decline in the catch of chum salmon. In 1994, the catch declined steadily after the late July peak (along with overall catches of chum salmon).

Run Timing – Escapement

Run timing in the escapement was quite variable, both for the run as a whole and for each returning age class. The midpoint of the escapement moved progressively earlier over the five years of weir operations;

the 1995 escapement was five weeks earlier than the 1991 escapement (Figure 8). Median run dates were 3 September (1991), 25 August (1992 and 1993), 10 August (1994), and 31 July (1995). Older fish generally returned to Fish Creek before younger fish; although there was much annual variation (Figure 9). The midpoint of the run of age 0.4 and age 0.5 fish generally occurred prior to mid-August. Age 0.2 fish were the latest migrating age class over all five years of the study, and from 1991 to 1994, nearly the entire escapement of age 0.2 fish arrived after mid-August. The midpoint of the age 0.3 escapement occurred after mid-August from 1991 to 1993, but occurred earlier in 1994, and earlier still in 1995. The 1995 escapement was the earliest for all four age classes over the five years of the study.

Survival Rate

The marine survival rates of coded-wire-tagged Fish Creek chum salmon ranged from 0.08% (1987 brood year) to 0.96% (1989 brood year; Table 5). No tagged age 0.2 fish from the 1987 brood year, or age 0.5 fish from the 1991 brood year, were recovered from foot surveys of Fish Creek or from the commercial fisheries. The survival and maturation rates of age 0.2 and 0.3 fish returning in 1991 were adjusted to account for unsampled stray escapement, though that adjustment changed the estimates only slightly.

More than 200,000 fry were tagged and released during the month of May over the four years of tagging (23% of the total tags released). However, fish tagged in May only represented a mean 1.4% of subsequent total recoveries of tagged adults (Figure 10). Further, eight of the tag codes used during May (representing 130,459 tagged fry) were never subsequently recovered as adults.

Age and Length Distribution

The age composition of the Fish Creek chum salmon escapement varied annually over the five-year study (Table 6). Age-0.3 fish dominated the escapements of 1991, 1992, and 1993. In 1994, however, the proportion of age-0.3 to age-0.4 fish was approximately equal, and in 1995 the escapement was predominantly age-0.4 fish. With the exception of 1991, the estimated age compositions of the annual total run, based on coded-wire-tag recoveries, were very similar to the age compositions found in the escapement (Table 7).

Some interpolation of the data was required to estimate the total returns of the age classes that were not represented by coded-wire-tag recoveries. For 1991, we interpolated the missing 0.4 and 0.5 age classes by subtracting age 0.2 and 0.3 totals from the estimated total return, then multiplying the remainder by the proportion of age 0.4 *to* age 0.5 fish in the escapement. Similarly, for 1995, missing age 0.2 and 0.3 age classes were interpolated by subtracting age 0.4 and 0.5 totals from the estimated total return, then multiplying the remainder by the proportion of age 0.2 *to* age 0.3 fish in the escapement. The missing age classes in 1992 (age 0.5) and 1994 (age 0.2) were estimated by simply subtracting the other three age classes from the estimated total return of each year. In addition, the total run in 1991 was adjusted for unsampled stray escapement using the average proportion (0.209) of the estimated stray escapement from 1992 to 1995.

Coded-wire-tagged fish returned primarily as age-0.3 adults (range 65% to 80%; Table 5), followed by age-0.4 adults (range 20% to 30%). Age-0.2 and age-0.5 fish composed only a small percentage of the total adult return of any brood year.

The mean length of age 0.3 fish, of both sexes, increased over each year of the study (Table 8). Mean lengths of age 0.3 males increased annually from 621 mm (1991) to 693 mm (1995), and age 0.3 females increased annually from 592 mm (1991) to 669 mm (1995). With the exception of age 0.5 females, the mean lengths of fish in the 1995 escapement were the largest for all sex and age classes.

Fish Creek Stream Life

The mean annual stream life of the Fish Creek chum salmon that passed upstream of the weir ranged from 8.5 days (median 8 days; 1991) to 10.5 days (median 10 days; 1992; Table 9). Stream life generally decreased through the season. The poor recovery rate of stream-life tags in 1991 (5.3%) was probably attributable to a high rate of Petersen disc tag loss (e.g. 158 loose tags were found in the creek). Better results were obtained with numbered jaw tags in 1992 (16.8% recovered) and 1995 (11.1% recovered).

Foot-to-Weir Escapement Estimate

A linear regression through the origin of the weir counts on the foot survey index counts displayed a good fit ($weir = 2.093 * index$, $R^2=0.971$; Figure 11). However, because count data typically have a multiplicative error structure, a more appropriate model may be $weir = a * index^b \varepsilon$, where ε is the error term, assumed to be log-normally distributed. Taking natural logarithms on both sides, we obtain $log_e(weir) = log_e(a) + b*log_e(index) + \varepsilon$. The fit of this model is also good: $log_e(weir) = 0.395 + 1.038*log_e(index)$, $R^2 = .981$. However, with a standard error of 0.083, the coefficient of $log_e(index)$ is not significantly different from 1. If this coefficient is assumed to be 1, the model is the same as using the geometric mean. Because the geometric mean model has a smaller root mean squared error (0.122 compared to 0.136) and a smaller predicted residual sum of squares (0.093 compared to 0.148; see Montgomery and Peck 1992, for a discussion of this statistic), we elected to use the geometric mean. The geometric mean foot-to-weir conversion factor (2.114429; Table 10) was used to extrapolate the Fish Creek escapement from historical foot surveys in years 1971 to 1999 (Figure 12; Appendix 10). There does not appear to have been any long term decreasing or increasing trends in escapements (Spearman's rho rank correlation trend test, $r = -0.176$, $p = 0.362$, n = 29; Conover 1980).

Spawner-Recruit

Our data provided a rough reconstruction of the four brood-year returns from 1987-1990, and also partial returns for 1986 and 1991 (Table 11). There was nearly a 12-fold range in estimated returns from the 4-fold range in escapements. The smallest return was from a high escapement of approximately 61,000 fish in 1987, and the largest return was from an intermediate escapement of approximately 36,000 fish in 1989. These two brood years also had the lowest and highest marine survival rates. When the total returns were adjusted for variations in marine survival, the range of returns decreased from 12-fold to 2-fold. Although we had only partial returns from the 1991 escapement (approximately 10,000 fish), it appeared that the returns from this brood year were below replacement.

If we assume that the spawner-recruit relationship was primarily influenced by spawner abundance and density-dependent effects in both the freshwater and early marine environments, then the median fit of the observed spawner-recruit relationship yields a maximum sustained yield (MSY) escapement range of 16,000-33,000 fish (Figure 13). Conversely, if we assume that marine survivals were unrelated to spawner abundance, then adjusting returns for natural variability in fry-to-adult survivals would be appropriate. Doing so improves the "fit" of the spawner-recruit relationship, R^2 increases from 0.5 to 0.8, and the MSY escapement range shifts upward to 28,000-56,000 fish.

DISCUSSION

Assessment of Fish Creek Chum Salmon

Commercial Fisheries

Joint U.S./Canada adult salmon tagging studies in 1983 and 1984 found that chum salmon migrating to spawning streams in Alaska District 101 and adjacent British Columbia Area 3 (both of which encompass Portland Canal), entered the inside waters primarily through Dixon Entrance and contributed to boundary area fisheries on both sides of the border (Hoffman et al. 1984, 1985). Our coded-wire-tag recoveries also show that the primary migration route of Fish Creek chum salmon is through Dixon Entrance to Portland Canal.

Coded-wire-tagged Fish Creek chum salmon were primarily harvested in the outside waters of Alaska District 104, and in Dixon Entrance, near the mouth of Portland Canal, in the Alaska District 101 drift gillnet fishery, and the British Columbia Area 3 gillnet and seine, and Area 4 gillnet fisheries (Table 4). Aside from District 104 purse seine, there were few tag recoveries from fisheries that were any distance from the entrance of Portland Canal. The few tag recoveries in Alaska Districts 105 and 106 indicate that in some years very small numbers of Fish Creek chum salmon migrate through the Alaska inside waters of Sumner and Clarence Straits. The few recoveries in British Columbia Area 5 probably reflect a southward lagging of some Fish Creek chum salmon out of Dixon Entrance into Hecate Strait prior to entering Portland Canal; an observation consistent with that of the adult tagging studies (Hoffman et al. 1984, 1985).

There appears to be some annual variability in the north-south distribution of Fish Creek chum salmon as they migrate through the boundary area. Alaska fisheries accounted for 73-78% of the Fish Creek chum salmon harvested in 1991-1992; but only 38-42% of those harvested in 1993-1995 (Table 4). The cause of this variation in harvest distribution is not known, but may reflect a combination of the influence that annual oceanographic conditions have on migration patterns, and the annual variations in the conduct of the respective boundary fisheries.

Overall assessment of run timing in the commercial fisheries was somewhat difficult because of variation in the fishing effort and the length of the fishing season; both between different fisheries in the same year, and for the same fishery in different years (Figures 14, 15, and 16). The smaller numbers of coded wire tags recovered in 1991 and 1995 (compared to 1992, 1993, and 1994; Table 2; Appendices 4-8) also precluded examination of run timing on a weekly basis for those two years. Still, some useful information on run timing through individual fisheries was obtained. For example, Fish Creek chum salmon displayed run timing consistent with “summer-run” fish, and did not contribute to the late season peak catches of “fall-run” chum salmon in the Alaska District 104 purse seine fishery (late-August to early September; Figure 4) or the Alaska District 101 drift gillnet fishery (late August through late September; Figure 5). The run timing of Fish Creek chum salmon through the Alaska District 104 purse seine fishery (most abundant in the opening three weeks beginning in early July) coincides with reduced fishing effort because of early season treaty obligations for Nass and Skeena River sockeye salmon *Oncorhynchus nerka* conservation. Thus, the decreased fishing effort in District 104 through statistical week 30 (mid-week date 23 July; Figure 15) has likely reduced the exploitation of Fish Creek chum salmon since 1984, and should continue to do so.

Fish Creek chum salmon experienced an average exploitation rate of 57% (range 38.1% to 67.8%). Given the highly mixed stock nature of Dixon Entrance fisheries (Hoffman et al. 1984, 1985), and the annual variation in the distribution of tag recoveries in those fisheries (Table 4), it might be very difficult to effect changes in the exploitation rate of Fish Creek chum salmon by attempting subtle adjustments to total catches in those fisheries. Lloyd (1996) showed that adjusting the total catch of a mixed stock fishery to benefit one stock would lead to a great reduction in the overall harvest, and the resulting reduction of the exploitation rate on the specific stock of concern may be insubstantial. Sands and Marshall (1995) also point out that there are currently no practical inseason management methods for controlling stock-specific harvests to achieve a fixed escapement goal for salmon that spawn far from the mixed stock fisheries where they are harvested. A reduction in exploitation rate would be best achieved by reducing the harvest in terminal or near terminal areas (Lloyd 1996). Fish Creek chum salmon (and Portland Canal chum salmon) have certainly benefited from the general closure of Portland Canal waters to commercial gillnet fishing since the mid 1970s (Figure 16).

Ricker (1980, 1981) reported that the mean age of chum salmon harvested in northern British Columbia fisheries increased between 1957 and 1972, possibly because of selection by the gillnet fishery on the smaller age 0.2 fish. Our data shows that age 0.2 Fish Creek chum salmon experienced a 14.7% (95% CI: 5.4%, 23.9%) higher harvest rate than age 0.3 fish during 1991-1993; however, there were too few age 0.2 tag recoveries to show gear selectivity. As has been reported for chum salmon elsewhere (Helle 1979, 1984; Beacham and Murray 1987), annual run timing by age class is somewhat segregated, with older fish returning before younger fish (Figure 9). It should be expected that exploitation rates would be different for each age class, at least in some years, because each age class would be exposed to different fishery openings and to different degrees of fishing effort.

Escapement and Total Return

Reconstruction of the 1971-1999 Fish Creek chum salmon escapements suggests that escapements were stable, if highly variable, over the last several decades (Figure 12). There does not appear to have been any long-term decreasing or increasing trend in escapements. This analysis is somewhat speculative because the data is extrapolated from an incomplete data set (Appendix 10), and does not take into account the effects of exploitation rate on the total escapement. Nonetheless, even if exploitation rates could be calculated for runs prior to 1990, the total runs would probably still appear highly variable, with no distinct trends over time.

Our data appears to show that large returns from a single brood year produce large returns over all age classes, while weak returns from a single brood year produce weak returns over all age classes (Tables 7 and 11). This suggests that the magnitude of the total return of chum salmon from a single brood year is determined very early on; an observation supported by the fact that most marine mortality occurs within the first few months of life (see Salo 1991). The strength of the year-class returns greatly influenced the magnitude and age compositions of the 1991-1995 Fish Creek runs. For example, the 1989 brood year had by far the largest total return of fish, and the largest individual returns of age 0.3, 0.4, and 0.5 fish (Table 11). The returns of those age classes greatly influenced the age composition of the escapements and total runs in 1993-1995 (Tables 6 and 7). Conversely, the 1991 brood year had the smallest return of age 0.2 and 0.3 fish. The result is that the 1995 escapement, which might have been dominated by the age 0.3 fish from the 1991 brood year, was instead dominated by age 0.4 fish from the stronger 1990 brood year. This fluctuation in the annual age composition caused the mean age of spawners to increase steadily from 2.98 years in 1991 to 3.79 years in 1995. It is difficult to draw any conclusions from this data given the short time period of our study. Helle and Hoffman (1995, 1998) also reported that the age composition of the Fish Creek escapement was highly variable between 1972 and 1996, and the overall mean age at maturity of chum salmon has increased since the mid 1980s.

The size of spawning Fish Creek chum salmon was also highly variable on an annual basis (Table 8). A 25-year study by Helle and Hoffman (1995, 1998) found a significant decline in the mean length of spawning Fish Creek chum salmon of all ages, from 1980 to 1994, followed by a significant increase in size in 1995 and 1996. Our data confirm the increase in size for 1995 and suggest an increasing trend during the period 1991-1995 for age 0.2 and 0.3 fish as well.

The factors that limit Fish Creek chum salmon production are poorly understood. It is difficult to assess the relative influence that escapements and climate/ocean effects on survival have on returns with only four brood years reconstructed (1987-1990; Table 11). Hilborn and Walters (1992) cautioned that spawner-recruit analysis can be severely biased if there is no more than a 2-4-fold range in escapements. Our 15,000-66,000 range in escapements was only 4-fold. While we cannot pretend to establish accurate escapement goals with our limited spawner-recruit data, this data offers a preliminary insight into probable MSY escapement ranges. A Ricker recruitment curve fit to the observed spawner-recruit data suggests that the production of Fish Creek chum would be maximized with escapements in the range of 16,000-33,000 fish (Figure 13). Adjusting for natural variations in marine survival rates, suggests that production might instead be maximized with escapements in the range of 28,000-56,000 fish (Figure 13). There is some evidence to suggest adjusting chum salmon returns for variations in marine survivals, as we have done, may not be appropriate. For example, Beacham and Starr (1982) concluded that marine survival of chum salmon was negatively related to both the total abundance of chum and pink salmon fry from the same brood year, and to the abundance of adjacent year classes of chum salmon. The upper end of the true escapement goal range, then, is probably some intermediate interval between the two methods presented here. It is apparent that returns from the 1991 brood year (escapement of 9,996) were probably well below replacement, and may indicate that production is limited by escapements of 10,000 fish or fewer. The estimated escapements in 1997 (2,810 fish) and 1999 (5,350 fish) were the lowest on record (Appendix 10), and returns from those escapements are expected to be poor.

Every effort should be made to continue the long series of escapement data that has been collected at Fish Creek since 1972 (Helle and Hoffman 1998). This is especially important given that concerns over Portland Canal chum salmon stocks originated partly out of the fact that accurate estimates of the total escapements did not exist for any of its chum salmon systems. The method developed here for indexing the Fish Creek escapement from three foot surveys would allow a much needed measure of the abundance of the annual escapement, and would be a cost effective (though rough) alternative to operating a weir or conducting a mark-recapture estimate on an annual basis. Three foot surveys conducted on specific dates over the course of the spawning season would also be better than estimates based only on a single "peak" survey, because it should better account for the great annual variation in run timing, both for the escapement as a whole and for each returning age class (Figures 8 and 9).

Assessment of the Coded-Wire-Tagging Study

This coded-wire-tagging study has gathered much needed baseline information on the abundance, exploitation rate, and time and area distribution of Fish Creek chum salmon in the commercial fisheries over a relatively short time period. This information was completely lacking prior to this study. Coded-wire-tagging studies have been conducted on a long-term basis in Southeast Alaska for index stocks of wild coho salmon *O. kisutch* (Shaul 1994, 1998; Clark et al. 1994; Shaul and Crabtree 1998) and wild chinook salmon *O. tshawytscha* (Pahlke 1995; Pahlke et al. 1996). Coded-wire-tagging studies of Fish Creek chum salmon conducted on a long-term basis would help to distinguish real trends versus annual variation, lead to a better understanding of the timing and migration patterns over a greater range of fish runs and fishing effort, and help establish meaningful escapement goals through spawner-recruit analysis. However, we must acknowledge the limitations in the quality of the data obtained using coded wire tags to study wild chum salmon. Problems in this study, that would need to be taken into consideration in any future study, include: straying of tagged fish, low rates of initial tag application, and high rates of tag loss. It is clear from the tag-recovery data that chum salmon originating from Fish Creek annually returned to spawn in Marx Creek, and in some years the adjacent Salmon River (Table 2). Marx Creek chum salmon originated from both naturally straying, and transplanted Fish Creek stock (Novak and Denton 1989).

Marx Creek was formed by upwelling groundwater in the impounded area of a dyke that was built in the mid 1970s to protect the Hyder road and the Fish Creek drainage from seasonal flooding by the Salmon River (Novak 1983). Naturally straying Fish Creek chum salmon began spawning in the Marx Creek channel soon after its formation (maximum escapement count 2,026 in 1982; Novak 1983). In a cooperative effort by state and federal agencies, Marx Creek was developed into an enhanced spawning channel between 1982 and 1985, and was stocked with adult chum salmon from Fish Creek from 1985 to 1988 (Novak and Denton 1989). It was no surprise, then, that tagged fish strayed to nearby spawning areas.

We attempted to account for recoveries of stray tags by extrapolating from the marked-to-unmarked ratio from Fish Creek. Had we not, our estimates of exploitation rate would have been biased high and our calculated survival rates would have been biased low. Habicht et al. (1998) reported that stray coded-wire-tagged Prince William Sound pink salmon were recovered at an average distance of 40 km from their original sites of tagging and release in 1992, and at an average distance of 7.5 km in 1994. We did not search more distant river systems in Portland Canal for stray tags (e.g. the Bear River in Stewart, British Columbia), and it is possible that some Fish Creek chum salmon strayed undetected to other systems.

Of more concern is the question of whether or not stray tagged fish are representative of the untagged population. It is well known that olfaction plays an important role in the orientation and homing ability of salmon (e.g., see Doving et al. 1985; Dittman and Quinn 1996), and that poor placement of coded wire tags during tagging can cause damage to olfactory organs and nerves, especially if the tagged fish are very small (Morrison and Zajac 1987; Morrison et al. 1990; Habicht et al. 1998). Habicht et al. (1998) found that stray coded-wire-tagged pink salmon recovered in 1992 were more likely to have been tagged in critical areas of the head (e.g. olfactory organs and nerves) than tagged pink salmon that homed successfully; i.e. tag position affected the homing ability of tagged fish. It would be very difficult to tag the large numbers of small fry that were tagged in this study, without inducing olfactory nerve damage in some portion of the tagged fish. Yet it is not unreasonable to assume that natural straying occurs on an annual basis between Fish and Marx Creeks, given their very close proximity and history (Novak 1983; Novak and Denton 1989). How to assess the stray coded-wire-tag recoveries in our study is a problematic issue at best. Future coded-wire-tagging studies of wild chum salmon would benefit from histological examination of tagged adults (Habicht et al. 1998), and perhaps of tagged fry as well (Morrison et al. 1990).

The Alaska Department of Fish and Game Fisheries Rehabilitation, Enhancement, and Development Division conducted coded-wire-tagging of Marx Creek chum salmon fry from 1986 to 1989 (Novak and Denton 1989). Recovery data from the Marx Creek study were initially intended to be incorporated into this report. However, there were many problems with the Marx Creek data, including: (1) very small releases of tags and few or no recoveries of tagged adult fish from some tag years, (2) lack of an adult escapement weir for enumeration and tag recovery, and (3) straying of fish between Marx Creek, Fish Creek, and the Salmon River. These problems led to dropping the Marx Creek tag data from this report. Not surprisingly, a few stray coded-wire-tagged Marx Creek chum salmon were also recovered at the Fish Creek weir in 1991 (2), 1992 (9), and 1993 (6). These tags were dropped from the data analysis because there were relatively few Marx Creek tags in the Fish Creek escapement, and there was no simple method of determining a marking fraction for Marx Creek tags from which numbers of fish could be calculated and subtracted from the Fish Creek escapement. For the purposes of simplification, we considered all fish that entered Fish Creek to be of Fish Creek origin.

Despite tagging a very large number of fry, we recovered a relatively small number of tagged adults (Table 2). There are several possible reasons for this including low survival rate, low initial rates of tagging, and high rates of tag loss. The marine survival rate of coded-wire-tagged Fish Creek chum salmon ranged from 0.08% to 0.96% (Table 5). Chum salmon fry that were tagged and released in May survived at an extremely low rate compared to fry tagged and released in March and April (Figure 10).

Eight of the tag codes used during May (representing 130,459 tagged fry) were subsequently *never* recovered as adults. Salo (1991) reported overall marine survival rates of 1.4% to 2.4% (mean 1.9%) for chum salmon in a Washington stream from 1938 to 1954. Salo (1991) also cited five other sources reporting marine fry-to-adult survival rates ranging from 0.3% to 3.2%; though some of those studies did not account for fishery mortality (i.e. biased low).

