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1993 Juvenile and Adult Coho Salmon Enumeration Studies at Black Creek, Vancouver Island

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Canadian Manuscript Report of
Fisheries and Aquatic Sciences 2291

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1993 JUVENILE AND ADULT COHO SALMON
ENUMERATION STUDIES
AT BLACK CREEK, VANCOUVER ISLAND

by

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ABSTRACT

Nelson, T. C., R. E. Bailey, and J. R. Irvine. 1995. 1993 juvenile and adult coho salmon enumeration studies at Black Creek, Vancouver Island. Can. Manuscr. Rep. Fish. Aquat. Sci. 2291: x + 74 p.

Coho smolts leaving Black Creek between April 23 and June 15, 1993 were trapped, adipose clipped, and coded-wire tagged (marked). A total of 56,078 smolts were captured at an enumeration fence and 55,565 of these (99.1%) were marked and released downstream. Two flood events occurred during the study in 1993; the total number of smolts estimated (by linear interpolation) to have migrated past the fence site unmarked and uncounted during the flood events was 9,093. It is likely that some additional unmarked smolts emigrated from Black Creek uncounted. A low number of coho fry (143) were caught in 1993, and 138 (96.5%) of these were successfully adipose clipped, tagged with half-length coded-wire tags, and released. Smolt mortalities due to trapping and tagging were low (0.36%). All smolt data were stratified into three predetermined sampling periods. The calculated freshwater age structure of Black Creek smolts was 85.4% age 1 and 14.6% age 2. Most of the age-2 smolts (91.3%) migrated during the first sampling period. Both the length and weight of migrating age-1 smolts decreased significantly between both the first and second sampling period and the second and third sampling period. There were no significant differences between the ratios of male and female smolts among sampling periods and for all sampling periods combined.

Coho escapements to Black Creek in 1993 were monitored by an adult enumeration fence operated between October 22 and December 9, and by conducting mark-recapture, carcass, and area-under-the-curve (AUC) visual surveys upstream of the fence from December 6-27. Escapement estimates for adult and jack coho were derived using three methods: 1) a pooled Petersen estimate (adults 959, jacks 1,502); 2) the AUC method (adults 847, jacks 968); and 3) the minimum (known) number of fish in the system above the enumeration fence (adults 917, jacks 1,389). The mean postorbital-hypural lengths of adult male, female, and jack coho were 43.4 cm, 50.8 cm, and 25.9 cm, respectively. Female coho were significantly larger than adult male coho. Adult males significantly outnumbered females; the total number of males (adult plus jack) outnumbered females by more than 5:1. A slight majority of adults (55.8%) spent one year in freshwater, whereas a high proportion of jacks (85.2% spent) one year in freshwater.

RÉSUMÉ

Nelson, T. C., R. E. Bailey, and J. R. Irvine. 1995. 1993 juvenile and adult coho salmon enumeration studies at Black Creek, Vancouver Island. Can. Manuscr. Rep. Fish