How the marine survival rates of coded-wire-tagged fry compare to the survival rates experienced by untagged fry is not known. The rate of tagging and handling induced mortality was very low at the time tagged fry were released (≤ 0.4%), but it is possible that our survival rate estimates are biased low because of an unmeasured degree of *post*-release tagging and handling induced mortality. We were unable to enumerate the entire fry population because of trap location. Had we done so, a more accurate estimate of the survival rate might have been calculated by comparing the brood-year fry population to the total adult return. Fry were initially tagged at a very low rate (Table 1). Our best year was a maximum rate of 4.5% in 1990. If the true fry population had been twice as large, our rate of tagging would only be 2.3% in 1990 (and much lower for the other three years of tagging). That, combined with low survival rate, is probably the principal reason for our small recoveries of tagged adults. This is something of a quandary because it would clearly be difficult, and probably not desirable, to tag at a higher rate.

Coded-wire-tagged chum salmon experienced a high degree of tag loss in our study. The rate of fish missing adipose fins and lacking tags in the entire Fish Creek escapement ranged from 0.09% (1992) to 0.57% (1995). Peltz and Miller (1990) reported the rate of missing adipose fins in untagged adult Prince William Sound pink salmon to be 0.042% in 1985. Similarly, we also found that 0.05% of the 1992 adult sockeye salmon run to Hugh Smith Lake were naturally missing adipose fins (12 fish in 23,929 examined; ADF&G unpublished data). While we have no data on the rate of naturally missing adipose fins for Fish Creek chum salmon, the rates were much higher than can be assumed for untagged populations. Therefore, we estimated that tag loss, by year of tagging, ranged from 15% to 36% (we did not attempt to adjust for naturally missing adipose fins). The loss of tags did not bias our estimates because we compared tags in the escapement to tags in the harvest (i.e. our estimates were not based on the tagging fraction at time of release), but tag loss certainly reduced the quantity of our data and the precision of our estimates (Table 2).

Tag loss was most likely the result of tagging very small fish (0.34 to 0.42 g). Experiments by Blankenship (1990) showed that tag loss in coho and chinook salmon did not stabilize until up to 17 days after tagging (with half-length tags), and that tag loss increased with a decrease in the size of the fish. Opdycke and Zajac (1981) reported a tag loss of 34% for 0.8 g chum salmon fry tagged with half-length tags by an inexperienced crew; however, they reported only a 2% tag loss up to six weeks after tagging with a more experienced crew. Both Peltz and Miller (1990) and Sharr et al. (1995) reported tag loss problems similar to ours with tagged Prince William Sound hatchery pink salmon. Peltz and Miller (1990) reported that 0.2 g pink salmon, tagged at three hatcheries in Prince William Sound in 1986 were released with a 24 hour tag retention exceeding 95%; but, as in our study, they later estimated tag loss in returning adults to be 13.7% to 51.4%.

Our tagging crews were experienced, and we made many inseason adjustments in an attempt to reduce tag loss; e.g., we experimented with custom made head molds and gave close attention to the condition of the tagging equipment. We only held tagged fry less than 24 hours prior to release, at which time tag loss appeared to be acceptable. Although better quality control during tagging, including a longer-term tag retention study, might have improved the number of tag recoveries in our study, it may be that a tag retention of even 90% would be very difficult to achieve when tagging such large quantities of very small fish.

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TABLES

Table 1. Area under the curve (AUC) fry population estimate and total number of fry coded-wire-tagged at Fish Creek, 1988-1991.

Brood Year	Tag Year	Dates	AUC Population Estimate[a]	Tagged Fry Released	Maximum Tagging Rate	Adult Return Years
1987	1988	11 Mar-17 May	4,515,595	152,791	3.4%	1990-1993
1988	1989	01 Mar-23 May	11,037,404	245,724	2.2%	1991-1994
1989	1990	18 Feb-27 May	7,068,239	317,833	4.5%	1992-1995
1990	1991	16 Feb-15 May	6,431,703	248,932	3.9%	1993-1996
Total				965,280		

[a] The AUC estimate is a minimum population estimate because of fyke net location.

Table 2. Expanded coded-wire-tag recoveries, estimated commercial harvest, Fish Creek escapement, other escapement (strays to Marx Creek and the Salmon River), and total run of Fish Creek chum salmon, all age classes combined, 1991-1995.

Year		Commercial Harvest	Escapement			Total Run
			Fish Creek	Other	Total	
1991	Expanded Tags	76	33	---	33	109
	Number of Fish	23,026	9,996		9,996	33,022
	SE	4,867				4,867
	95% CI	± 9,539				± 9,539
	Adjusted[a]	23,026	9,996	2,641[a]	12,637[a]	35,663[a]
1992	Expanded Tags	211	283	60	343	554
	Number of Fish	34,996	46,971	9,944	56,915	91,911
	SE	4,237		2,137	2,137	5,044
	95% CI	± 8,305		± 4,188	± 4,188	± 9,885
1993	Expanded Tags	1,176	579	179	758	1,934
	Number of Fish	122,819	60,447	18,722	79,169	201,989
	SE	7,476		1,541	1,541	7,965
	95% CI	± 14,652		± 3,020	± 3,020	± 15,611
1994	Expanded Tags	505	357	107	464	970
	Number of Fish	45,760	32,322	9,727	42,049	87,809
	SE	5,055		1,307	1,307	5,299
	95% CI	± 9,908		± 2,561	± 2,561	± 10,386
1995	Expanded Tags	151	58	14	72	222
	Number of Fish	25,437	9,742	2,324	12,066	37,503
	SE	3,791		1,516	1,516	4,095
	95% CI	± 7,430		± 2,971	± 2,971	± 8,027

[a] No foot surveys were conducted at Marx Creek or the Salmon River in 1991. The stray escapement in 1991 was estimated using the average proportion (0.209) of the estimated stray escapement from 1992 to 1995.

Table 3. Estimated exploitation rate of coded-wire-tagged Fish Creek chum salmon, by age class, and all age classes combined, 1991-1995.

Year		Age Class 0.2	0.3	0.4	0.5	All Ages Combined
1991	Exploitation Rate	80.2%	63.3%			69.7%
	SE	5.7%	6.0%			4.5%
	95% CI	± 11.2%	± 11.7%			± 8.7%
	Adjusted[a]	76.2%	57.7%			64.6%
1992	Exploitation Rate	46.6%	38.3%	---		38.1%
	SE	7.6%	3.2%	---		2.8%
	95% CI	± 14.8%	± 6.2%	---		± 5.6%
1993	Exploitation Rate	78.0%	60.2%	63.4%	---	60.8%
	SE	8.0%	1.5%	4.2%	---	1.4%
	95% CI	± 15.7%	± 3.0%	± 8.2%	---	± 2.8%
1994	Exploitation Rate		50.1%	54.0%	22.1%	52.1%
	SE		3.8%	4.0%	7.7%	2.8%
	95% CI		± 7.5%	± 7.9%	± 15.1%	± 5.5%
1995	Exploitation Rate			67.4%	72.8%	67.8%
	SE			4.6%	8.9%	4.2%
	95% CI			± 8.9%	± 17.3%	± 8.3%

[a] The 1991 exploitation rates were adjusted to account for unsampled stray escapement.

Table 4. Estimated distribution of the Fish Creek chum salmon catch in the commercial fisheries of Southeast Alaska and northern British Columbia, all age classes combined, 1991-1995.

	Proportion Harvested by Area and Gear					Five-Year Mean
	1991	1992	1993	1994	1995	
AK Dist. 101 Gillnet	40.9%	50.7%	22.9%	28.9%	30.4%	34.8%
AK Dist. 101 MIC Gillnet	---	---	---	0.9%	---	0.2%
AK Dist. 101 Seine	---	1.9%	1.7%	---	3.8%	1.5%
AK Dist. 102 Seine	---	1.5%	0.2%	---	---	0.3%
AK Dist. 103 Seine	---	---	1.1%	---	---	0.2%
AK Dist. 104 Seine	37.0%	18.8%	11.4%	10.9%	2.4%	16.1%
AK Dist. 105 Seine	---	---	0.5%	---	---	0.1%
AK Dist. 106 Gillnet	---	---	---	0.7%	1.5%	0.4%
AK Troll	---	---	0.4%	0.5%	---	0.2%
Total Alaska Harvest	77.9%	72.9%	38.1%	41.8%	38.2%	53.8%
BC Area 2 Seine	---	2.9%	---	---	---	0.6%
BC Area 3 Gillnet	---	6.1%	16.0%	35.0%	15.7%	14.6%
BC Area 3 Seine	22.1%	7.3%	35.6%	9.9%	36.3%	22.2%
BC Area 4 Gillnet	---	10.1%	7.8%	12.6%	9.9%	8.1%
BC Area 4 Seine	---	---	1.1%	---	---	0.2%
BC Area 5 Gillnet	---	---	0.2%	---	---	0.0%
BC Area 5 Seine	---	0.7%	---	0.4%	---	0.2%
BC Troll	---	---	1.1%	0.3%	---	0.3%
Total BC Harvest	22.1%	27.1%	61.9%	58.2%	61.8%	46.2%

Table 5. Survival and maturation rates of coded-wire-tagged Fish Creek chum salmon.

Brood Year	Tag Year	Survival Rate	SE	Maturation Rate 0.2	0.3	0.4	0.5
1987	1988	0.07%	0.01%	[a]	78%	22%	0%
	Adjusted[b]	0.08%			80%	20%	0%
1988	1989	0.34%	0.02%	6%	65%	28%	1%
	Adjusted[b]	0.34%		6%	65%	28%	1%
1989	1990	0.96%	0.03%	3%	73%	23%	1%
1990	1991	0.41%	0.03%	5%	65%	30%	[a]

[a] No weir was in operation in 1990 or 1996 – Foot surveys failed to find any tagged age 0.2 fish in 1990, or tagged age 0.5 fish in 1996, nor were any of those tags recovered in the fisheries.
[b] The survival and maturation rates for age 0.2 and 0.3 fish returning in 1991 were adjusted to account for unsampled stray escapement.

Table 6. Age distribution of the Fish Creek chum salmon escapement, weighted by week of escapement, 1991-1995.

Run Year		Sample Size	Brood Year 1992	1991	1990	1989	1988	1987	1986	1985	Total
1991	Age Class						0.2	0.3	0.4	0.5	
	Number	973					2,792	4,763	2,288	153	9,996
	Proportion						27.8%	48.0%	22.7%	1.6%	100.0%
	SE						1.3%	1.6%	1.2%	0.4%	
1992	Age Class					0.2	0.3	0.4	0.5		
	Number	2,785				2,426	41,858	2,651	36		46,971
	Proportion					5.1%	89.2%	5.6%	0.1%		100.0%
	SE					0.5%	0.7%	0.5%	0.1%		
1993	Age Class				0.2	0.3	0.4	0.5			
	Number	1,671			859	50,012	9,300	286			60,447
	Proportion				1.4%	83.0%	15.2%	0.5%			100.0%
	SE				0.3%	1.0%	0.9%	0.2%			
1994	Age Class			0.2	0.3	0.4	0.5				
	Number	1,233		82	15,985	15,850	405				32,322
	Proportion			0.3%	49.1%	49.4%	1.3%				100.0%
	SE			0.1%	1.6%	1.6%	0.4%				
1995	Age Class		0.2	0.3	0.4	0.5					
	Number	1,007	995	653	7,462	632					9,742
	Proportion		10.2%	6.7%	76.6%	6.5%					100.0%
	SE		1.1%	1.2%	1.9%	1.3%					

Table 7. Age distribution of the estimated total run of Fish Creek chum salmon based on coded-wire-tag recoveries, 1991-1995.

Run Year		Brood Year								Total Run
		1992	1991	1990	1989	1988	1987	1986	1985	
1991	Age Class					0.2	0.3	0.4	0.5	
	Number					14,008	13,062	**5,568**[a]	**384**	33,022
	SE					4,094	2,160			4,867
	Adjusted[b]					14,742[b]	14,329[b]	6,167[b]	425[b]	35,663[b]
	Proportion					41.3%	40.2%	17.3%	1.2%	100.0%
1992	Age Class				0.2	0.3	0.4	0.5		
	Number				4,928	83,480	3,261	**243**		91,911
	SE				866	5,166	607			5,044
	Proportion				5.4%	90.8%	3.5%	0.3%		
1993	Age Class			0.2	0.3	0.4	0.5			
	Number			3,765	167,823	29,158	286			201,989
	SE			1,517	7,319	3,927	121			7,965
	Proportion			1.9%	83.1%	14.4%	0.1%			
1994	Age Class		0.2	0.3	0.4	0.5				
	Number		**393**	39,322	47,539	555				87,809
	SE			3,359	4,528	159				5,299
	Proportion		0.4%	44.8%	54.1%	0.6%				
1995	Age Class	0.2	0.3	0.4	0.5					
	Number	**3,820**	**2,509**	28,847	2,326					37,503
	SE			3,410	856					4,095
	Proportion	10.2%	6.7%	76.9%	6.2%					

[a] Bold numbers are interpolated (see text).
[b] The 1991 run was adjusted to account for unsampled stray escapement.

Table 8. Mean mid-eye-to-tail-fork length of Fish Creek chum salmon by sex and age class, weighted by week of escapement, 1991-1995.

		Male				Female			
	Age Class	0.2	0.3	0.4	0.5	0.2	0.3	0.4	0.5
1991	Mean Length (mm)	560	621	707	715	543	592	668	679
	SE	3.6	3.8	4.5	15.8	2.8	2.9	5.0	8.1
	n	147	222	126	7	119	238	104	10
1992	Mean Length (mm)	574	637	676	705	567	606	650	
	SE	5.4	1.5	7.6	10.9	4.5	0.3	5.5	
	n	122	1,195	90	2	77	1,232	67	0
1993	Mean Length (mm)	599	649	704	690	568	622	664	750
	SE	13.7	1.6	4.4	35.8	7.2	1.4	4.2	
	n	8	675	181	7	16	659	124	1
1994	Mean Length	589	663	686	700	555	630	653	662
	SE	3.6	2.3	2.5	14.3	8.9	2.5	2.9	8.7
	n	7	324	362	10	3	266	254	7
1995	Mean Length	619	693	732	722	598	669	698	714
	SE	5.8	5.8	3.8	10.4	5.5	10.6	3.6	11.6
	n	233	42	314	28	115	31	226	18

Table 9. Number of stream-life tags released and recovered, and mean stream life (days) by week, of Fish Creek chum salmon, 1991, 1992, and 1995.

	1991				1992				1995			
Week	Stream Life	SE	No. Tags Recov.	No. Tags Released	Stream Life	SE	No. Tags Recov.	No. Tags Released	Stream Life	SE	No. Tags Recov.	No. Tags Released
2-Jul					18		1	6	12	0.7	8	99
9-Jul	17		1	81	15	1.5	21	230	11	0.4	36	354
16-Jul	9		1	113	13	0.7	37	345	10	0.3	53	262
23-Jul	12	1.7	11	298	11	0.3	159	633	9	0.2	52	300
30-Jul	11	1.2	13	298	12	0.5	68	489	9	0.2	58	297
6-Aug	10	0.9	26	300	11	0.5	60	314	7	0.4	34	298
13-Aug	8	0.6	25	200	10	0.4	65	338	6	0.6	10	184
20-Aug	7	0.7	28	300	9	0.3	79	337	7	0.7	13	106
27-Aug	9	1.1	25	299	9	0.4	65	345	5		1	150
3-Sep	8	1.0	15	300	9	0.5	54	350	6	1.0	2	78
10-Sep	7	0.8	8	299	10	0.6	39	250	12		1	274
17-Sep	7	0.8	6	300	10	1.2	37	299	11	1.7	4	46
24-Sep	4	0.9	5	300	11	0.4	39	298				
1-Oct					10	0.7	23	161				
8-Oct					7	1.3	4	77				
Mean	8.5	0.3	164	3,088	10.5	0.2	751	4,472	9.4	0.2	272	2,448
Median	8				10				9			

Table 10. Comparison of the escapement, estimated from an index count of foot surveys, to the annual weir count of chum salmon at Fish Creek, 1991-1995.

Year	1991	1992	1993	1994	1995
Period 1 (23 Jul-5 Aug)	2,075[a]	6,375[a]	11,388	4,686	3,667
Period 2 (6 Aug-22 Aug)	1,817	5,941	14,620	4,500	1,300
Period 3 (23 Aug-8 Sep)	946	8,731	4,820	3,590	305
Index Count (Total)	4,838	21,047	30,828	12,776	5,272
Weir Count	9,996	46,971	60,447	32,319	9,742
Foot to Weir Conversion[b]	2.066143	2.231719	1.960782	2.529665	1.847876
Estimated Escapement[c]	10,230	44,502	65,184	27,014	11,147
Difference from Weir	234	-2,469	4,737	-5,305	1,405
% Difference from Weir	2%	-5%	8%	-16%	14%

[a] The cumulative weir count through 5 August was substituted for missing foot surveys for Survey Period 1 in 1991 and 1992.
[b] The geometric mean of the foot-to-weir conversion factors = 2.114429.
[c] The estimated escapement = Index Count*2.114429.

Table 11. Reconstruction of total returns, and survival rate adjusted total returns, of Fish Creek chum salmon from the 1986-1991 brood years.

Brood Year	Brood Year Escapement[a]	Adult Return by Age Class[b]				Total Return	Survival Rate	Survival Adjusted Return[c]
		0.2	0.3	0.4	0.5			
1986	30,277			**6,167**	**243**	6,410		
1987	60,795	**1,056**	14,329	3,261	286	18,932	0.0008	76,124
1988	65,548	14,742	83,480	29,158	555	127,935	0.0034	121,036
1989	35,903	4,928	167,823	47,539	2,326	222,617	0.0096	74,592
1990	15,494	3,765	39,322	28,847	**627**	72,561	0.0041	56,928
1991	9,996	**393**	**2,509**			2,902		

[a] The 1986-1990 escapements are estimated from an index count of foot surveys.
[b] Bold age class returns are interpolated (see text).
[c] The total returns were adjusted by dividing by the brood-year survival rate, and multiplying by the geometric mean of the 1987-1990 brood-year survival rates (0.0032).

FIGURES

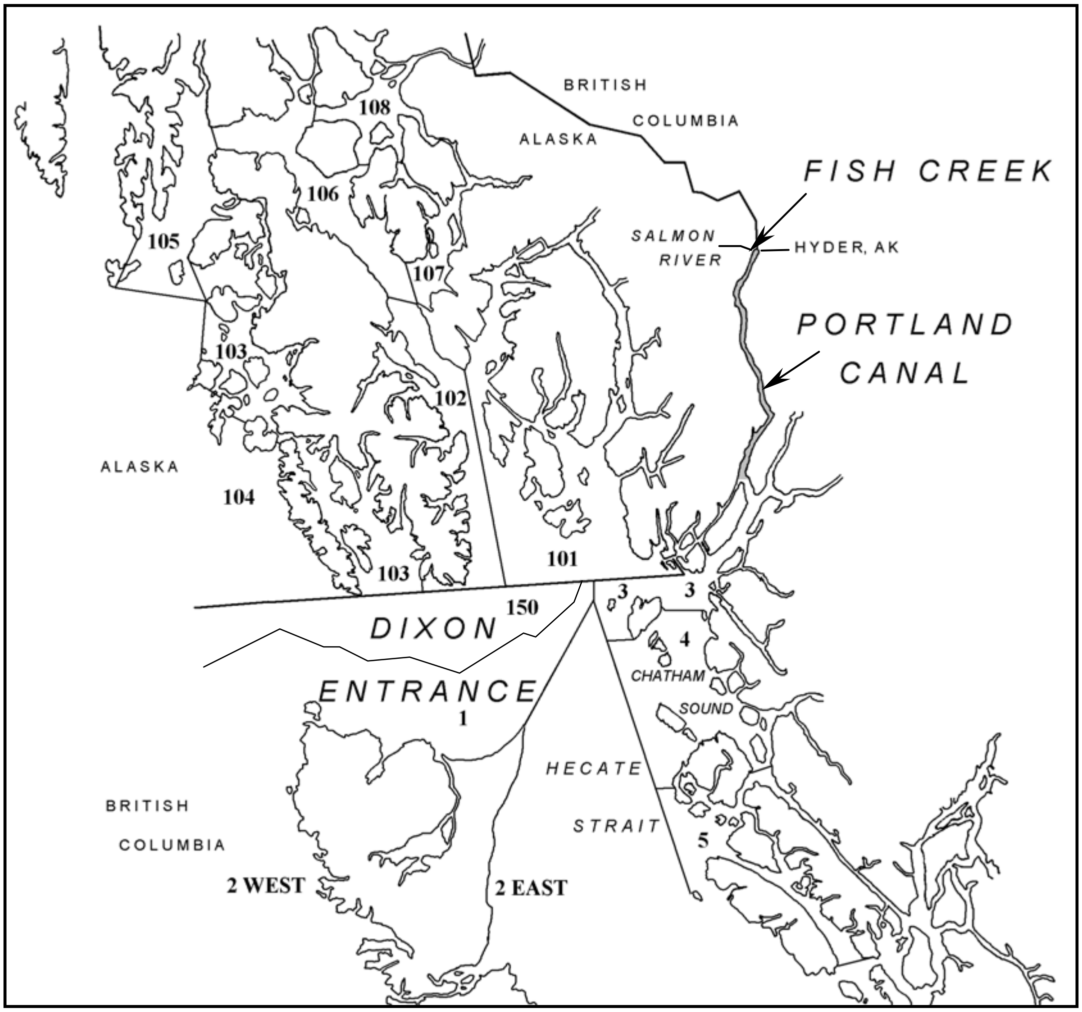

Figure 1. Map of southern Southeast Alaska and northern British Columbia, showing the ADF&G commercial salmon Regulatory Districts 101 to 108 and 150, and the Canadian Department of Fisheries Statistical Areas 1 to 5.

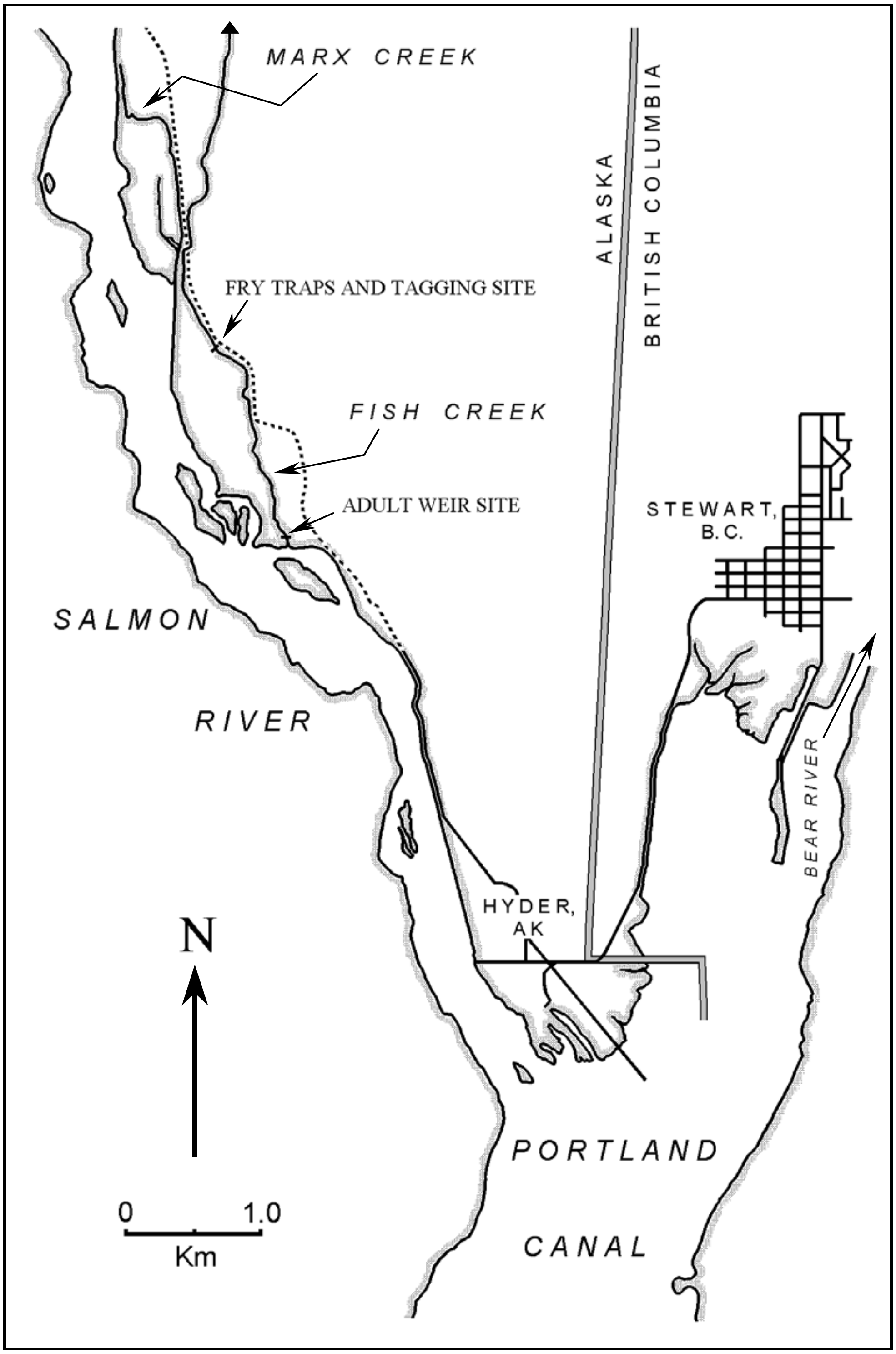

Figure 2. Upper Portland Canal area, showing the locations of Fish and Marx Creeks, the fry tagging site and the adult recovery weir.

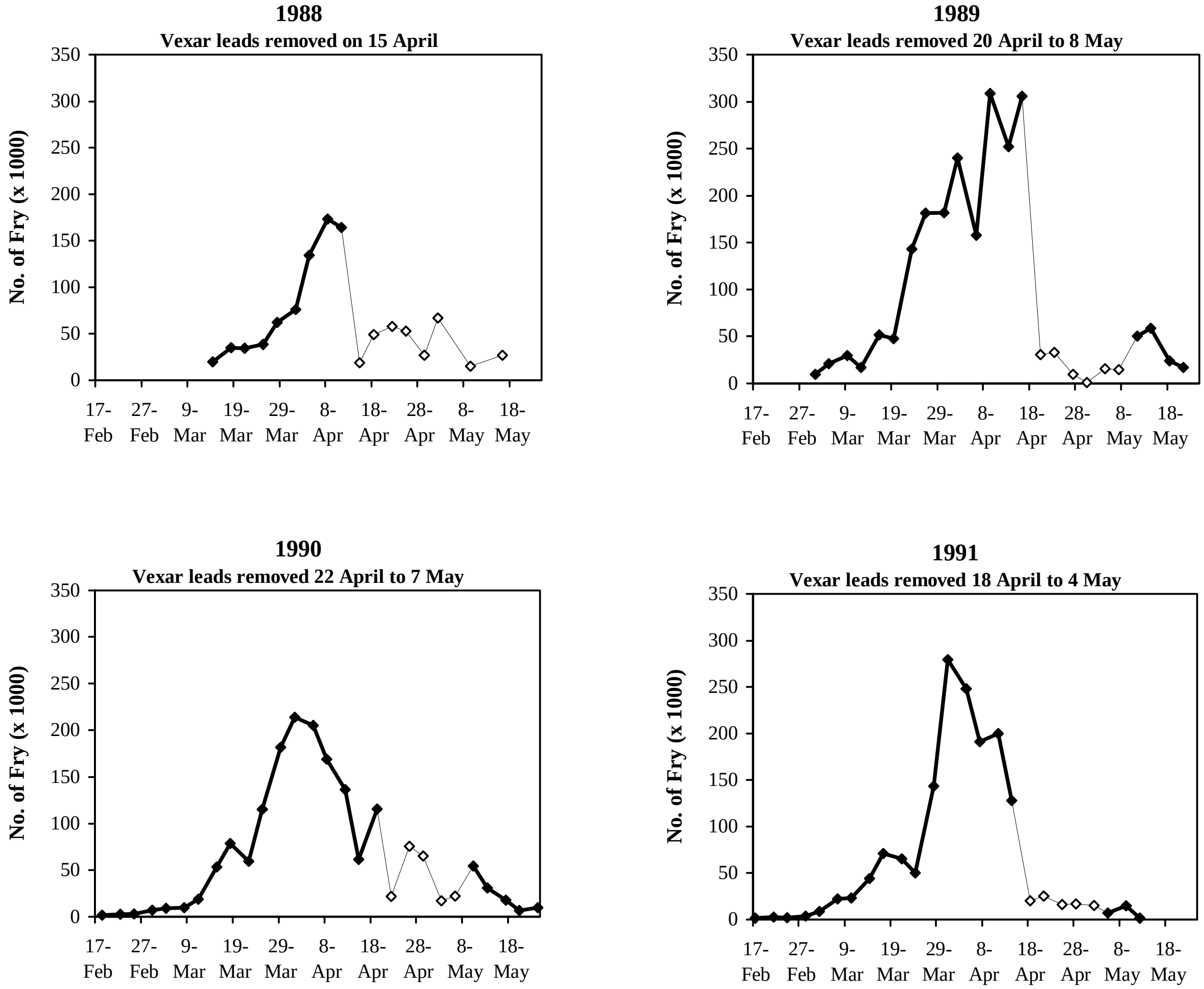

Figure 3. Migrant chum salmon fry enumerated on biweekly 12-hour count nights at Fish Creek, 1988-1991. The vexar leads to the fyke nets had to be removed each season in mid-April (represented by fine line and open markers) because of high water flows.

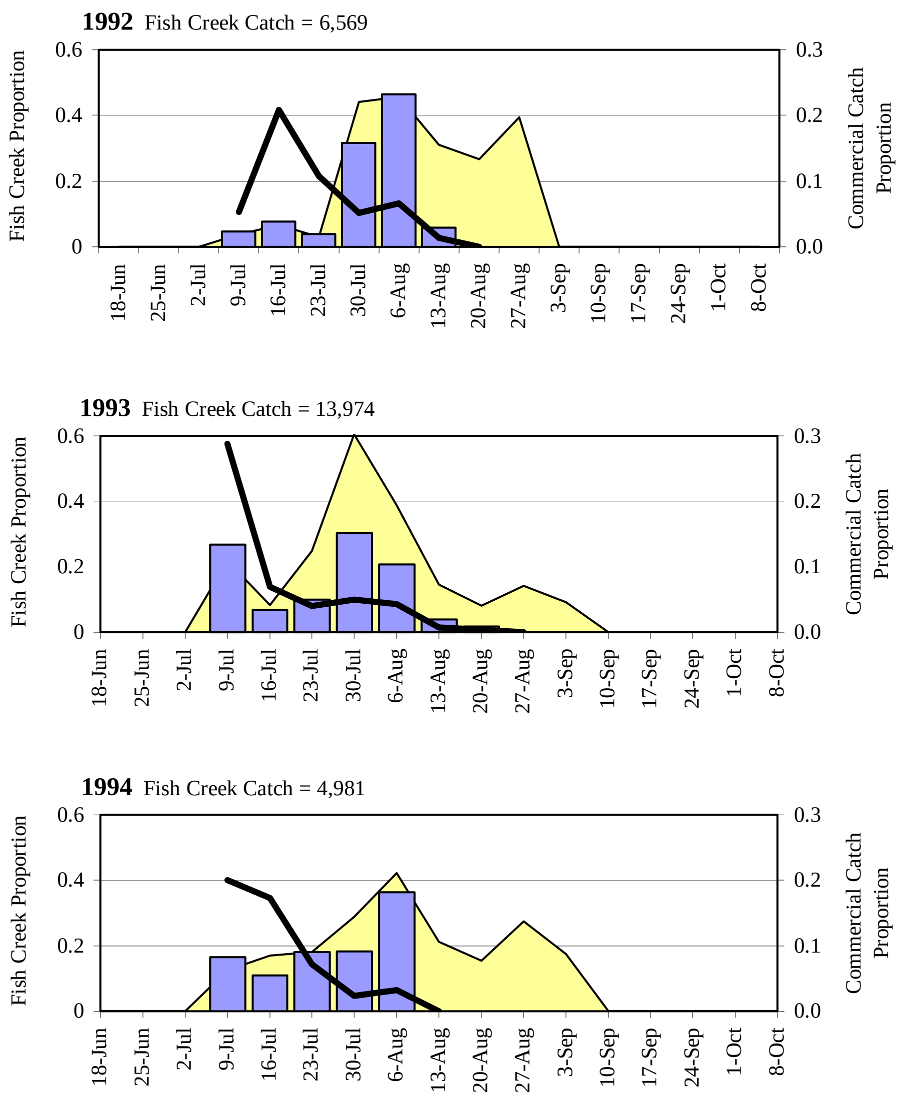

Figure 4. The weekly proportions of the total coded-wire-tag recoveries (columns), and catch per unit effort (black lines), of Fish Creek chum salmon in the Alaska District 104 purse seine fishery, 1992-1994. The weekly catch proportions of the total District 104 purse seine chum salmon harvest (shaded areas, right axis) are also shown for comparison.

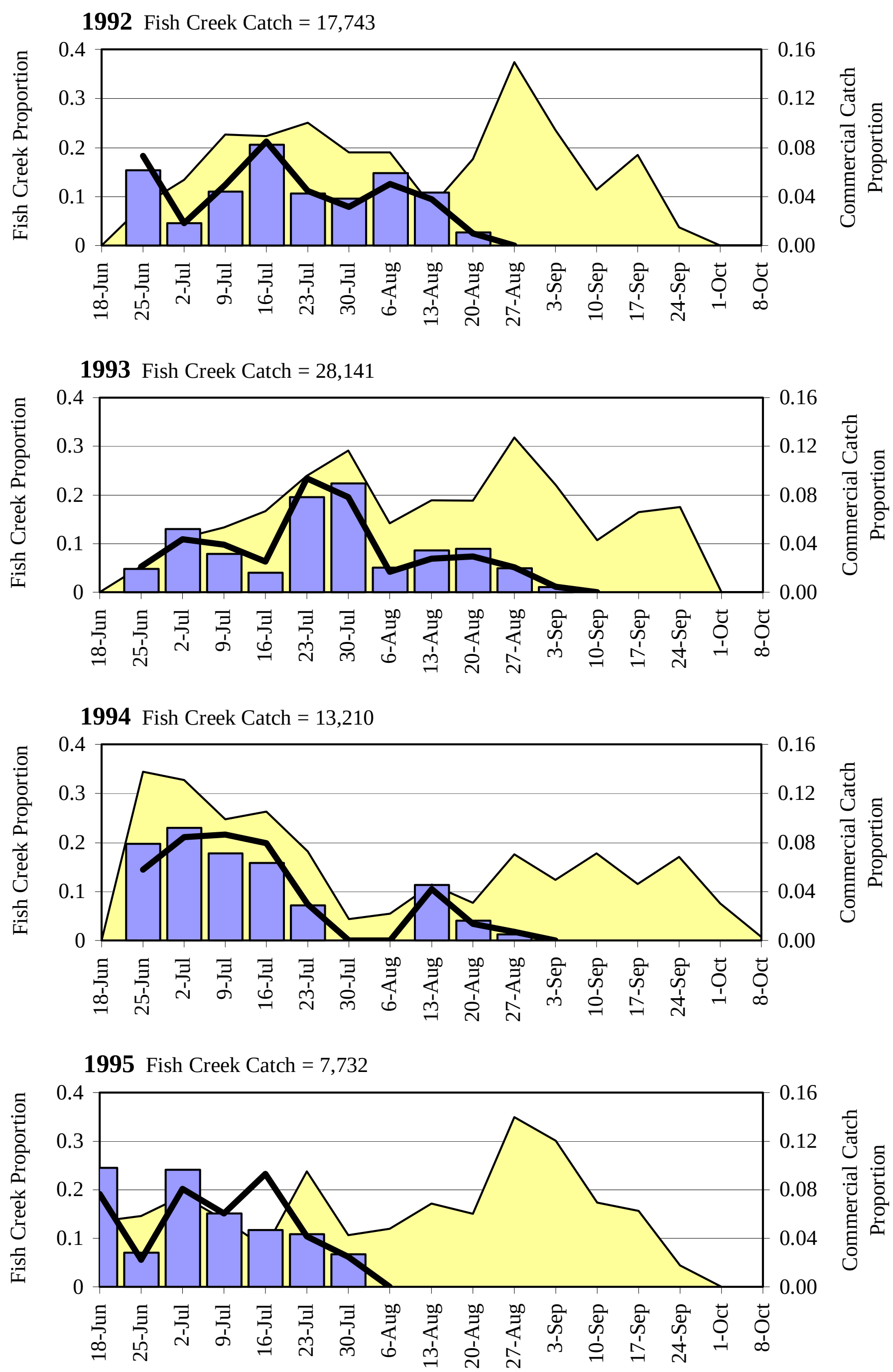

Figure 5. The weekly proportions of the total coded-wire-tag recoveries (columns), and catch per unit effort (solid lines), of Fish Creek chum salmon in the Alaska District 101 drift gillnet fishery, 1992-1995. The weekly catch proportions of the total District 101 drift gillnet chum salmon harvest (shaded areas, right axis) are also shown for comparison.

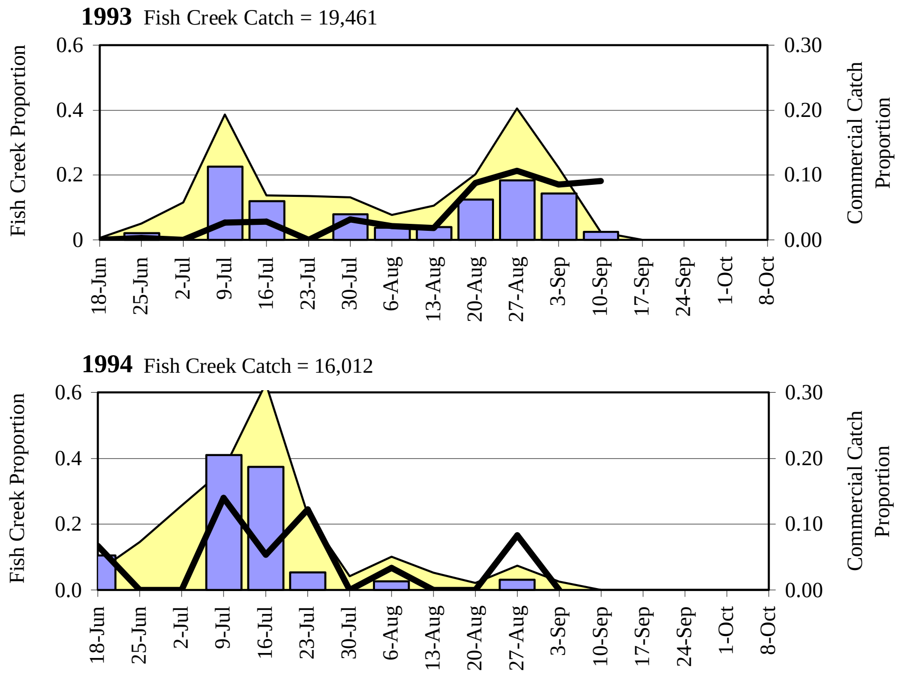

Figure 6. The weekly proportions of the total coded-wire-tag recoveries (columns), and catch per unit effort (solid lines), of Fish Creek chum salmon in the British Columbia Area 3 gillnet fishery, 1993-1994. The weekly catch proportions of the total Area 3 gillnet chum salmon harvest (shaded areas, right axis) are also shown for comparison.

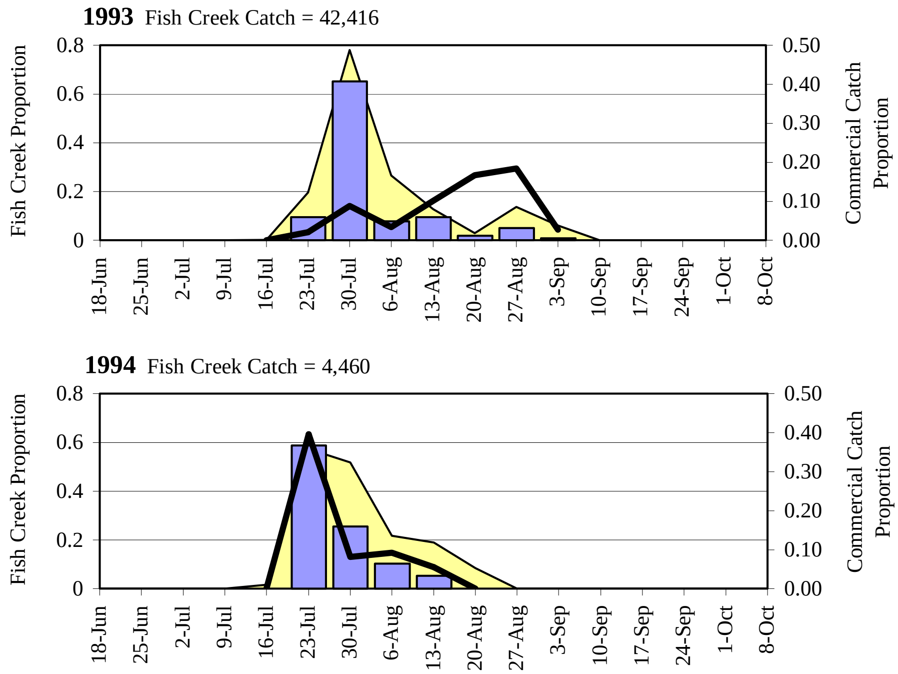

Figure 7. The weekly proportions of the total coded-wire-tag recoveries (columns), and catch per unit effort (solid lines), of Fish Creek chum salmon in the British Columbia Area 3 seine fishery, 1993-1994. The weekly catch proportions of the total Area 3 seine chum salmon harvest (shaded areas, right axis) are also shown for comparison.

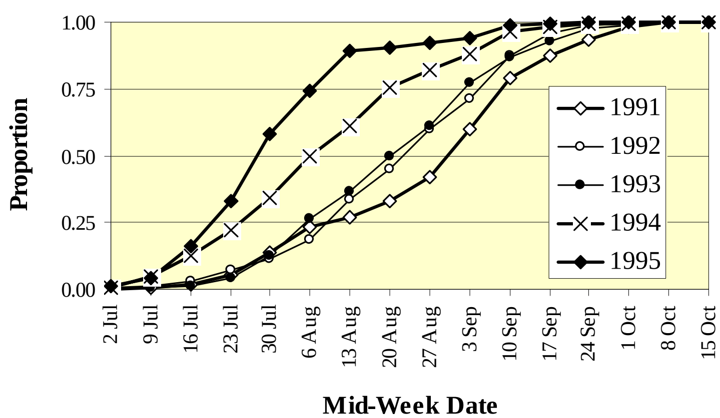

Figure 8. Cumulative weekly proportions of the Fish Creek chum salmon escapement, illustrating overall run timing, 1991-1995.

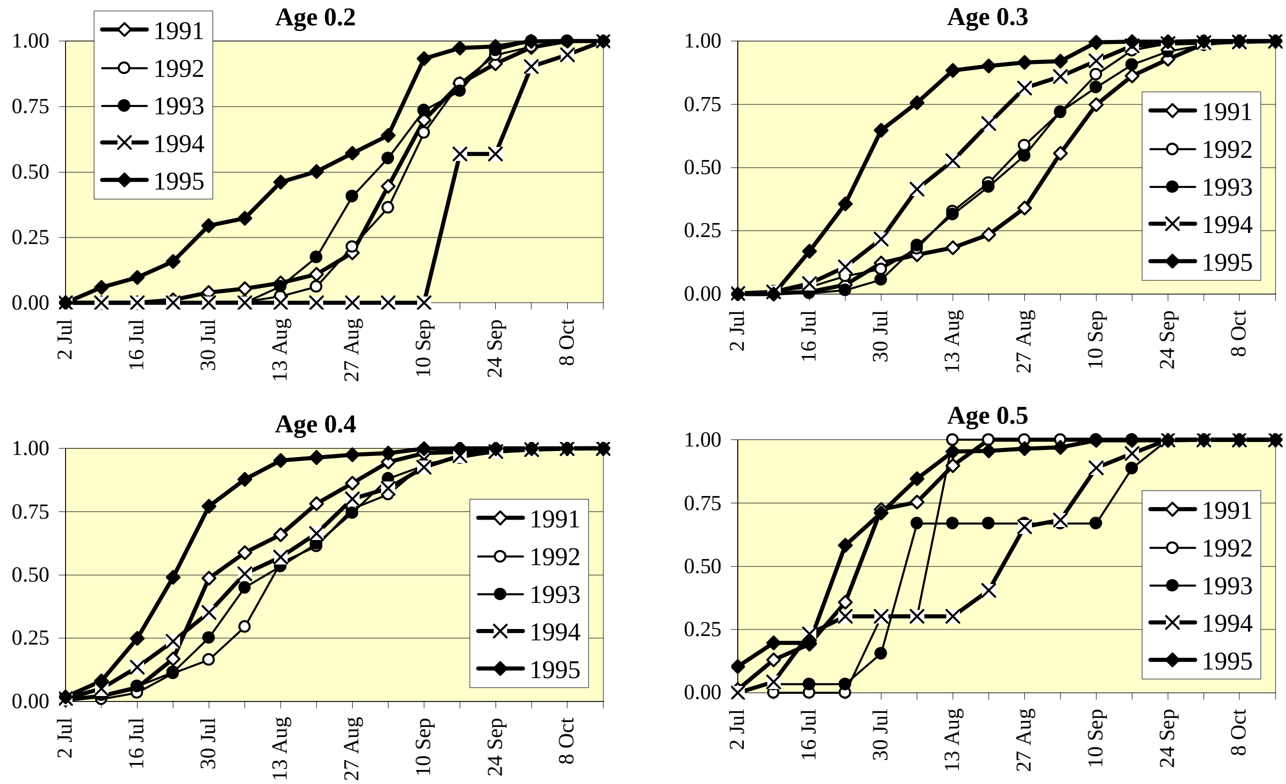

Figure 9. Cumulative weighted weekly proportions of the total Fish Creek chum salmon escapement by age class, illustrating overall run timing, 1991-1995.

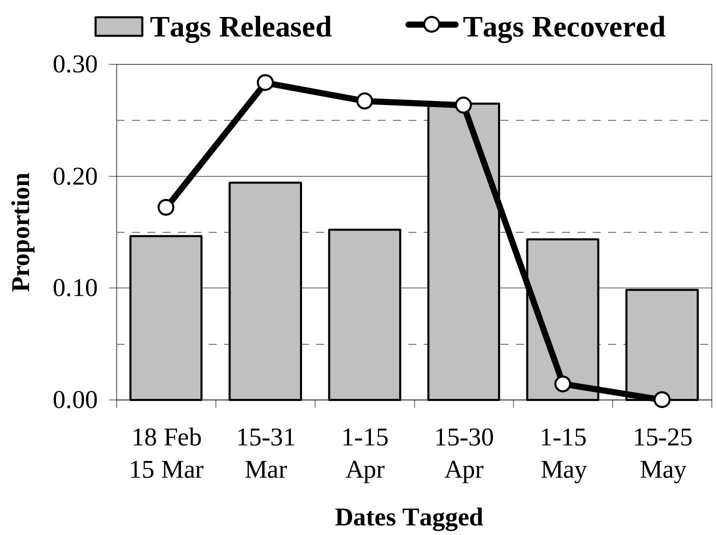

Figure 10. Mean proportions of coded-wire-tagged chum salmon fry released (1988-1991), and subsequent mean proportions recovered (1991-1995), by approximate date of release.

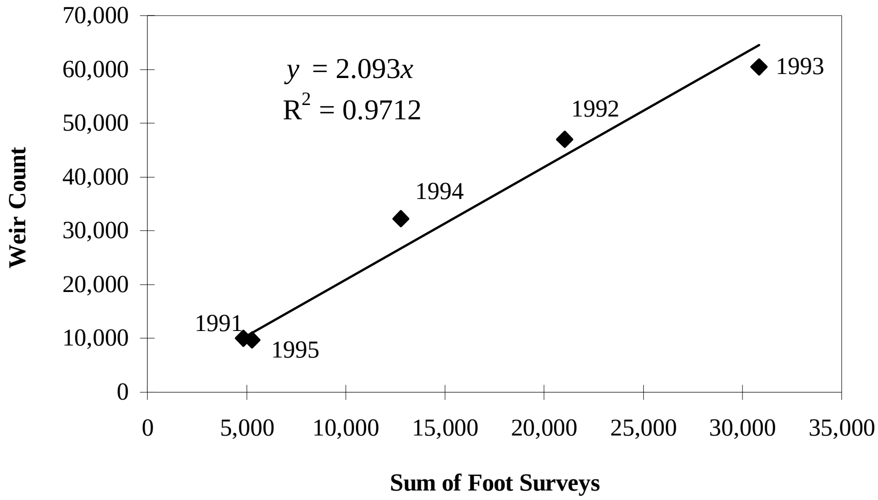

Figure 11. Comparison of the sum of three annual foot surveys (index count) to the annual weir count of chum salmon at Fish Creek, 1991-1995.

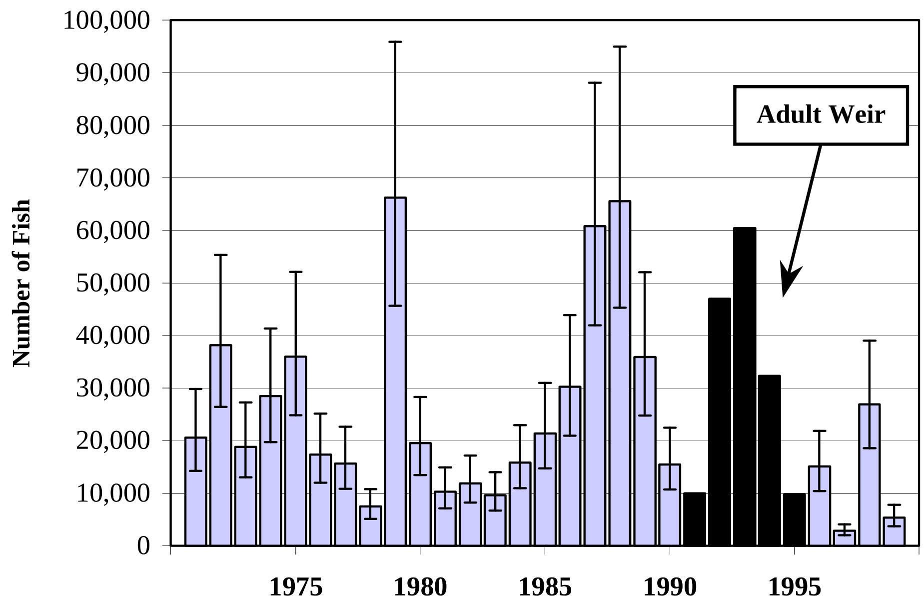

Figure 12. Estimated escapement (± 95% prediction interval) of chum salmon to Fish Creek, 1971-1999 (the 1991-1995 data points represent weir counts).

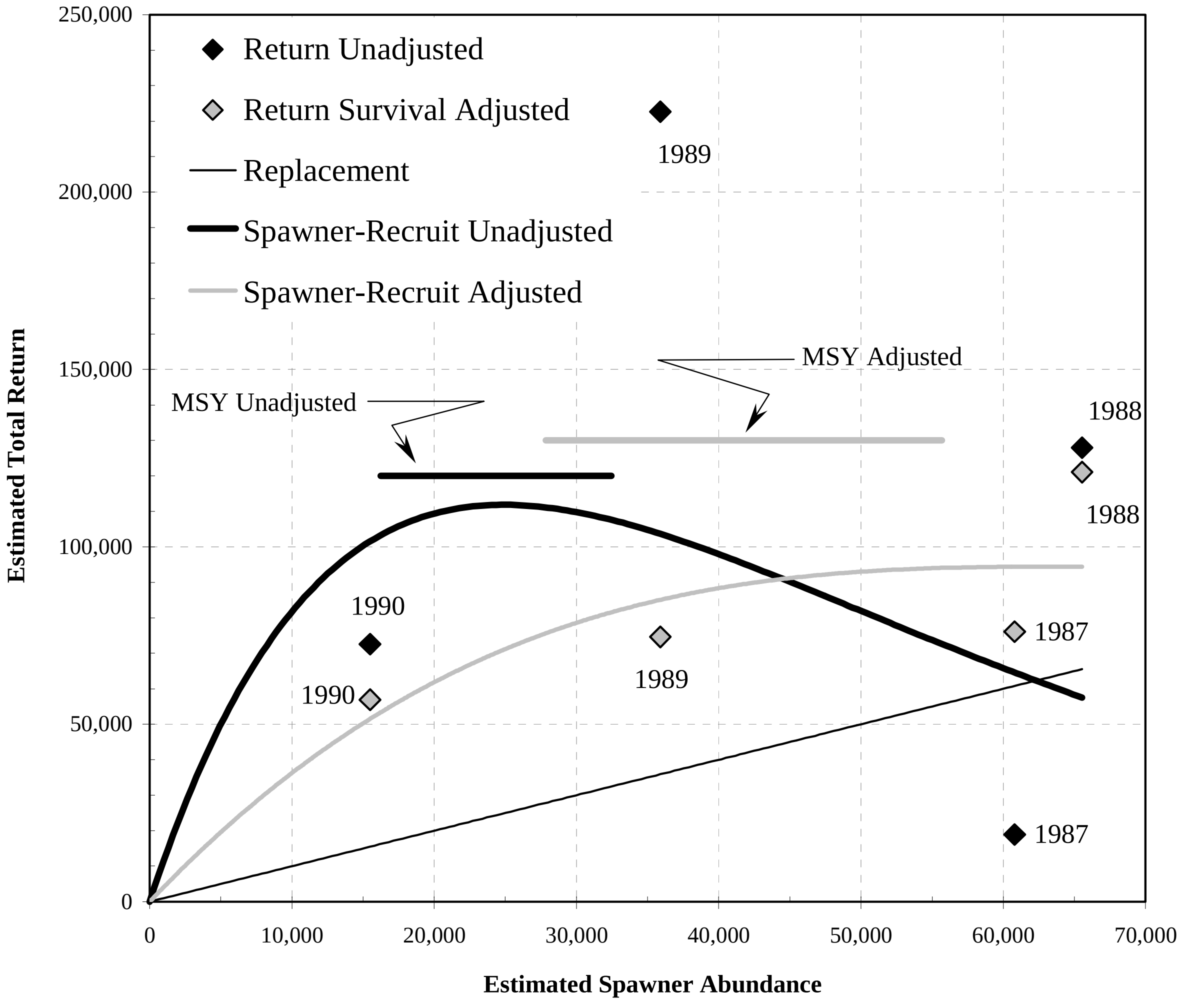

Figure 13. Spawner-recruit relationship for Fish Creek chum salmon using unadjusted total returns from the 1987-1990 brood years, and total returns adjusted to geometric mean marine survival conditions.

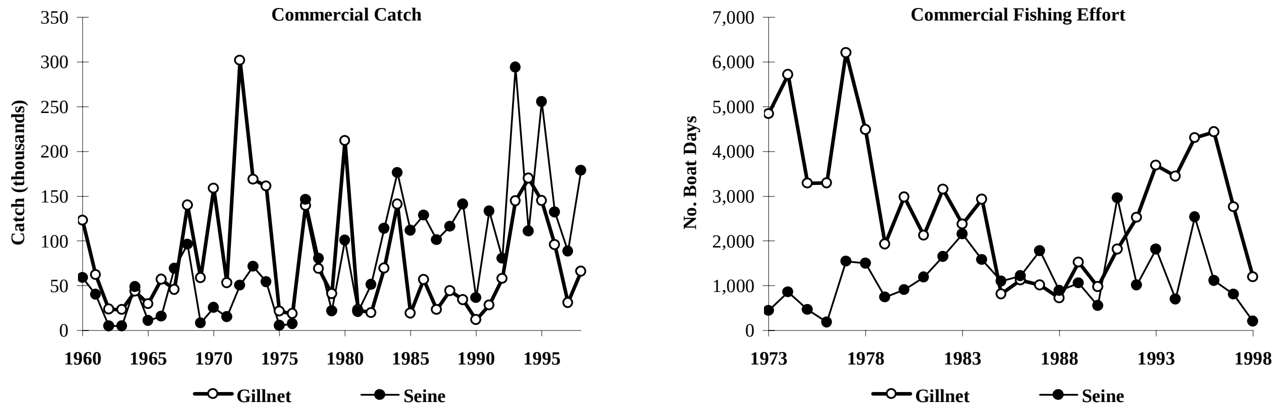

Figure 14. British Columbia Area 3 commercial chum salmon catch (1960-1998), and commercial fishing effort (1973-1998).

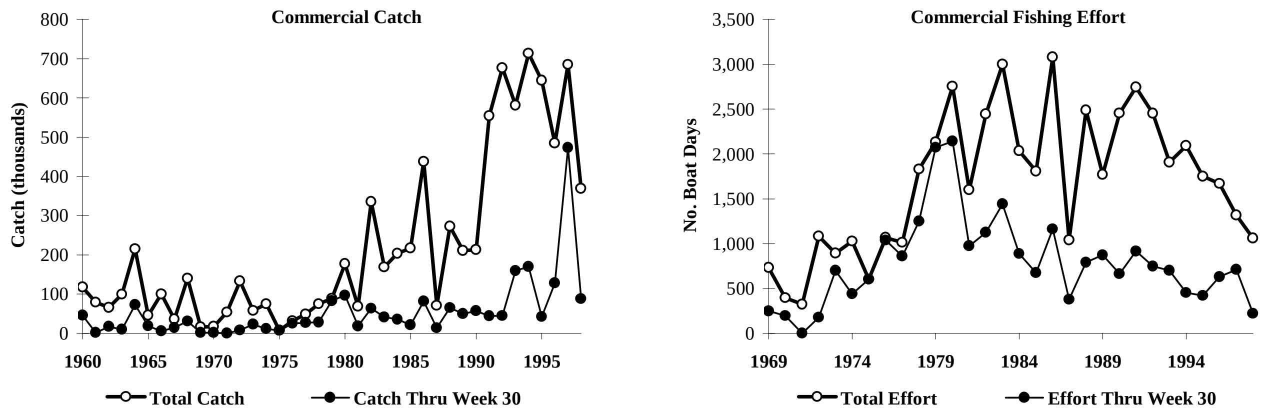

Figure 15. Alaska District 104 purse seine commercial chum salmon catch (1960-1998) and commercial fishing effort (1969-1998).

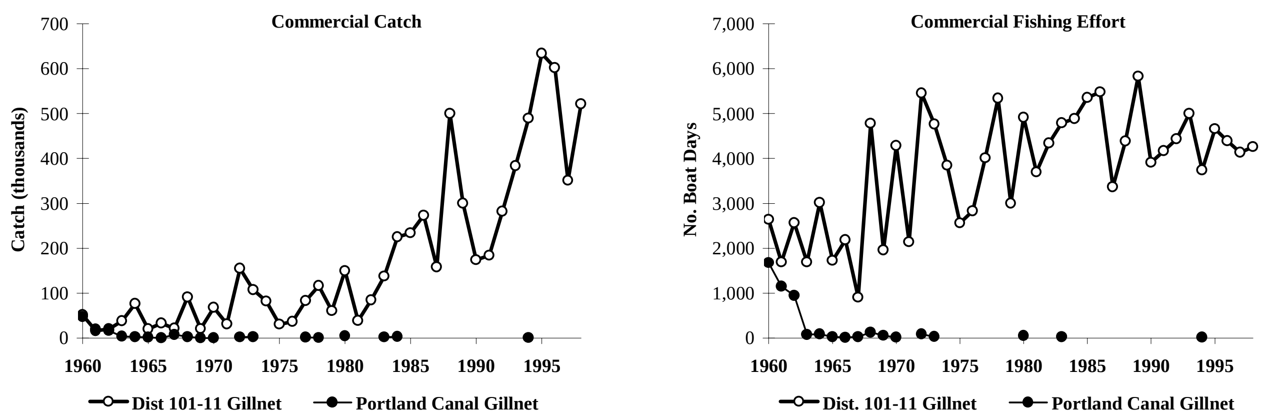

Figure 16. Alaska District 101 drift gillnet commercial chum salmon catch and commercial fishing effort (1960-1998).

APPENDICES

Appendix 1. The standardized average mid-week date corresponding to ADF&G statistical weeks 24 to 41.

Statistical Week	Average Mid-Week Date	Statistical Week	Average Mid-Week Date
24	11 June	33	13 August
25	18 June	34	20 August
26	25 June	35	27 August
27	2 July	36	3 September
28	9 July	37	10 September
29	16 July	38	17 September
30	23 July	39	24 September
31	30 July	40	1 October
32	6 August	41	8 October

Appendix 2. Methods for calculating variances for Fish Creek coded-wire-tag statistics.

This appendix derives variance estimators for statistics derived from coded-wire-tag returns: exploitation rate, contribution (and total run), and survival rate. These estimators are based on standard sampling theory as discussed, for example, by Cochran (1977), Kish (1965), or Hansen, Hurwitz and Madow (1953).

Notation

^	indicates estimator when placed over a parameter
A_E	number of adipose-clipped fish in the escapement
A_{Tot}	number of adipose-clipped fish in the return
a_h	number of adipose-clipped fish in the sample from the *h*th stratum
α	number of sampled heads that reach the lab
α'	number of sampled heads
C_F	contribution to the catches of the set of fisheries *F*
C_{Tot}	size of total run
cov	estimated covariance
E	size of escapement
E_j	size of escapement for *j*th age class
F	a set of fisheries or catches
$\mathcal{F}$	the set of all fisheries or catches
f_h	sampling fraction of the *h*th stratum: n_h / N_h
f_h^*	adjusted sampling fraction of the *h*th stratum: n_h^* / N_h
H	the set of all strata in the population
h	index of strata
N_h	size of stratum *h* in the population
n_h'	initial sample size of the *h*th stratum
n_h^*	sample size of the *h*th stratum adjusted for loss of heads and tag information
p	used to denote various estimated proportions
R_F	exploitation rate for set of fisheries *F*
S	survival rate for a given release year
s_y^2	sample variance for variable *y*
s_{yx}	sample covariance of variables *x* and *y*
T_E	number of tagged fish in the escapement
T_F	number of tagged fish in the set of fisheries *F*
$T_{\mathcal{F}}$	number of tagged fish in all fisheries
T_{Rel}	number of tagged fish initially released
T_{Run}	total number of tagged fish in the run
t	number of decoded Fish Creek tags in the sample
t'	number of coded wire tags in the sample
v	estimated variance

General Approach

For exploitation rates and contributions, the population is the set of all catches and escapement(s) for a given return year. For survival rates, the population is the set of all catches and escapements in which fish from a given release year are found. The sampling is considered to be stratified random; i.e., an independent simple random sample is taken in each of the strata, and the sizes of the strata are assumed known. Stratification should be based on the sampling; i.e., a stratum is defined as that part of the population from which a fixed sample size was taken. For example, a stratum could consist of a specific gear, statistical area, opening combination. Strata may be collapsed, though this may lead to slight overestimation of the variance.

Because of head and tag loss, we need to adjust the initial sample size per stratum, n'_h, as follows:

$$n_h^* = \left(\frac{\alpha}{\alpha'}\right)\left(\frac{t}{t'}\right)n'_h \tag{1}$$

where α' is the number of heads sampled, α is the number of heads that reach the lab, t' is the number of tags detected and t is the number of tags successfully decoded. That is, we assume both head and tag information are randomly lost and we reduce the *entire* sample size accordingly (i.e., we assume we would have randomly lost the same proportion of unclipped fish). Although there are more complex models (e.g., double-sampling -- see Cochran 1977, ch. 12; or Thompson 1992, ch. 14) to deal with this problem, using this adjustment is generally quite adequate especially for the large sample sizes here (and it is conservative, meaning that, if anything, the variance will be overestimated).

We will begin with the exploitation rate which is the simplest case. The variance estimators of all the other statistics of interest are, although slightly more complicated, closely related to this case. We will make repeated use of two formulas throughout. The first, derived from Cochran (1977, eqns. 6.51 and 6.12) or Hansen, Hurwitz, and Madow (1953, vol 1, eqn. 4.5), is the estimated approximate variance of a “combined” ratio:

$$\mathrm{v}\left(\frac{\hat{Y}_{st}}{\hat{X}_{st}}\right) \cong \frac{1}{\hat{X}_{st}^2}\sum_{h=1}^{H}\frac{N_h^2(1-f_h)}{n_h}\left[s_{y_h}^2 + \left(\frac{\hat{Y}_{st}}{\hat{X}_{st}}\right)^2 s_{x_h}^2 - 2\left(\frac{\hat{Y}_{st}}{\hat{X}_{st}}\right)s_{y_h x_h}\right]. \tag{2}$$

The second, from Kish (1965, eqn. 6.6.17), is for the estimated variance of the product of two random variables:

$$\mathrm{v}(\hat{X}\hat{Y}) \cong \hat{X}^2\mathrm{v}(\hat{Y}) + \hat{Y}^2\mathrm{v}(\hat{X}) + 2\hat{X}\hat{Y}\mathrm{cov}(\hat{X}\hat{Y}). \tag{3}$$

If the two random variables are independent, Goodman (1960) demonstrates that the following is an unbiased estimate of the variance of their product:

$$\mathrm{v}(\hat{X}\hat{Y}) = \hat{X}^2\mathrm{v}(\hat{Y}) + \hat{Y}^2\mathrm{v}(\hat{X}) - 2\mathrm{v}(\hat{X})\mathrm{v}(\hat{Y}) . \tag{4}$$

Exploitation Rate

The exploitation rate of a set of fisheries *F*, is estimated by the estimated number of tags caught by *F* divided by the estimated number of tags in all catches and escapements:

$$\hat{R}_F = \frac{\hat{T}_F}{\hat{T}_{Run}} = \frac{\sum_{h=1}^{F}\left(\frac{N_h}{n_h^*}\right)t_h}{\sum_{h=1}^{H}\left(\frac{N_h}{n_h^*}\right)t_h} \tag{5}$$

The exploitation rate may be estimated for a specific age class (or any subpopulation) by including only those tags belonging to the age-class (or subpopulation) in question.

The variance of $\hat{R}_F$ may be estimated by using equation 5A.75 in Cochran (1977, p. 144), which describes the estimated variance of the mean of a subpopulation. In this case, the subpopulation is the set of all fish having Fish Creek tags (possibly restricted to age class *j*). Define an indicator variable I_h which equals 1 if the stratum (*h*) is a member of the set *F* (denoted as $h\in F$), and 0 otherwise (denoted as $h\notin F$). Using the notation from Cochran (1977), the variable of interest is $y_{hij} = I_h$ for each fish in the subpopulation. Then, $t_h = n_{hj} = \sum_{i=1}^{n_h^*} y_{hij}$, $\hat{T}_F = \hat{Y}_j$, $\hat{T}_{Run} = \hat{N}_j$, and $\hat{R}_F = \hat{\bar{Y}}$.

Given the definition of the variable yhij, Cochran's equation 5A.75 simplifies to the following:

$$\mathrm{v}(\hat{R}_F) \cong \frac{1}{\hat{T}_{Run}^2}\sum_{h=1}^{H}\frac{N_h^2}{n_h^*(n_h^*-1)}\left(1-f_h^*\right)t_h\left(1-\frac{t_h}{n_h^*}\right)\left(I_h-\hat{R}_F\right)^2 . \tag{6}$$

We can also derive equation (6) directly from equation (2). Let the variable y_{hi} equal 1 if the fish is tagged and is caught by an exploiting fishery (and possibly of age class *j*), and 0 otherwise, and x_{hi} equal 1 if the fish is tagged in any stratum (and possibly of age class *j*). Then, from equation 3.5 in Cochran (1977, p. 51), the sample variance of y_h is $\frac{n_h^* p_{y_h}\left(1-p_{y_h}\right)}{n_h^*-1}$, where $p_{y_h} = \frac{t_h}{n_h^*}$, if $h\in F$, and 0 otherwise. Similarly, the sample variance of x_h is $\frac{n_h^* p_{x_h}\left(1-p_{x_h}\right)}{n_h^*-1}$, where $p_{x_h} = \frac{t_h}{n_h^*}$ for all strata, and the covariance of *x* and *y* equals the variance of *y* if $h\in F$, and 0 otherwise. Then $s_{y_h}^2 = s_{y_h x_h} = \frac{t_h}{n_h^*-1}\left(1-\frac{t_h}{n_h^*}\right)$ if $h \in F$, and 0 otherwise, and $s_{x_h}^2 = \frac{t_h}{n_h^*-1}\left(1-\frac{t_h}{n_h^*}\right)$ for all strata. So, if $h \in F$, we have,

$$\text{v}(\hat{R}_F) \cong \frac{1}{\hat{T}_{Run}^2} \sum_{h=1}^{H} \frac{N_h^2(1-f_h^*)}{n_h^*(n_h^*-1)} t_h \left(1-\frac{t_h}{n_h^*}\right)\left(1+\hat{R}_F^2-2\hat{R}_F\right)$$

$$= \frac{1}{\hat{T}_{Run}^2} \sum_{h=1}^{H} \frac{N_h^2(1-f_h^*)}{n_h^*(n_h^*-1)} t_h \left(1-\frac{t_h}{n_h^*}\right)\left(1-\hat{R}_F\right)^2 \qquad (7)$$

and if $h \notin F$, then

$$\text{v}(\hat{R}_F) \cong \frac{1}{\hat{T}_{Run}^2} \sum_{h=1}^{H} \frac{N_h^2(1-f_h^*)}{n_h^*(n_h^*-1)} t_h \left(1-\frac{t_h}{n_h^*}\right)\left(\hat{R}_F^2\right)$$

$$= \frac{1}{\hat{T}_{Run}^2} \sum_{h=1}^{H} \frac{N_h^2(1-f_h^*)}{n_h^*(n_h^*-1)} t_h \left(1-\frac{t_h}{n_h^*}\right)\left(0-\hat{R}_F^2\right) . \qquad (8)$$

Taken together for all h, we get equation (6), since $I_h = 1$ if $h \in F$, and 0 if not.

Contribution and Total Run Size

We can obtain an estimate of the contribution of the Fish Creek stock to a set of fisheries by assuming the marking fraction of contribution equals the marking fraction of the escapement:

$$\frac{T_F}{C_F} = \frac{T_E}{E} \ .$$

Then:

$$\hat{C}_F = \hat{E}\left(\frac{\hat{T}_F}{\hat{T}_E}\right) \qquad (9)$$

If the size of the escapement is known, an estimate of the variance is:

$$\text{v}(\hat{C}_F) = E^2 \text{v}\left(\frac{\hat{T}_F}{\hat{T}_E}\right) \ . \qquad (10)$$

If the size of the escapement is estimated, we use equation (4) and the fact that $\hat{E}$ and $\frac{\hat{T}_F}{\hat{T}_E}$ are independent (since $\hat{E}$, $\hat{T}_E$, and $\hat{T}_F$ are estimated from different samples) to obtain:

$$\mathrm{v}(\hat{C}_F) = \hat{E}^2 \mathrm{v}\left(\frac{\hat{T}_F}{\hat{T}_E}\right) + \left(\frac{\hat{T}_F}{\hat{T}_E}\right)^2 \mathrm{v}(\hat{E}) - 2\mathrm{v}(\hat{E})\mathrm{v}\left(\frac{\hat{T}_F}{\hat{T}_E}\right) \qquad (11)$$

We can derive the estimated variance of $\frac{\hat{T}_F}{\hat{T}_E}$ in a similar fashion to the estimated variance of the exploitation rate. From equation (2) we have:

$$\mathrm{v}\left(\frac{\hat{T}_F}{\hat{T}_E}\right) \cong \frac{1}{\hat{T}_E^2} \sum_{h=1}^{H} \frac{N_h^2(1-f_h^*)}{n_h^*} \left[s_{y_F}^2 + \left(\frac{\hat{T}_F}{\hat{T}_E}\right)^2 s_{y_E}^2 - 2\left(\frac{\hat{T}_F}{\hat{T}_E}\right) s_{y_F y_E} \right] \qquad (12)$$

If $h \in F$, then $s_{y_F}^2 = \frac{t_h}{n_h^* - 1}\left(1 - \frac{t_h}{n_h^*}\right)$, and 0 otherwise, whereas if $h \in E$, then $s_{y_E}^2 = \frac{t_h}{n_h^* - 1}\left(1 - \frac{t_h}{n_h^*}\right)$ and 0 otherwise. Also, the covariance between y_F and y_E is zero, since they are independent. Therefore, we have,

$$\mathrm{v}\left(\frac{\hat{T}_F}{\hat{T}_E}\right) \cong \frac{1}{\hat{T}_E^2} \sum_{h=1}^{H} \frac{N_h^2(1-f_h^*)}{n_h^*(n_h^*-1)} t_h \left(1 - \frac{t_h}{n_h^*}\right) Z_h \qquad (13)$$

where Z_h equals 1 if $h \in F$, $\left(\frac{\hat{T}_F}{\hat{T}_E}\right)^2$ if $h \in E$, and 0 otherwise.

For this study, $\mathrm{v}(\hat{E})$ is straightforward. The total escapement E is considered known, but escapements for specific age classes are estimated as Ep_j, where p_j is the estimated proportion of age-class j in the escapement. If there is only one escapement stratum, then equation 3.12 in Cochran (1977, p. 52) gives:

$$\mathrm{v}(\hat{E}_j) = \frac{E(E - n_E)}{n_E - 1} p_j(1 - p_j), \qquad (14a)$$

where n_E is the number of fish in the escapement that were aged. If there are multiple strata (e.g., weeks), then the variances for each stratum are added together (this can be derived from equation 5A.68 in Cochran) as:

$$\mathrm{v}(\hat{E}) = \sum_{w=1}^{W} \frac{E_w(E_w - n_w)}{n_w - 1} p_w(1 - p_w) . \tag{14b}$$

The variance of the contribution is then equation (11), substituting equations (13) and (14a) or (14b).

Note also that the estimator of total run size is a special case of the contribution estimator. Let **F** refer to the entire set of fisheries. Because $\hat{T}_{Run} = \hat{T}_{\mathbf{F}} + \hat{T}_E$, we have:

$$\hat{C}_{Tot} = \hat{E}\left(\frac{\hat{T}_{Run}}{\hat{T}_E}\right) = \hat{E}\left(\frac{\hat{T}_{\mathbf{F}} + \hat{T}_E}{\hat{T}_E}\right) = \hat{E}\left(\frac{\hat{T}_{\mathbf{F}}}{\hat{T}_E} + 1\right). \tag{15}$$

Because $\mathrm{v}\left(\frac{\hat{T}_{\mathbf{F}}}{\hat{T}_E} + 1\right) = \mathrm{v}\left(\frac{\hat{T}_{\mathbf{F}}}{\hat{T}_E}\right)$, we have:

$$\mathrm{v}\left(\hat{C}_{Tot}\right) = \hat{E}^2 \mathrm{v}\left(\frac{\hat{T}_{\mathbf{F}}}{\hat{T}_E}\right) + \left(\frac{\hat{T}_{Run}}{\hat{T}_E}\right)^2 \mathrm{v}(\hat{E}) - 2\mathrm{v}(\hat{E})\mathrm{v}\left(\frac{\hat{T}_{\mathbf{F}}}{\hat{T}_E}\right) \tag{16}$$

Note that equation (9) can be viewed as $\frac{\hat{T}_F}{\hat{\theta}}$, where $\hat{\theta} = \frac{\hat{T}_E}{\hat{E}}$; i.e., the estimated marking fraction of the escapement. This estimate is the same as that used by Bernard and Clark (1996) and others. Note that we are applying the marking fraction of the escapement to the catch. Bernard and Clark also derive a variance for this estimator. Their formulas include a second source of uncertainty that is due to the fact that we do not have a direct estimate of the marking fraction in the catch. Instead of assuming that the marking fraction of a catch equals the marking fraction of the escapement, they implicitly assume only that the expected value of the marking fraction in the catch is the same as that of the escapement. This allows for variability of the marking fraction in the catch. Although it is beyond the scope of this appendix, we will show in a future report that this additional *nonsampling* variability is generally considerably smaller than what Bernard and Clark propose. For the Fish Creek data it is less than 1% of the sampling variance 88% of the time, less than 5% of the sampling variance 97% of the time, and is always less than 10%. Because of the relative negligibility of this variation and because of the confusion it entails, we have elected to simply make the stronger assumption that the marking fraction is the same for all strata.

Survival Rate

Survival rate is estimated as the expanded number of returning Fish Creek adipose-clipped fish of a given release year ($\hat{A}_{Tot}$) divided by the number of tags released (TRel):

$$\hat{S} = \frac{\hat{A}_{Tot}}{T_{Rel}}. \tag{17}$$

It is necessary to consider the number of adipose clips because of possible tag loss.

An estimate of the number of adipose-clipped fish is:

$$\hat{A}_{Tot} = \hat{T}_{Tot}\left(\frac{\hat{A}_E}{\hat{T}_E}\right) \tag{18}$$

where $\hat{A}_E = \sum_k \left(\frac{N_{kE}}{n^*_{kE}}\right) a_{kE}$ and $\hat{T}_E = \sum_k \left(\frac{N_{kE}}{n^*_{kE}}\right) t_{kE}$ are the estimated number of adipose-clipped and tagged fish respectively in the escapements (k indexes the return year), and $\hat{T}_{Tot} = \sum_k \sum_h \left(\frac{N_{kh}}{n^*_{kh}}\right) t_{kh}$ is the total number of tagged fish estimated to have returned (h indexes the catch and escapement strata). Again, we have a product of two random variables, one of which is a ratio of two random variables, along with the known T_{Rel}. Although $\hat{T}_{Tot}$ and $\frac{\hat{A}_E}{\hat{T}_E}$ are not independent, their covariance is extremely small (and negative) so that we can safely ignore the right-hand term in (3). Then we have:

$$\mathrm{v}(\hat{S}) \cong \left(\frac{1}{T_{Rel}}\right)^2 \left[\hat{T}^2_{Tot}\,\mathrm{v}\left(\frac{\hat{A}_E}{\hat{T}_E}\right) + \left(\frac{\hat{A}_E}{\hat{T}_E}\right)^2 \mathrm{v}\left(\hat{T}_{Tot}\right)\right]. \tag{19}$$

The $\mathrm{v}\left(\frac{\hat{A}_E}{\hat{T}_E}\right)$ is obtained using (2) as follows. Let the variable y_{ki} equal 1 if the ith fish is adipose-clipped, and 0 otherwise. Let the variable x_{ki} equal 1 if the ith fish is tagged, and 0 otherwise. Then from equation 3.5 in Cochran (1977, p. 51), $s^2_{y_k} = \frac{n^*_k p_{y_k}(1-p_{y_k})}{n^*_k - 1}$, where $p_{y_k} = \frac{a_k}{n^*_k}$, and $s^2_{x_k} = \frac{n^*_k p_{x_k}(1-p_{x_k})}{n^*_k - 1}$, where $p_{x_k} = \frac{t_k}{n^*_k}$. The derivation of $s_{xy} = \frac{\sum_i (x_{ki} - \overline{x})(y_{ki} - \overline{y})}{n^*_k - 1}$ assumes that all tagged fish are also adipose-clipped. There are three possible combinations: tagged and clipped with frequency t_k, untagged and unclipped with frequency $n^*_k - a_k$, and untagged but clipped with frequency $a_k - t_k$. The corrected crossproduct of each of these combinations weighted by its frequency is then $(1-p_x)(1-p_y)t_k$, $p_x p_y (n^*_k - a_k)$, and $-p_x(1-p_y)(a_k - t_k)$ respectively. After summing and dividing by $n^*_k - 1$, we get $s_{xy} = \frac{n^*_k p_{x_k}(1-p_{y_k})}{n^*_k - 1}$. Substituting for $s^2_{y_k}$, $s^2_{x_k}$, and s_{xy} into (2) and then simplifying results in:

$$v\left(\frac{\hat{A}_E}{\hat{T}_E}\right) \cong \sum_k \frac{N_k^2(1-f_k^*)}{n_k^*(n_k^*-1)}\left[a_k\left(1-\frac{a_k}{n_k^*}\right)+\hat{R}^2 t_k\left(1-\frac{t_k}{n_k^*}\right)-2\hat{R}t_k\left(1-\frac{a_k}{n_k^*}\right)\right] \quad (20)$$

where $\hat{R} = \frac{\hat{A}_E}{\hat{T}_E}$. The $v(\hat{T}_{Tot})$ is simply the variance of a stratified total, and analogous to (14b) we have:

$$v(\hat{T}_{Tot}) = \sum_h \frac{N_h(N_h - n_h^*)}{n_h^* - 1} p_h(1-p_h) \quad (21)$$

where $p_h = \frac{t_h}{n_h^*}$.

In some years the actual enumeration of adipose-clipped fish was complicated because not all clipped fish were aged and because some of the clipped fish originated outside of Fish Creek. However, there were only a small number of these fish so that the extra uncertainty due to these irregularities will also be small. For that reason, we have not included this uncertainty in our analysis. In addition, we have assumed that there are no naturally occurring adipose-clipped fish, although we suspect that there are small numbers.

Note that just as for contributions, we are using a ratio derived from the escapement and applying it to the catch. We assume that the adipose clip to tag ratio is the same for all strata.

Summary of Formulas

Exploitation Rate:

$$\hat{R}_F = \frac{\hat{T}_F}{\hat{T}_{Run}} = \frac{\sum_{h=1}^{F}\left(\frac{N_h}{n_h^*}\right)t_h}{\sum_{h=1}^{H}\left(\frac{N_h}{n_h^*}\right)t_h}$$

$$v(\hat{R}_F) \cong \frac{1}{\hat{T}_{Run}^2}\sum_{h=1}^{H}\frac{N_h^2}{n_h^*(n_h^*-1)}\left(1-f_h^*\right)t_h\left(1-\frac{t_h}{n_h^*}\right)\left(I_h - \hat{R}_F\right)^2$$

where I_h equals 1 if $h \in F$, and 0 otherwise

Contribution:

$$\hat{C}_F = \hat{E}\left(\frac{\hat{T}_F}{\hat{T}_E}\right)$$

$$\mathrm{v}(\hat{C}_F) = \hat{E}^2 \mathrm{v}\left(\frac{\hat{T}_F}{\hat{T}_E}\right) + \left(\frac{\hat{T}_F}{\hat{T}_E}\right)^2 \mathrm{v}(\hat{E}) - 2\mathrm{v}(\hat{E})\mathrm{v}\left(\frac{\hat{T}_F}{\hat{T}_E}\right)$$

$$\mathrm{v}\left(\frac{\hat{T}_F}{\hat{T}_E}\right) \cong \frac{1}{\hat{T}_E^2}\sum_{h=1}^{H}\frac{N_h^2(1-f_h^*)}{n_h^*(n_h^*-1)} t_h\left(1-\frac{t_h}{n_h^*}\right) Z_h$$

$$\mathrm{v}(\hat{E}) = \sum_{w=1}^{W}\frac{E_w(E_w-n_w)}{n_w-1} p_w(1-p_w)$$

where Z_h equals 1 if $h \in F$, $\left(\frac{\hat{T}_F}{\hat{T}_E}\right)^2$ if $h \in E$, and 0 otherwise, and p_w is the proportion of age-class j in escapement stratum w.

Survival Rate:

$$\hat{S} = \frac{\hat{A}_{Tot}}{T_{Rel}}$$

$$\hat{A}_{Tot} = \hat{T}_{Tot}\left(\frac{\hat{A}_E}{\hat{T}_E}\right)$$

$$\hat{A}_E = \sum_k\left(\frac{N_{kE}}{n_{kE}^*}\right) a_{kE}$$

$$\hat{T}_E = \sum_k\left(\frac{N_{kE}}{n_{kE}^*}\right) t_{kE}$$

$$\hat{T}_{Tot} = \sum_k\sum_h\left(\frac{N_{kh}}{n_{kh}^*}\right) t_{kh}$$

$$\mathrm{v}(\hat{S}) \cong \left(\frac{1}{T_{Rel}}\right)^2 \left[\hat{T}_{Tot}^2 \mathrm{v}\left(\frac{\hat{A}_E}{\hat{T}_E}\right) + \left(\frac{\hat{A}_E}{\hat{T}_E}\right)^2 \mathrm{v}\left(\hat{T}_{Tot}\right)\right]$$

$$\mathrm{v}\left(\frac{\hat{A}_E}{\hat{T}_E}\right) \cong \sum_k \frac{N_k^2(1-f_k^*)}{n_k^*(n_k^*-1)}\left[a_k\left(1-\frac{a_k}{n_k^*}\right) + \hat{R}^2 t_k\left(1-\frac{t_k}{n_k^*}\right) - 2\hat{R}t_k\left(1-\frac{a_k}{n_k^*}\right)\right]$$

$$\mathrm{v}(\hat{T}_{Tot}) = \sum_h \frac{N_h(N_h-n_h^*)}{n_h^*-1}\, p_h(1-p_h)$$

where $\hat{R} = \frac{\hat{A}_E}{\hat{T}_E}$ and $p_h = \frac{t_h}{n_h^*}$.

Appendix 3. The number of Fish Creek chum salmon fry coded-wire-tagged by tag code, and tag retention at time of release (up to 12 hours after tagging), 1988-1991.

Year of Tagging	Tagging Dates	Tag Code	Total Tagged	Tag Retention	Valid Tags Released
	11 Mar-17 Mar	B30401	11,120	85.7%	9,530
1988	17 Mar-22 Mar	B30402	11,555	93.8%	10,839
Adult Return Years	23 Mar-28 Mar	B30403	11,703	97.5%	11,410
1990 to 1993	28 Mar-04 Apr	B30404	11,991	97.8%	11,727
	04 Apr-07 Apr	B30405	12,096	99.6%	12,048
	07 Apr-13 Apr	B30303	11,935	99.2%	11,840
	14 Apr-19 Apr	B30304	12,002	98.3%	11,798
	19 Apr-22 Apr	B30305	12,099	99.3%	12,014
	22 Apr-27 Apr	B30306	11,775	96.8%	11,398
	27 Apr-04 May	B30307	10,951	95.3%	10,436
	04 May-09 May	401010401	9,522	94.1%	8,960
	10 May-12 May	401010402	9,530	92.0%	8,768
	12 May-16 May	401010313	9,333	93.3%	8,708
	16 May-18 May	401010314	7,179	90.0%	6,461
Total Valid Tags Released in 1988:			152,791	95.5%	145,937
	02 Mar-16 Mar	401010601	23,488	89.5%	21,022
1989	16 Mar-23 Mar	401010602	25,228	96.1%	24,244
Adult Return Years	24 Mar-04 Apr	401010603	27,283	97.1%	26,492
1991 to 1994	04 Apr-14 Apr	401010604	27,439	98.7%	27,082
	14 Apr-24 Apr	401010605	25,731	91.6%	23,570
	25 Apr-03 May	401010606	26,380	89.1%	23,505
	03 May-11 May	401010607	26,316	91.3%	24,027
	12 May-17 May	401010608	25,683	82.4%	21,163
	17 May-20 May	401010609	24,265	88.7%	21,523
	20 May-24 May	401010610	13,911	95.0%	13,215
Total Valid Tags Released in 1989:			245,724	91.9%	225,843
	19 Feb-14 Mar	401011101	34,394	92.5%	31,814
1990	14 Mar-26 Mar	401011102	37,981	96.9%	36,804
Adult Return Years	26 Mar-04 Apr	401011103	38,654	93.1%	35,987
1992 to 1995	04 Apr-13 Apr	401011104	38,285	94.6%	36,218
	13 Apr-23 Apr	401011105	40,493	97.8%	39,602
	23 Apr-02 May	401011106	39,009	94.9%	37,020
	02 May-11 May	401011107	38,863	90.1%	35,016
	11 May-22 May	401011108	38,217	95.1%	36,344
	23 May-25 May	401011109	11,937	99.6%	11,889
Total Valid Tags Released in 1990:			317,833	94.6%	300,694
	18 Feb-06 Mar	401011110	36,619	94.4%	34,568
1991	06 Mar-19 Mar	401011506	39,103	91.3%	35,701
Adult Return Years	19 Mar-29 Mar	401011507	32,032	96.1%	30,783
1993 to 1996	01 Apr-11 Apr	401011508	40,749	96.9%	39,486
	11 Apr-22 Apr	401011509	38,420	95.4%	36,653
	22 Apr-02 May	401020101	37,218	92.6%	34,464
	02 May-16 May	401020102	24,791	95.0%	23,551
Total Valid Tags Released in 1991:			248,932	94.5%	235,206

Appendix 4. Fish Creek chum salmon coded-wire-tag recoveries and associated statistics, by age class and by all ages combined, 1991.

Note: SN = seine, GN = gillnet, TR = troll, NN = B.C. northern net, NTR = B.C. northern troll, and Age Class Comb. = All tags combined regardless of age class.

Age Class	Year	Stratum (***h***)	Stat Week	Catch N_h	Sample n_h	Clips Obs. ***a***	Heads Rec. ***a'***	Tags Det. ***t***	Tags Dec. ***t'***	Effective Sample n'_h	Fish Cr Tags n_{hj}	Expanded Tags Y_j	Exploitation Rate ***R***	SE(***R***)	Contribution C_j	SE(C_j)
0.2	1991	Esc. Fish Creek		9,996	9,811	46	40	30	30	8,531	7	8.202	19.8%	5.7%	2,778	135
0.2	1991	GN 101-11	28	10,371	4,079	23	23	14	14	4,079	1	2.543	6.1%	4.8%	861	682
0.2	1991	GN 101-11	29	13,590	5,061	24	23	20	20	4,850	2	5.604	13.6%	7.5%	1,898	1,112
0.2	1991	GN 101-11	31	11,467	4,754	13	13	13	13	4,754	1	2.412	5.8%	4.5%	817	636
0.2	1991	GN 101-11	33	14,809	4,475	10	10	7	7	4,475	1	3.309	8.0%	6.5%	1,121	950
0.2	1991	SN 104	28	15,019	9,320	34	34	22	22	9,320	1	1.611	3.9%	2.5%	546	346
0.2	1991	SN 104	29	23,431	4,408	7	7	4	4	4,408	1	5.316	12.9%	10.6%	1,800	1,641
0.2	1991	SN 104	32	146,774	33,752	21	21	12	12	33,752	1	4.349	10.5%	8.7%	1,473	1,309
0.2	1991	SN 104	36	19,542	2,439	2	2	2	2	2,439	1	8.012	19.4%	15.1%	2,714	2,566
0.3	1991	Esc. Fish Creek		9,996	9,811	46	40	30	30	8,531	21	24.605	36.71%	5.95%	4,796	159
0.3	1991	GN 101-11	29	13,590	5,061	24	23	20	20	4,850	2	5.604	8.36%	4.52%	1,092	626
0.3	1991	GN 101-11	30	10,333	4,467	17	15	13	13	3,941	2	5.243	7.82%	4.18%	1,022	575
0.3	1991	GN 101-11	32	15,523	4,849	14	14	13	13	4,849	1	3.201	4.78%	3.84%	624	520
0.3	1991	GN 101-11	34	22,733	7,601	13	13	12	12	7,601	1	2.991	4.46%	3.54%	583	478
0.3	1991	SN 104	32	146,774	33,752	21	21	12	12	33,752	2	8.697	12.98%	7.22%	1,695	1,062
0.3	1991	SN NN-3	29	23,909	6,018	7	7	6	6	6,018	1	3.973	5.93%	4.90%	774	673
0.3	1991	SN NN-3	30	34,506	8,473	7	7	4	4	8,473	2	8.145	12.15%	6.77%	1,587	984
0.3	1991	SN NN-3	32	26,005	7,797	4	4	2	2	7,797	1	3.335	4.98%	4.03%	650	546
0.3	1991	SN NN-3	35	3,699	3,017	2	2	2	2	3,017	1	1.226	1.83%	0.82%	239	105
Comb.	1991	Esc. Fish Creek		9,996	9,811	46	40	30	30	8,531	28	32.807	30.27%	4.46%	9,996	0
Comb.	1991	GN 101-11	28	10,371	4,079	23	23	14	14	4,079	1	2.543	2.35%	1.81%	775	606
Comb.	1991	GN 101-11	29	13,590	5,061	24	23	20	20	4,850	4	11.208	10.34%	3.97%	3,415	1,391
Comb.	1991	GN 101-11	30	10,333	4,467	17	15	13	13	3,941	2	5.243	4.84%	2.65%	1,598	896
Comb.	1991	GN 101-11	31	11,467	4,754	13	13	13	13	4,754	1	2.412	2.23%	1.69%	735	565
Comb.	1991	GN 101-11	32	15,523	4,849	14	14	13	13	4,849	1	3.201	2.95%	2.41%	975	812
Comb.	1991	GN 101-11	33	14,809	4,475	10	10	7	7	4,475	1	3.309	3.05%	2.51%	1,008	845
Comb.	1991	GN 101-11	34	22,733	7,601	13	13	12	12	7,601	1	2.991	2.76%	2.22%	911	746
Comb.	1991	SN 104	28	15,019	9,320	34	34	22	22	9,320	1	1.611	1.49%	0.93%	491	305
Comb.	1991	SN 104	29	23,431	4,408	7	7	4	4	4,408	1	5.316	4.90%	4.25%	1,620	1,464
Comb.	1991	SN 104	32	146,774	33,752	21	21	12	12	33,752	3	13.046	12.04%	5.58%	3,975	2,034
Comb.	1991	SN 104	36	19,542	2,439	2	2	2	2	2,439	1	8.012	7.39%	6.47%	2,441	2,291
Comb.	1991	SN NN-3	29	23,909	6,018	7	7	6	6	6,018	1	3.973	3.67%	3.10%	1,211	1,051
Comb.	1991	SN NN-3	30	34,506	8,473	7	7	4	4	8,473	2	8.145	7.52%	4.38%	2,482	1,535
Comb.	1991	SN NN-3	32	26,005	7,797	4	4	2	2	7,797	1	3.335	3.08%	2.53%	1,016	853
Comb.	1991	SN NN-3	35	3,699	3,017	2	2	2	2	3,017	1	1.226	1.13%	0.51%	374	163

Appendix 5. Fish Creek chum salmon coded-wire-tag recoveries and associated statistics, by age class and by all ages combined, 1992.

Note: SN = seine, GN = gillnet, TR = troll, NN = B.C. northern net, NTR = B.C. northern troll, and Age Class Comb. = All tags combined regardless of age class.

Age Class	Year	Stratum (***h***)	Stat Week	Catch N_h	Sample n_h	Clips Obs. a	Heads Rec. a'	Tags Det. t	Tags Dec. t'	Effective Sample n'_h	Fish Cr Tags n_{hj}	Expanded Tags Y_j	Exploitation Rate R	Exploitation Rate SE(R)	Contribution C_j	Contribution SE(C_j)
0.2	1992	Esc. Fish Creek		46,971	26,435	195	158	138	138	21,419	17	37.280	49.25%	7.37%	2,403	217
0.2	1992	Esc. Marx Creek		17,597	5,120	41	40	34	34	4,995	1	3.523	4.65%	3.81%	227	196
0.2	1992	GN 101-11	28	25,581	11,217	37	36	30	30	10,914	1	2.344	3.10%	2.32%	151	117
0.2	1992	GN 101-11	29	25,205	13,996	60	59	48	48	13,763	1	1.831	2.42%	1.63%	118	82
0.2	1992	GN 101-11	31	21,400	10,665	46	45	38	38	10,433	2	4.102	5.42%	2.71%	264	143
0.2	1992	GN 101-11	33	9,009	2,569	11	10	9	9	2,335	3	11.572	15.29%	6.72%	746	396
0.2	1992	GN 101-11	34	19,979	7,346	46	45	41	40	7,011	1	2.850	3.76%	2.97%	184	151
0.2	1992	GN NN-3	37	1,330	**426**[a]	18	18	15	15	426	1	3.124	4.13%	3.32%	201	170
0.2	1992	GN NN-4	30	15,124	5,010	7	7	2	2	5,010	1	3.019	3.99%	3.18%	195	163
0.2	1992	SN 104	29	22,168	8,218	10	9	6	6	7,396	1	2.997	3.96%	3.16%	193	161
0.2	1992	SN 104	32	131,695	44,755	26	25	18	18	43,034	1	3.060	4.04%	3.24%	197	165
0.3	1992	Esc. Fish Creek		46,971	26,435	195	158	138	138	21,419	105	230.259	50.2%	3.1%	41,880	309
0.3	1992	Esc. Marx Creek		17,597	5,120	41	40	34	34	4,995	15	52.843	11.5%	2.3%	9,611	2,209
0.3	1992	GN 101-11	26	9,251	3,648	13	12	11	11	3,367	6	16.483	3.6%	1.1%	2,998	999
0.3	1992	GN 101-11	27	15,109	6,205	22	22	14	14	6,205	2	4.870	1.1%	0.6%	886	485
0.3	1992	GN 101-11	28	25,581	11,217	37	36	30	30	10,914	4	9.376	2.0%	0.8%	1,705	657
0.3	1992	GN 101-11	29	25,205	13,996	60	59	48	48	13,763	11	20.145	4.4%	0.9%	3,664	790
0.3	1992	GN 101-11	30	28,223	12,437	68	68	53	53	12,437	5	11.346	2.5%	0.8%	2,064	706
0.3	1992	GN 101-11	31	21,400	10,665	46	45	38	38	10,433	3	6.153	1.3%	0.6%	1,119	470
0.3	1992	GN 101-11	32	21,505	5,968	23	21	19	19	5,449	4	15.786	3.4%	1.4%	2,871	1,257
0.3	1992	GN NN-3	28	15,587	3,820	8	7	2	2	3,343	1	4.663	1.0%	0.9%	848	754
0.3	1992	GN NN-3	31	8,207	1,624	9	9	2	2	1,624	1	5.054	1.1%	1.0%	919	826
0.3	1992	GN NN-4	30	15,124	5,010	7	7	2	2	5,010	1	3.019	0.7%	0.5%	549	451
0.3	1992	GN NN-4	31	20,292	5,661	12	12	5	4	4,529	2	8.961	2.0%	1.2%	1,630	1,022
0.3	1992	GN NN-4	32	10,517	3,315	3	3	2	2	3,315	2	6.345	1.4%	0.8%	1,154	680
0.3	1992	SN 101	28	25,710	6,292	12	12	10	10	6,292	1	4.086	0.9%	0.8%	743	648
0.3	1992	SN 102	28	4,256	1,357	1	1	1	1	1,357	1	3.136	0.7%	0.6%	570	473
0.3	1992	SN 104	28	12,867	6,845	21	21	18	18	6,845	1	1.880	0.4%	0.3%	342	235
0.3	1992	SN 104	30	9,796	6,430	14	14	10	10	6,430	1	1.523	0.3%	0.2%	277	164
0.3	1992	SN 104	31	148,300	60,174	69	68	43	43	59,302	5	12.504	2.7%	0.9%	2,274	805
0.3	1992	SN 104	32	131,695	44,755	26	25	18	18	43,034	5	15.301	3.3%	1.2%	2,783	1,041
0.3	1992	SN 104	33	122,449	55,265	58	56	34	34	53,359	1	2.295	0.5%	0.4%	417	315
0.3	1992	SN NN-2	31	1,978	319	1	1	1	1	319	1	6.201	1.4%	1.2%	1,128	1,036
0.3	1992	SN NN-3	29	12,417	4,584	6	6	3	3	4,584	2	5.418	1.2%	0.7%	985	558
0.3	1992	SN NN-3	30	4,272	1,931	3	3	2	2	1,931	1	2.212	0.5%	0.4%	402	299
0.3	1992	SN NN-3	32	24,584	3,183	1	1	1	1	3,183	1	7.724	1.7%	1.5%	1,405	1,315
0.3	1992	SN NN-5	30	118	85	1	1	1	1	85	1	1.388	0.3%	0.2%	252	135
0.4	1992	Esc. Fish Creek		46,971	26,435	195	158	138	138	21,419	7	15.351	81.33%	13.53%	2,652	228
0.4	1992	Esc. Marx Creek		17,597	5,120	41	40	34	34	4,995	1	3.523	18.67%	13.53%	609	541
Comb.	1992	Esc. Fish Creek		46,971	26,435	195	158	138	138	21,419	129	282.890	51.10%	2.80%	46,971	0
Comb.	1992	Esc. Marx Creek		17,597	5,120	41	40	34	34	4,995	17	59.888	10.82%	2.05%	9,944	2,137
Comb.	1992	GN 101-11	26	9,251	3,648	13	12	11	11	3,367	6	16.483	2.98%	0.95%	2,737	908
Comb.	1992	GN 101-11	27	15,109	6,205	22	22	14	14	6,205	2	4.870	0.88%	0.48%	809	442
Comb.	1992	GN 101-11	28	25,581	11,217	37	36	30	30	10,914	5	11.720	2.12%	0.71%	1,946	671
Comb.	1992	GN 101-11	29	25,205	13,996	60	59	48	48	13,763	12	21.977	3.97%	0.77%	3,649	748
Comb.	1992	GN 101-11	30	28,223	12,437	68	68	53	53	12,437	5	11.346	2.05%	0.68%	1,884	642

[a] The reported sample size for BC Northern Net Area 3 gillnet, week 37, was 2,770. The sample was reduced by taking the average sampling proportion over all BC strata (0.32) and multiplying it by the reported catch of 1,330 fish.

Appendix 5. (1992 continued)

Age Class	Year	Stratum (h)	Stat Week	Catch N_h	Sample n_h	Clips Obs. a	Heads Rec. a'	Tags Det. t	Tags Dec. t'	Effective Sample n'_h	Fish Cr Tags n_{hj}	Expanded Tags Y_j	Exploitation Rate R	SE(R)	Contribution C_j	SE(C_j)
Comb.	1992	GN 101-11	31	21,400	10,665	46	45	38	38	10,433	5	10.256	1.85%	0.59%	1,703	556
Comb.	1992	GN 101-11	32	21,505	5,968	23	21	19	19	5,449	4	15.786	2.85%	1.21%	2,621	1,145
Comb.	1992	GN 101-11	33	9,009	2,569	11	10	9	9	2,335	3	11.572	2.09%	1.02%	1,921	962
Comb.	1992	GN 101-11	34	19,979	7,346	46	45	41	40	7,011	1	2.850	0.51%	0.41%	473	382
Comb.	1992	GN NN-3	28	15,587	3,820	8	7	2	2	3,343	1	4.663	0.84%	0.74%	774	688
Comb.	1992	GN NN-3	31	8,207	1,624	9	9	2	2	1,624	1	5.054	0.91%	0.81%	839	753
Comb.	1992	GN NN-3	37	1,330	**426**[a]	18	18	15	15	426	1	3.124	0.56%	0.46%	519	429
Comb.	1992	GN NN-4	30	15,124	5,010	7	7	2	2	5,010	2	6.038	1.09%	0.63%	1,002	583
Comb.	1992	GN NN-4	31	20,292	5,661	12	12	5	4	4,529	2	8.961	1.62%	1.00%	1,488	932
Comb.	1992	GN NN-4	32	10,517	3,315	3	3	2	2	3,315	2	6.345	1.15%	0.67%	1,054	620
Comb.	1992	SN 101	28	25,710	6,292	12	12	10	10	6,292	1	4.086	0.74%	0.64%	678	591
Comb.	1992	SN 102	28	4,256	1,357	1	1	1	1	1,357	1	3.136	0.57%	0.47%	521	431
Comb.	1992	SN 104	28	12,867	6,845	21	21	18	18	6,845	1	1.880	0.34%	0.23%	312	214
Comb.	1992	SN 104	29	22,168	8,218	10	9	6	6	7,396	1	2.997	0.54%	0.44%	498	408
Comb.	1992	SN 104	30	9,796	6,430	14	14	10	10	6,430	1	1.523	0.28%	0.16%	253	149
Comb.	1992	SN 104	31	148,300	60,174	69	68	43	43	59,302	5	12.504	2.26%	0.77%	2,076	732
Comb.	1992	SN 104	32	131,695	44,755	26	25	18	18	43,034	6	18.362	3.32%	1.09%	3,049	1,040
Comb.	1992	SN 104	33	122,449	55,265	58	56	34	34	53,359	1	2.295	0.41%	0.31%	381	287
Comb.	1992	SN NN-2	31	1,978	319	1	1	1	1	319	1	6.201	1.12%	1.02%	1,030	945
Comb.	1992	SN NN-3	29	12,417	4,584	6	6	3	3	4,584	2	5.418	0.98%	0.55%	900	508
Comb.	1992	SN NN-3	30	4,272	1,931	3	3	2	2	1,931	1	2.212	0.40%	0.30%	367	273
Comb.	1992	SN NN-3	32	24,584	3,183	1	1	1	1	3,183	1	7.724	1.40%	1.29%	1,282	1,199
Comb.	1992	SN NN-5	30	118	85	1	1	1	1	85	1	1.388	0.25%	0.13%	231	123

[a] The reported sample size for BC Northern Net Area 3 gillnet, week 37, was 2,770. The sample was reduced by taking the average sampling proportion over all BC strata (0.32) and multiplying it by the reported catch of 1,330 fish.

Appendix 6. Fish Creek chum salmon coded-wire-tag recoveries and associated statistics, by age class and by all ages combined, 1993.

Note: SN = seine, GN = gillnet, TR = troll, NN = B.C. northern net, NTR = B.C. northern troll, and Age Class Comb. = All tags combined regardless of age class.

Age Class	Year	Stratum (***h***)	Stat Week	Catch N_h	Sample n_h	Clips Obs. ***a***	Heads Rec. ***a'***	Tags Det. ***t***	Tags Dec. ***t'***	Effective Sample n'_h	Fish Cr Tags n_{hj}	Expanded Tags Y_j	Exploitation Rate ***R***	SE(***R***)	Contribution C_j	SE(C_j)
0.2	1993	Esc. Fish Creek		60,447	36,616	463	461	355	355	36,458	4	6.632	22.01%	7.99%	829	169
0.2	1993	Esc. Marx Creek		36,303	25,108	147	147	114	112	24,668	0	0.000	0.00%	0.00%	0	0
0.2	1993	Esc. Salmon River		18,485	4,690	12	12	10	10	4,690	0	0.000	0.00%	0.00%	0	0
0.2	1993	GN 101-11	31	44,607	11,275	66	65	48	48	11,104	1	4.017	13.33%	10.56%	502	455
0.2	1993	GN NN-3	36	16,132	8,411	40	40	30	30	8,411	1	1.918	6.37%	4.47%	240	181
0.2	1993	SN 104	32	112,574	44,578	82	82	48	48	44,578	1	2.525	8.38%	6.38%	316	261
0.2	1993	SN NN-3	31	143,494	33,591	167	165	119	116	32,352	3	13.306	44.16%	14.39%	1,663	1,010
0.2	1993	SN NN-3	36	11,058	6,384	22	22	17	17	6,384	1	1.732	5.75%	3.86%	216	156
0.3	1993	Esc. Fish Creek		60,447	36,616	463	461	355	355	36,458	307	509.005	29.88%	1.26%	50,148	586
0.3	1993	Esc. Marx Creek		36,303	25,108	147	147	114	112	24,668	88	129.509	7.60%	0.50%	12,759	906
0.3	1993	Esc. Salmon River		18,485	4,690	12	12	10	10	4,690	10	39.414	2.31%	0.62%	3,883	1,070
0.3	1993	GN 101-11	26	8,134	3,151	13	13	10	10	3,151	1	2.581	0.15%	0.12%	254	199
0.3	1993	GN 101-11	27	17,054	6,676	40	38	29	29	6,342	10	26.890	1.58%	0.39%	2,649	671
0.3	1993	GN 101-11	28	20,425	9,036	46	44	35	35	8,643	8	18.905	1.11%	0.30%	1,863	505
0.3	1993	GN 101-11	29	25,649	10,322	53	49	42	42	9,543	4	10.751	0.63%	0.25%	1,059	421
0.3	1993	GN 101-11	30	36,765	13,422	102	97	79	78	12,602	16	46.676	2.74%	0.55%	4,599	947
0.3	1993	GN 101-11	31	44,607	11,275	66	65	48	48	11,104	13	52.223	3.07%	0.72%	5,145	1,251
0.3	1993	GN 101-11	32	21,717	8,663	40	38	30	29	7,956	5	13.649	0.80%	0.28%	1,345	481
0.3	1993	GN 101-11	33	28,917	16,183	61	58	46	45	15,053	11	21.132	1.24%	0.26%	2,082	441
0.3	1993	GN 101-11	34	28,783	11,283	42	40	34	34	10,746	9	24.107	1.42%	0.37%	2,375	633
0.3	1993	GN 101-11	35	48,829	18,846	102	100	89	89	18,476	5	13.214	0.78%	0.27%	1,302	462
0.3	1993	GN 101-11	36	33,869	12,468	97	97	92	92	12,468	1	2.716	0.16%	0.13%	268	213
0.3	1993	GN NN-3	26	3,682	985	6	6	3	3	985	1	3.738	0.22%	0.19%	368	315
0.3	1993	GN NN-3	28	27,996	5,340	30	29	14	14	5,162	6	32.541	1.91%	0.69%	3,206	1,187
0.3	1993	GN NN-3	29	9,914	3,085	20	20	14	14	3,085	6	19.282	1.13%	0.38%	1,900	647
0.3	1993	GN NN-3	31	9,534	1,300	2	2	2	2	1,300	2	14.668	0.86%	0.56%	1,445	951
0.3	1993	GN NN-3	32	5,573	3,888	12	11	8	8	3,564	4	6.255	0.37%	0.11%	616	186
0.3	1993	GN NN-3	33	7,642	3,115	8	8	4	4	3,115	3	7.360	0.43%	0.19%	725	323
0.3	1993	GN NN-3	34	14,681	7,557	18	18	13	13	7,557	12	23.312	1.37%	0.28%	2,297	469
0.3	1993	GN NN-3	35	29,362	1,722	3	3	3	3	1,722	2	34.102	2.00%	1.35%	3,360	2,307
0.3	1993	GN NN-3	36	16,132	8,411	40	40	30	30	8,411	13	24.934	1.46%	0.28%	2,456	480
0.3	1993	GN NN-3	37	1,699	1,095	4	4	4	4	1,095	3	4.655	0.27%	0.09%	459	159
0.3	1993	GN NN-4	27	9,094	1,376	4	4	3	3	1,376	1	6.609	0.39%	0.36%	651	600
0.3	1993	GN NN-4	28	33,864	9,416	34	34	21	21	9,416	5	17.982	1.06%	0.40%	1,772	676
0.3	1993	GN NN-4	29	42,304	10,663	41	40	20	20	10,403	3	12.200	0.72%	0.36%	1,202	604
0.3	1993	GN NN-4	30	26,033	9,783	28	27	19	19	9,434	6	16.558	0.97%	0.32%	1,631	535
0.3	1993	GN NN-4	31	30,562	6,686	10	10	6	6	6,686	2	9.142	0.54%	0.33%	901	564
0.3	1993	GN NN-4	34	2,613	1,363	1	1	1	1	1,363	1	1.917	0.11%	0.08%	189	131
0.3	1993	GN NN-5	33	741	285	1	1	1	1	285	1	2.600	0.15%	0.12%	256	201
0.3	1993	SN 101	29	20,232	3,735	7	6	5	5	3,201	1	6.320	0.37%	0.34%	623	572
0.3	1993	SN 101	30	52,368	17,000	43	39	29	29	15,419	1	3.396	0.20%	0.17%	335	281
0.3	1993	SN 101	31	70,695	22,398	54	52	44	44	21,568	2	6.555	0.38%	0.23%	646	381
0.3	1993	SN 102	29	6,149	4,211	11	9	7	7	3,445	1	1.785	0.10%	0.07%	176	117
0.3	1993	SN 103	34	22,857	1,847	2	2	1	1	1,847	1	12.375	0.73%	0.69%	1,219	1,170
0.3	1993	SN 104	28	63,295	19,728	70	69	51	51	19,446	10	32.549	1.91%	0.50%	3,207	852
0.3	1993	SN 104	29	24,061	10,975	27	26	20	20	10,569	4	9.107	0.53%	0.20%	897	338
0.3	1993	SN 104	30	71,879	40,169	93	88	53	53	38,009	7	13.238	0.78%	0.20%	1,304	342
0.3	1993	SN 104	31	175,911	64,895	134	126	75	75	61,021	14	40.359	2.37%	0.51%	3,976	872
0.3	1993	SN 104	32	112,574	44,578	82	82	48	48	44,578	10	25.253	1.48%	0.36%	2,488	618
0.3	1993	SN 104	33	36,229	6,952	16	16	9	9	6,952	1	5.211	0.31%	0.27%	513	462
0.3	1993	SN 104	34	26,033	11,479	15	15	9	9	11,479	1	2.268	0.13%	0.10%	223	167

Appendix 6. (1993 continued)

Age Class	Year	Stratum (h)	Stat Week	Catch N_h	Sample n_h	Clips Obs. a	Heads Rec. a'	Tags Det. t	Tags Dec. t'	Effective Sample n'_h	Fish Cr Tags n_{hj}	Expanded Tags Y_j	Exploitation Rate R	SE(R)	Contribution C_j	SE(C_j)
0.3	1993	SN 105	35	4,304	667	1	1	1	1	667	1	6.453	0.38%	0.35%	636	585
0.3	1993	SN NN-3	30	36,075	7,582	45	43	30	30	7,245	8	39.834	2.34%	0.73%	3,924	1,248
0.3	1993	SN NN-3	31	143,494	33,591	167	165	119	116	32,352	51	226.205	13.28%	1.48%	22,286	2,869
0.3	1993	SN NN-3	32	48,735	16,774	48	48	24	24	16,774	8	23.243	1.36%	0.39%	2,290	661
0.3	1993	SN NN-3	33	23,488	11,501	44	43	29	29	11,240	19	39.705	2.33%	0.39%	3,912	664
0.3	1993	SN NN-3	34	5,536	4,836	11	11	10	10	4,836	7	8.013	0.47%	0.07%	789	110
0.3	1993	SN NN-3	35	25,059	18,005	44	44	32	32	18,005	15	20.877	1.23%	0.17%	2,057	292
0.3	1993	SN NN-3	36	11,058	6,384	22	22	17	17	6,384	1	1.732	0.10%	0.07%	171	111
0.3	1993	SN NN-4	30	22,614	5,448	18	18	9	9	5,448	2	8.302	0.49%	0.30%	818	505
0.3	1993	SN NN-4	31	6,818	1,466	8	8	4	4	1,466	1	4.651	0.27%	0.24%	458	406
0.3	1993	TR 104	35	1,405	329	1	1	1	1	329	1	4.271	0.25%	0.22%	421	368
0.3	1993	TR NTR-1	28	4,884	1,526	2	2	2	2	1,526	2	6.401	0.38%	0.22%	631	370
0.3	1993	TR NTR-3	29	4,689	2,567	7	7	3	3	2,567	1	1.827	0.11%	0.07%	180	121
0.3	1993	TR NTR-3	30	7,792	3,081	3	3	2	2	3,081	1	2.529	0.15%	0.12%	249	194
0.3	1993	TR NTR-3	33	2,261	964	4	4	3	3	964	1	2.345	0.14%	0.10%	231	175
0.4	1993	Esc. Fish Creek		60,447	36,616	463	461	355	355	36,458	38	63.004	31.5%	3.8%	9,185	559
0.4	1993	Esc. Marx Creek		36,303	25,108	147	147	114	112	24,668	7	10.302	5.2%	1.2%	1,502	366
0.4	1993	Esc. Salmon River		18,485	4,690	12	12	10	10	4,690	0	0.000	0.0%	0.0%	0	0
0.4	1993	GN 101-11	26	8,134	3,151	13	13	10	10	3,151	4	10.326	5.2%	2.0%	1,505	613
0.4	1993	GN 101-11	27	17,054	6,676	40	38	29	29	6,342	3	8.067	4.0%	1.8%	1,176	554
0.4	1993	GN 101-11	28	20,425	9,036	46	44	35	35	8,643	1	2.363	1.2%	0.9%	344	264
0.4	1993	GN 101-11	30	36,765	13,422	102	97	79	78	12,602	2	5.835	2.9%	1.7%	851	496
0.4	1993	GN 101-11	31	44,607	11,275	66	65	48	48	11,104	1	4.017	2.0%	1.7%	586	510
0.4	1993	GN 101-11	33	28,917	16,183	61	58	46	45	15,053	1	1.921	1.0%	0.7%	280	196
0.4	1993	GN NN-3	28	27,996	5,340	30	29	14	14	5,162	2	10.847	5.4%	3.3%	1,581	1,023
0.4	1993	GN NN-3	29	9,914	3,085	20	20	14	14	3,085	1	3.214	1.6%	1.3%	468	391
0.4	1993	GN NN-3	32	5,573	3,888	12	11	8	8	3,564	1	1.564	0.8%	0.5%	228	139
0.4	1993	GN NN-4	27	9,094	1,376	4	4	3	3	1,376	2	13.218	6.6%	4.1%	1,927	1,271
0.4	1993	GN NN-4	28	33,864	9,416	34	34	21	21	9,416	1	3.596	1.8%	1.5%	524	448
0.4	1993	GN NN-4	29	42,304	10,663	41	40	20	20	10,403	2	8.133	4.1%	2.4%	1,186	739
0.4	1993	GN NN-4	30	26,033	9,783	28	27	19	19	9,434	1	2.760	1.4%	1.1%	402	324
0.4	1993	SN 101	30	52,368	17,000	43	39	29	29	15,419	1	3.396	1.7%	1.4%	495	418
0.4	1993	SN 104	28	63,295	19,728	70	69	51	51	19,446	1	3.255	1.6%	1.3%	474	397
0.4	1993	SN NN-3	31	143,494	33,591	167	165	119	116	32,352	8	35.483	17.7%	4.8%	5,173	1,717
0.4	1993	SN NN-3	32	48,735	16,774	48	48	24	24	16,774	3	8.716	4.4%	2.0%	1,271	611
Comb.	1993	Esc. Fish Creek		60,447	36,616	463	461	355	355	36,458	349	578.641	29.93%	1.18%	60,447	0
Comb.	1993	Esc. Marx Creek		36,303	25,108	147	147	114	112	24,668	95	139.811	7.23%	0.46%	14,605	978
Comb.	1993	Esc. Salmon River		18,485	4,690	12	12	10	10	4,690	10	39.414	2.04%	0.55%	4,117	1,132
Comb.	1993	GN 101-11	26	8,134	3,151	13	13	10	10	3,151	5	12.907	0.67%	0.23%	1,348	474
Comb.	1993	GN 101-11	27	17,054	6,676	40	38	29	29	6,342	13	34.957	1.81%	0.39%	3,652	811
Comb.	1993	GN 101-11	28	20,425	9,036	46	44	35	35	8,643	9	21.268	1.10%	0.28%	2,222	567
Comb.	1993	GN 101-11	29	25,649	10,322	53	49	42	42	9,543	4	10.751	0.56%	0.22%	1,123	447
Comb.	1993	GN 101-11	30	36,765	13,422	102	97	79	78	12,602	18	52.511	2.72%	0.51%	5,485	1,064
Comb.	1993	GN 101-11	31	44,607	11,275	66	65	48	48	11,104	15	60.257	3.12%	0.68%	6,295	1,423
Comb.	1993	GN 101-11	32	21,717	8,663	40	38	30	29	7,956	5	13.649	0.71%	0.25%	1,426	510
Comb.	1993	GN 101-11	33	28,917	16,183	61	58	46	45	15,053	12	23.053	1.19%	0.24%	2,408	488
Comb.	1993	GN 101-11	34	28,783	11,283	42	40	34	34	10,746	9	24.107	1.25%	0.33%	2,518	670
Comb.	1993	GN 101-11	35	48,829	18,846	102	100	89	89	18,476	5	13.214	0.68%	0.24%	1,380	489
Comb.	1993	GN 101-11	36	33,869	12,468	97	97	92	92	12,468	1	2.716	0.14%	0.11%	284	226
Comb.	1993	GN NN-3	26	3,682	985	6	6	3	3	985	1	3.738	0.19%	0.17%	390	334
Comb.	1993	GN NN-3	28	27,996	5,340	30	29	14	14	5,162	8	43.388	2.24%	0.70%	4,532	1,454
Comb.	1993	GN NN-3	29	9,914	3,085	20	20	14	14	3,085	7	22.495	1.16%	0.36%	2,350	741
Comb.	1993	GN NN-3	31	9,534	1,300	2	2	2	2	1,300	2	14.668	0.76%	0.50%	1,532	1,008
Comb.	1993	GN NN-3	32	5,573	3,888	12	11	8	8	3,564	5	7.818	0.40%	0.11%	817	221
Comb.	1993	GN NN-3	33	7,642	3,115	8	8	4	4	3,115	3	7.360	0.38%	0.17%	769	343
Comb.	1993	GN NN-3	34	14,681	7,557	18	18	13	13	7,557	12	23.312	1.21%	0.24%	2,435	496
Comb.	1993	GN NN-3	35	29,362	1,722	3	3	3	3	1,722	2	34.102	1.76%	1.19%	3,562	2,446
Comb.	1993	GN NN-3	36	16,132	8,411	40	40	30	30	8,411	14	26.852	1.39%	0.26%	2,805	527

Appendix 6. (1993 continued)

Age Class	Year	Stratum (***h***)	Stat Week	Catch N_h	Sample n_h	Clips Obs. ***a***	Heads Rec. ***a'***	Tags Det. ***t***	Tags Dec. ***t'***	Effective Sample n'_h	Fish Cr Tags n_{hj}	Expanded Tags Y_j	Exploitation Rate ***R***	SE(***R***)	Contribution C_j	SE(C_j)
Comb.	1993	GN NN-3	37	1,699	1,095	4	4	4	4	1,095	3	4.655	0.24%	0.08%	486	168
Comb.	1993	GN NN-4	27	9,094	1,376	4	4	3	3	1,376	3	19.827	1.03%	0.54%	2,071	1,103
Comb.	1993	GN NN-4	28	33,864	9,416	34	34	21	21	9,416	6	21.579	1.12%	0.38%	2,254	785
Comb.	1993	GN NN-4	29	42,304	10,663	41	40	20	20	10,403	5	20.333	1.05%	0.41%	2,124	828
Comb.	1993	GN NN-4	30	26,033	9,783	28	27	19	19	9,434	7	19.317	1.00%	0.30%	2,018	613
Comb.	1993	GN NN-4	31	30,562	6,686	10	10	6	6	6,686	2	9.142	0.47%	0.29%	955	598
Comb.	1993	GN NN-4	34	2,613	1,363	1	1	1	1	1,363	1	1.917	0.10%	0.07%	200	139
Comb.	1993	GN NN-5	33	741	285	1	1	1	1	285	1	2.600	0.13%	0.11%	272	213
Comb.	1993	SN 101	29	20,232	3,735	7	6	5	5	3,201	1	6.320	0.33%	0.30%	660	606
Comb.	1993	SN 101	30	52,368	17,000	43	39	29	29	15,419	2	6.793	0.35%	0.21%	710	422
Comb.	1993	SN 101	31	70,695	22,398	54	52	44	44	21,568	2	6.555	0.34%	0.20%	685	404
Comb.	1993	SN 102	29	6,149	4,211	11	9	7	7	3,445	1	1.785	0.09%	0.06%	186	124
Comb.	1993	SN 103	34	22,857	1,847	2	2	1	1	1,847	1	12.375	0.64%	0.61%	1,293	1,240
Comb.	1993	SN 104	28	63,295	19,728	70	69	51	51	19,446	11	35.804	1.85%	0.46%	3,740	947
Comb.	1993	SN 104	29	24,061	10,975	27	26	20	20	10,569	4	9.107	0.47%	0.18%	951	358
Comb.	1993	SN 104	30	71,879	40,169	93	88	53	53	38,009	7	13.238	0.68%	0.18%	1,383	362
Comb.	1993	SN 104	31	175,911	64,895	134	126	75	75	61,021	14	40.359	2.09%	0.45%	4,216	921
Comb.	1993	SN 104	32	112,574	44,578	82	82	48	48	44,578	11	27.779	1.44%	0.34%	2,902	687
Comb.	1993	SN 104	33	36,229	6,952	16	16	9	9	6,952	1	5.211	0.27%	0.24%	544	490
Comb.	1993	SN 104	34	26,033	11,479	15	15	9	9	11,479	1	2.268	0.12%	0.09%	237	177
Comb.	1993	SN 105	35	4,304	667	1	1	1	1	667	1	6.453	0.33%	0.31%	674	620
Comb.	1993	SN NN-3	30	36,075	7,582	45	43	30	30	7,245	8	39.834	2.06%	0.64%	4,161	1,322
Comb.	1993	SN NN-3	31	143,494	33,591	167	165	119	116	32,352	62	274.994	14.22%	1.42%	28,727	3,350
Comb.	1993	SN NN-3	32	48,735	16,774	48	48	24	24	16,774	11	31.959	1.65%	0.40%	3,339	823
Comb.	1993	SN NN-3	33	23,488	11,501	44	43	29	29	11,240	19	39.705	2.05%	0.34%	4,148	701
Comb.	1993	SN NN-3	34	5,536	4,836	11	11	10	10	4,836	7	8.013	0.41%	0.06%	837	116
Comb.	1993	SN NN-3	35	25,059	18,005	44	44	32	32	18,005	15	20.877	1.08%	0.15%	2,181	307
Comb.	1993	SN NN-3	36	11,058	6,384	22	22	17	17	6,384	2	3.464	0.18%	0.08%	362	167
Comb.	1993	SN NN-4	30	22,614	5,448	18	18	9	9	5,448	2	8.302	0.43%	0.26%	867	535
Comb.	1993	SN NN-4	31	6,818	1,466	8	8	4	4	1,466	1	4.651	0.24%	0.21%	486	431
Comb.	1993	TR 104	35	1,405	329	1	1	1	1	329	1	4.271	0.22%	0.19%	446	391
Comb.	1993	TR NTR-1	28	4,884	1,526	2	2	2	2	1,526	2	6.401	0.33%	0.19%	669	393
Comb.	1993	TR NTR-3	29	4,689	2,567	7	7	3	3	2,567	1	1.827	0.09%	0.06%	191	129
Comb.	1993	TR NTR-3	30	7,792	3,081	3	3	2	2	3,081	1	2.529	0.13%	0.10%	264	206
Comb.	1993	TR NTR-3	33	2,261	964	4	4	3	3	964	1	2.345	0.12%	0.09%	245	186

Appendix 7. Fish Creek chum salmon coded-wire-tag recoveries and associated statistics, by age class and by all ages combined, 1994.

Note: SN = seine, GN = gillnet, TR = troll, NN = B.C. northern net, NTR = B.C. northern troll, and Age Class Comb. = All tags combined regardless of age class.

Age Class	Year	Stratum (***h***)	Stat Week	Catch N_h	Sample n_h	Clips Obs. a	Heads Rec. a'	Tags Det. t	Tags Dec. t'	Effective Sample n'_h	Fish Cr Tags n_{hj}	Expanded Tags Y_j	Exploitation Rate R	Exploitation Rate SE(R)	Contribution C_j	Contribution SE(C_j)
0.3	1994	Esc. Fish Creek		32,322	24,402	369	367	268	268	24,270	131	174.463	40.33%	3.18%	15,856	519
0.3	1994	Esc. Marx Creek		9,535	3,701	38	38	30	29	3,578	8	21.321	4.93%	1.36%	1,938	551
0.3	1994	Esc. Salmon River		2,453	733	12	12	9	9	733	6	20.079	4.64%	1.55%	1,825	629
0.3	1994	GN 101-11	26	67,392	23,726	67	66	49	49	23,372	1	2.883	0.67%	0.54%	262	212
0.3	1994	GN 101-11	27	64,182	21,373	68	67	52	52	21,059	3	9.143	2.11%	0.99%	831	395
0.3	1994	GN 101-11	28	48,379	16,121	68	63	54	54	14,936	4	12.957	2.99%	1.23%	1,178	493
0.3	1994	GN 101-11	29	51,666	22,457	60	60	50	50	22,457	6	13.804	3.19%	0.98%	1,255	391
0.3	1994	GN 101-11	30	35,671	14,054	39	38	35	35	13,694	2	5.210	1.20%	0.67%	474	264
0.3	1994	GN 101-11	33	22,411	7,007	37	37	32	31	6,788	3	9.905	2.29%	1.09%	900	436
0.3	1994	GN 101-11	34	15,125	5,394	25	24	18	18	5,178	1	2.921	0.68%	0.55%	265	216
0.3	1994	GN MIC	27	17,177	15,725	25	24	20	20	15,096	1	1.138	0.26%	0.09%	103	36
0.3	1994	GN MIC	34	1,973	1,619	2	2	2	2	1,619	1	1.219	0.28%	0.12%	111	47
0.3	1994	GN NN-3	25	4,808	1,035	8	8	7	7	1,035	1	4.645	1.07%	0.94%	422	374
0.3	1994	GN NN-3	29	53,284	4,030	10	10	10	10	4,030	3	39.666	9.17%	4.65%	3,605	2,008
0.3	1994	GN NN-3	30	19,563	2,056	5	5	5	5	2,056	1	9.515	2.20%	2.04%	865	819
0.3	1994	GN NN-3	32	8,631	1,840	3	3	3	3	1,840	1	4.691	1.08%	0.95%	426	378
0.3	1994	GN NN-3	35	6,282	2,299	8	8	8	8	2,299	1	2.732	0.63%	0.50%	248	198
0.3	1994	GN NN-4	28	21,208	4,619	17	17	10	10	4,619	4	18.366	4.25%	1.82%	1,669	743
0.3	1994	GN NN-4	30	48,163	18,977	65	65	29	29	18,977	2	5.076	1.17%	0.64%	461	255
0.3	1994	GN NN-4	31	32,347	8,697	30	30	22	22	8,697	3	11.158	2.58%	1.26%	1,014	503
0.3	1994	SN 104	28	44,332	14,988	47	46	38	38	14,669	1	3.022	0.70%	0.57%	275	225
0.3	1994	SN 104	29	60,863	20,710	44	43	34	34	20,239	1	3.007	0.70%	0.57%	273	224
0.3	1994	SN 104	30	64,265	26,818	57	55	44	44	25,877	3	7.450	1.72%	0.77%	677	304
0.3	1994	SN 104	31	100,464	40,155	81	81	58	58	40,155	3	7.506	1.73%	0.77%	682	307
0.3	1994	SN 104	32	151,266	23,374	35	34	22	22	22,706	1	6.662	1.54%	1.40%	605	559
0.3	1994	SN NN-3	30	39,778	10,984	48	48	36	36	10,984	4	14.486	3.35%	1.40%	1,317	564
0.3	1994	SN NN-3	31	35,868	11,426	25	25	14	14	11,426	3	9.417	2.18%	1.03%	856	410
0.3	1994	SN NN-3	32	15,109	5,909	25	25	17	16	5,561	1	2.717	0.63%	0.50%	247	197
0.3	1994	SN NN-3	33	13,168	10,119	25	23	16	16	9,309	1	1.414	0.33%	0.18%	129	70
0.3	1994	SN NN-5	32	850	422	3	3	3	3	422	1	2.014	0.47%	0.33%	183	130
0.3	1994	TR 104	29	688	290	4	4	3	3	290	1	2.372	0.55%	0.42%	216	164
0.3	1994	TR NTR-3	28	767	456	2	2	2	2	456	1	1.682	0.39%	0.25%	153	98
0.4	1994	Esc. Fish Creek		32,322	24,402	369	367	268	268	24,270	134	178.459	33.55%	3.01%	15,951	520
0.4	1994	Esc. Marx Creek		9,535	3,701	38	38	30	29	3,578	21	55.969	10.52%	1.85%	5,003	901
0.4	1994	Esc. Salmon River		2,453	733	12	12	9	9	733	3	10.040	1.89%	0.91%	897	435
0.4	1994	GN 101-11	26	67,392	23,726	67	66	49	49	23,372	9	25.951	4.88%	1.32%	2,320	637
0.4	1994	GN 101-11	27	64,182	21,373	68	67	52	52	21,059	8	24.382	4.58%	1.33%	2,179	642
0.4	1994	GN 101-11	28	48,379	16,121	68	63	54	54	14,936	4	12.957	2.44%	1.01%	1,158	485
0.4	1994	GN 101-11	29	51,666	22,457	60	60	50	50	22,457	4	9.203	1.73%	0.66%	823	312
0.4	1994	GN 101-11	30	35,671	14,054	39	38	35	35	13,694	2	5.210	0.98%	0.54%	466	259
0.4	1994	GN 101-11	33	22,411	7,007	37	37	32	31	6,788	2	6.603	1.24%	0.73%	590	350
0.4	1994	GN 101-11	34	15,125	5,394	25	24	18	18	5,178	1	2.921	0.55%	0.45%	261	212
0.4	1994	GN 101-11	35	34,512	18,904	69	69	51	51	18,904	1	1.826	0.34%	0.23%	163	110
0.4	1994	GN 106	26	4,881	1,459	10	10	9	9	1,459	1	3.345	0.63%	0.53%	299	251
0.4	1994	GN MIC	29	13,701	12,148	16	16	11	11	12,148	1	1.128	0.21%	0.07%	101	34
0.4	1994	GN NN-3	25	4,808	1,035	8	8	7	7	1,035	3	13.936	2.62%	1.32%	1,246	639
0.4	1994	GN NN-3	28	31,067	2,144	9	9	7	7	2,144	5	72.451	13.62%	5.14%	6,476	2,811
0.4	1994	GN NN-3	29	53,284	4,030	10	10	10	10	4,030	2	26.444	4.97%	3.24%	2,364	1,610
0.4	1994	GN NN-3	35	6,282	2,299	8	8	8	8	2,299	1	2.732	0.51%	0.41%	244	195
0.4	1994	GN NN-4	27	10,789	738	4	4	2	2	738	1	14.619	2.75%	2.59%	1,307	1,262
0.4	1994	GN NN-4	28	21,208	4,619	17	17	10	10	4,619	1	4.591	0.86%	0.76%	410	363

Appendix 7. (1993 continued)

Age Class	Year	Stratum (h)	Stat Week	Catch N_h	Sample n_h	Clips Obs. a	Heads Rec. a'	Tags Det. t	Tags Dec. t'	Effective Sample n'_h	Fish Cr Tags n_{hj}	Expanded Tags Y_j	Exploitation Rate R	SE(R)	Contribution C_j	SE(C_j)
0.4	1994	GN NN-4	30	48,163	18,977	65	65	29	29	18,977	1	2.538	0.48%	0.37%	227	177
0.4	1994	GN NN-4	31	32,347	8,697	30	30	22	22	8,697	2	7.439	1.40%	0.84%	665	403
0.4	1994	SN 104	28	44,332	14,988	47	46	38	38	14,669	2	6.044	1.14%	0.66%	540	313
0.4	1994	SN 104	29	60,863	20,710	44	43	34	34	20,239	1	3.007	0.57%	0.46%	269	220
0.4	1994	SN 104	30	64,265	26,818	57	55	44	44	25,877	1	2.483	0.47%	0.36%	222	172
0.4	1994	SN 104	31	100,464	40,155	81	81	58	58	40,155	1	2.502	0.47%	0.37%	224	173
0.4	1994	SN 104	32	151,266	23,374	35	34	22	22	22,706	2	13.324	2.51%	1.61%	1,191	778
0.4	1994	SN NN-3	30	39,778	10,984	48	48	36	36	10,984	4	14.486	2.72%	1.15%	1,295	555
0.4	1994	SN NN-3	31	35,868	11,426	25	25	14	14	11,426	1	3.139	0.59%	0.49%	281	232
0.4	1994	SN NN-3	32	15,109	5,909	25	25	17	16	5,561	1	2.717	0.51%	0.41%	243	193
0.4	1994	SN NN-3	33	13,168	10,119	25	23	16	16	9,309	1	1.414	0.27%	0.15%	126	69
0.5	1994	Esc. Fish Creek		32,322	24,402	369	367	268	268	24,270	3	3.995	77.91%	7.71%	433	117
0.5	1994	Esc. Marx Creek		9,535	3,701	38	38	30	29	3,578	0	0.000	0.00%	0.00%	0	0
0.5	1994	Esc. Salmon River		2,453	733	12	12	9	9	733	0	0.000	0.00%	0.00%	0	0
0.5	1994	GN MIC	32	2,171	1,916	3	3	3	3	1,916	1	1.133	22.09%	7.71%	123	61
Comb.	1994	Esc. Fish Creek		32,322	24,402	369	367	268	268	24,270	268	356.918	36.81%	2.22%	32,322	0
Comb.	1994	Esc. Marx Creek		9,535	3,701	38	38	30	29	3,578	29	77.290	7.97%	1.17%	6,999	1,045
Comb.	1994	Esc. Salmon River		2,453	733	12	12	9	9	733	9	30.119	3.11%	0.85%	2,728	762
Comb.	1994	GN 101-11	26	67,392	23,726	67	66	49	49	23,372	10	28.835	2.97%	0.76%	2,611	672
Comb.	1994	GN 101-11	27	64,182	21,373	68	67	52	52	21,059	11	33.525	3.46%	0.85%	3,036	756
Comb.	1994	GN 101-11	28	48,379	16,121	68	63	54	54	14,936	8	25.913	2.67%	0.78%	2,347	693
Comb.	1994	GN 101-11	29	51,666	22,457	60	60	50	50	22,457	10	23.007	2.37%	0.57%	2,083	499
Comb.	1994	GN 101-11	30	35,671	14,054	39	38	35	35	13,694	4	10.420	1.07%	0.42%	944	371
Comb.	1994	GN 101-11	33	22,411	7,007	37	37	32	31	6,788	5	16.508	1.70%	0.63%	1,495	560
Comb.	1994	GN 101-11	34	15,125	5,394	25	24	18	18	5,178	2	5.842	0.60%	0.35%	529	304
Comb.	1994	GN 101-11	35	34,512	18,904	69	69	51	51	18,904	1	1.826	0.19%	0.13%	165	111
Comb.	1994	GN 106	26	4,881	1,459	10	10	9	9	1,459	1	3.345	0.35%	0.29%	303	254
Comb.	1994	GN MIC	27	17,177	15,725	25	24	20	20	15,096	1	1.138	0.12%	0.04%	103	36
Comb.	1994	GN MIC	29	13,701	12,148	16	16	11	11	12,148	1	1.128	0.12%	0.04%	102	35
Comb.	1994	GN MIC	32	2,171	1,916	3	3	3	3	1,916	1	1.133	0.12%	0.04%	103	35
Comb.	1994	GN MIC	34	1,973	1,619	2	2	2	2	1,619	1	1.219	0.13%	0.05%	110	47
Comb.	1994	GN NN-3	25	4,808	1,035	8	8	7	7	1,035	4	18.582	1.92%	0.84%	1,683	746
Comb.	1994	GN NN-3	28	31,067	2,144	9	9	7	7	2,144	5	72.451	7.47%	3.00%	6,561	2,835
Comb.	1994	GN NN-3	29	53,284	4,030	10	10	10	10	4,030	5	66.109	6.82%	2.75%	5,987	2,579
Comb.	1994	GN NN-3	30	19,563	2,056	5	5	5	5	2,056	1	9.515	0.98%	0.92%	862	816
Comb.	1994	GN NN-3	32	8,631	1,840	3	3	3	3	1,840	1	4.691	0.48%	0.43%	425	377
Comb.	1994	GN NN-3	35	6,282	2,299	8	8	8	8	2,299	2	5.465	0.56%	0.32%	495	279
Comb.	1994	GN NN-4	27	10,789	738	4	4	2	2	738	1	14.619	1.51%	1.44%	1,324	1,278
Comb.	1994	GN NN-4	28	21,208	4,619	17	17	10	10	4,619	5	22.957	2.37%	0.92%	2,079	824
Comb.	1994	GN NN-4	30	48,163	18,977	65	65	29	29	18,977	3	7.614	0.79%	0.35%	690	311
Comb.	1994	GN NN-4	31	32,347	8,697	30	30	22	22	8,697	5	18.597	1.92%	0.73%	1,684	646
Comb.	1994	SN 104	28	44,332	14,988	47	46	38	38	14,669	3	9.066	0.94%	0.44%	821	389
Comb.	1994	SN 104	29	60,863	20,710	44	43	34	34	20,239	2	6.014	0.62%	0.36%	545	315
Comb.	1994	SN 104	30	64,265	26,818	57	55	44	44	25,877	4	9.934	1.02%	0.40%	900	349
Comb.	1994	SN 104	31	100,464	40,155	81	81	58	58	40,155	4	10.008	1.03%	0.40%	906	352
Comb.	1994	SN 104	32	151,266	23,374	35	34	22	22	22,706	3	19.986	2.06%	1.08%	1,810	965
Comb.	1994	SN NN-3	30	39,778	10,984	48	48	36	36	10,984	8	28.972	2.99%	0.89%	2,624	793
Comb.	1994	SN NN-3	31	35,868	11,426	25	25	14	14	11,426	4	12.557	1.29%	0.53%	1,137	471
Comb.	1994	SN NN-3	32	15,109	5,909	25	25	17	16	5,561	2	5.434	0.56%	0.31%	492	277
Comb.	1994	SN NN-3	33	13,168	10,119	25	23	16	16	9,309	2	2.829	0.29%	0.11%	256	98
Comb.	1994	SN NN-5	32	850	422	3	3	3	3	422	1	2.014	0.21%	0.15%	182	130
Comb.	1994	TR 104	29	688	290	4	4	3	3	290	1	2.372	0.24%	0.19%	215	164
Comb.	1994	TR NTR-3	28	767	456	2	2	2	2	456	1	1.682	0.17%	0.11%	152	97

Appendix 8. Fish Creek chum salmon coded-wire-tag recoveries and associated statistics, by age class and by all ages combined, 1995.

Note: SN = seine, GN = gillnet, TR = troll, NN = B.C. northern net, NTR = B.C. northern troll, and Age Class Comb. = All tags combined regardless of age class.

Age Class	Year	Stratum (***h***)	Stat Week	Catch N_h	Sample n_h	Clips Obs. ***a***	Heads Rec. ***a'***	Tags Det. ***t***	Tags Dec. ***t'***	Effective Sample n'_h	Fish Cr Tags n_{hj}	Expanded Tags Y_j	Exploitation Rate ***R***	SE(***R***)	Contribution C_j	SE(C_j)
0.4	1995	Esc. Fish Creek		9,742	9,360	114	113	55	55	9,278	50	52.501	25.86%	2.99%	7,459	189
0.4	1995	Esc. Marx Creek		1,054	153	2	2	2	2	153	2	13.778	6.79%	4.18%	1,957	1,277
0.4	1995	GN 101-11	25	33,959	12,753	19	18	15	15	12,082	4	11.243	5.54%	2.19%	1,597	644
0.4	1995	GN 101-11	26	37,226	11,848	36	35	28	28	11,519	1	3.232	1.59%	1.31%	459	382
0.4	1995	GN 101-11	27	47,558	15,731	73	60	44	44	12,930	3	11.035	5.43%	2.60%	1,568	774
0.4	1995	GN 101-11	28	34,896	16,029	67	63	53	53	15,072	3	6.946	3.42%	1.49%	987	431
0.4	1995	GN 101-11	29	20,675	12,145	47	45	35	35	11,628	3	5.334	2.63%	1.02%	758	291
0.4	1995	GN 101-11	30	60,448	25,010	82	80	67	67	24,400	2	4.955	2.44%	1.33%	704	385
0.4	1995	GN 101-11	31	26,852	8,693	32	32	20	20	8,693	1	3.089	1.52%	1.24%	439	361
0.4	1995	GN 106	31	29,087	12,719	19	19	13	13	12,719	1	2.287	1.13%	0.85%	325	244
0.4	1995	GN NN-3	25	9,726	4,297	14	14	8	8	4,297	2	4.527	2.23%	1.18%	643	340
0.4	1995	GN NN-3	27	43,080	4,499	12	10	5	5	3,749	1	11.491	5.66%	5.13%	1,633	1,560
0.4	1995	GN NN-3	31	7,885	1,481	3	3	2	2	1,481	1	5.324	2.62%	2.32%	756	682
0.4	1995	GN NN-4	28	26,909	8,998	24	24	14	14	8,998	5	14.953	7.36%	2.62%	2,124	779
0.4	1995	SN 101	32	55,351	9,626	17	17	12	12	9,626	1	5.750	2.83%	2.52%	817	743
0.4	1995	SN NN-3	29	51,041	9,552	38	37	21	21	9,301	2	10.976	5.41%	3.32%	1,559	998
0.4	1995	SN NN-3	30	71,144	18,195	41	41	29	29	18,195	7	27.371	13.48%	4.06%	3,889	1,276
0.4	1995	SN NN-3	32	35,162	8,521	13	13	9	9	8,521	2	8.253	4.06%	2.44%	1,173	723
0.5	1995	Esc. Fish Creek		9,742	9,360	114	113	55	55	9,278	5	5.250	27.24%	8.85%	634	123
0.5	1995	Esc. Marx Creek		1,054	153	2	2	2	2	153	0	0.000	0.00%	0.00%	0	0
0.5	1995	GN NN-3	25	9,726	4,297	14	14	8	8	4,297	1	2.263	11.74%	8.54%	273	205
0.5	1995	SN 104	32	160,570	45,343	31	30	11	11	43,880	1	3.659	18.98%	14.10%	442	374
0.5	1995	SN NN-3	30	71,144	18,195	41	41	29	29	18,195	1	3.910	20.28%	14.96%	472	404
0.5	1995	SN NN-3	33	32,249	7,690	10	10	6	6	7,690	1	4.194	21.76%	15.86%	506	438
Comb.	1995	Esc. Fish Creek		9,742	9,360	114	113	55	55	9,278	55	57.751	25.98%	2.84%	9,742	0
Comb.	1995	Esc. Marx Creek		1,054	153	2	2	2	2	153	2	13.778	6.20%	3.84%	2,324	1,516
Comb.	1995	GN 101-11	25	33,959	12,753	19	18	15	15	12,082	4	11.243	5.06%	2.00%	1,897	763
Comb.	1995	GN 101-11	26	37,226	11,848	36	35	28	28	11,519	1	3.232	1.45%	1.20%	545	453
Comb.	1995	GN 101-11	27	47,558	15,731	73	60	44	44	12,930	3	11.035	4.96%	2.38%	1,861	919
Comb.	1995	GN 101-11	28	34,896	16,029	67	63	53	53	15,072	3	6.946	3.12%	1.36%	1,172	511
Comb.	1995	GN 101-11	29	20,675	12,145	47	45	35	35	11,628	3	5.334	2.40%	0.93%	900	345
Comb.	1995	GN 101-11	30	60,448	25,010	82	80	67	67	24,400	2	4.955	2.23%	1.21%	836	457
Comb.	1995	GN 101-11	31	26,852	8,693	32	32	20	20	8,693	1	3.089	1.39%	1.14%	521	429
Comb.	1995	GN 106	31	29,087	12,719	19	19	13	13	12,719	1	2.287	1.03%	0.77%	386	290
Comb.	1995	GN NN-3	25	9,726	4,297	14	14	8	8	4,297	3	6.790	3.05%	1.32%	1,145	495
Comb.	1995	GN NN-3	27	43,080	4,499	12	10	5	5	3,749	1	11.491	5.17%	4.71%	1,938	1,853
Comb.	1995	GN NN-3	31	7,885	1,481	3	3	2	2	1,481	1	5.324	2.39%	2.12%	898	810
Comb.	1995	GN NN-4	28	26,909	8,998	24	24	14	14	8,998	5	14.953	6.73%	2.39%	2,522	923
Comb.	1995	SN 101	32	55,351	9,626	17	17	12	12	9,626	1	5.750	2.59%	2.31%	970	882
Comb.	1995	SN 104	32	160,570	45,343	31	30	11	11	43,880	1	3.659	1.65%	1.39%	617	527
Comb.	1995	SN NN-3	29	51,041	9,552	38	37	21	21	9,301	2	10.976	4.94%	3.04%	1,851	1,185
Comb.	1995	SN NN-3	30	71,144	18,195	41	41	29	29	18,195	8	31.281	14.07%	3.94%	5,277	1,617
Comb.	1995	SN NN-3	32	35,162	8,521	13	13	9	9	8,521	2	8.253	3.71%	2.23%	1,392	858
Comb.	1995	SN NN-3	33	32,249	7,690	10	10	6	6	7,690	1	4.194	1.89%	1.63%	707	618

Appendix 9. Weekly foot survey counts and estimated total escapements of chum salmon at Marx Creek and the Salmon River, 1992-1995.

	Mid-week Date	Marx Creek 1992	1993	1994	1995	Salmon River 1993	1994
	2-Jul				3		
	9-Jul	2	2	7	17		
	16-Jul	34	4	82	98		214
	23-Jul	154	104	323	264		**338**
	30-Jul	384	**845**	827	333		462
	6-Aug	621	1,585	1,369	245		897
	13-Aug	1,001	3,592	2,408	144		549
	20-Aug	4,105	7,191	1,989	106		651
	27-Aug	4,241	**7,610**	3,073	56		533
	3-Sep	6,186	8,028	2,049	63		
	10-Sep	4,648	7,663	850	41		
	17-Sep	3,180	7,994	586	19	18,485	
	24-Sep	635	**5,366**	255	19		
	1-Oct	551	2,736	158	8		
	8-Oct	276	857	115			
	15-Oct	84	249	75			
	22-Oct	39	110				
	SUM =	26,141	53,936	14,166	1,416	18,485	3,644
Fish Days (Total x 7) =		182,987	377,552	99,162	9,912		25,508
Stream Life[a] =		10.4	10.4	10.4	9.4		10.4
AUC Escapement Estimate (Fish Days / Stream Life) =		17,595	36,303	9,535	1,054	18,485[b]	2,453

[a] The 1992-1994 AUC escapement estimates were calculated using the 1992 Fish Creek chum salmon mean stream life of 10.4 days. The 1995 escapement estimate was calculated using the 1995 Fish Creek chum salmon mean stream life of 9.4 days.

[b] The 1993 escapement estimate for the Salmon River is the peak live+dead count from foot surveys conducted 1.5 to 6.0 miles upstream of the river mouth, September 15-22, 1993.

Bold surveys are interpolated estimates for missed surveys, calculated by taking the average of the preceding and following surveys.

Appendix 10. Summary of the foot survey counts of live Fish Creek chum salmon and estimated total spawning escapements from 1971 to 1999.

Year	Survey Period[a] 1	2	3	Sum of Surveys	Estimated Escapement	95% Prediction Interval -	+
1971	**2,632**	**3,503**	3,600	9,734	20,374	13,854	29,962
1972	**4,884**	6,500	**6,681**	18,065	37,810	25,710	55,603
1973	**2,404**	3,200	**3,289**	8,893	18,614	12,657	27,374
1974	**3,648**	**4,855**	4,990	13,493	28,241	19,203	41,531
1975	**4,599**	6,120	**6,290**	17,009	35,599	24,207	52,353
1976	2,000	1,955	4,249	8,204	17,171	11,676	25,252
1977	**1,999**	**2,660**	2,734	7,393	15,473	10,522	22,755
1978	**951**	1,149	1,418	3,518	7,364	5,007	10,829
1979	**8,466**	**11,268**	11,581	31,315	65,542	44,568	96,387
1980	**2,496**	1,785	4,951	9,232	19,323	13,139	28,416
1981	**1,314**	**1,748**	1,797	4,859	10,170	6,916	14,956
1982	**1,513**	**2,013**	2,069	5,595	11,709	7,962	17,220
1983	**1,232**	2,265	1,059	4,556	9,535	6,484	14,022
1984	2,554	**2,693**	2,237	7,484	15,664	10,651	23,035
1985	1,918	**3,639**	4,556	10,113	21,166	14,393	31,127
1986	**3,871**	4,844	5,604	14,319	29,971	20,380	44,075
1987	2,327	**10,346**	16,080	28,753	60,179	40,921	88,500
1988	8,255	**11,154**	11,591	31,000	64,884	44,120	95,419
1989	2,382	7,165	7,433	16,980	35,539	24,166	52,264
1990	2,288	**2,637**	2,403	7,328	15,337	10,429	22,554
1991[b]	2,075	1,817	946	4,838	10,126[c]	6,886	14,891
1992[b]	6,375	5,941	8,731	21,047	44,051[c]	29,955	64,782
1993	11,388	14,620	4,820	30,828	64,523[c]	43,875	94,888
1994	4,686	4,500	3,590	12,776	26,740[c]	18,183	39,324
1995	3,667	1,300	305	5,272	11,034[c]	7,503	16,227
1996	**1,927**	2,564	**2,635**	7,126	14,914	10,142	21,933
1997	**363**	483	**496**	1,342	2,810	1,910	4,132
1998	**3,441**	**4,580**	4,707	12,728	26,639	18,114	39,176
1999	1,380	335	815	2,530	5,350	7,751	3,692
Spearman's rho rank correlation trend test[d]:				rho	-0.1759		
				α	0.3615		
				N	29		

[a] Bold entries represent interpolations for missing surveys. (See Table 10 for survey dates). Survey 1 includes dead counts.

[b] The cumulative weir counts through 5 August were substituted for missing foot surveys for Survey Period 1 in 1991 and 1992.

[c] The weir counts for these years were 9,996 (1991), 46,971 (1992), 60,447 (1993), 32,322 (1994), and 9,742 (1995), and are the escapement counts used for those years, not the estimated escapement numbers shown on this table.

[d] From Conover 1980.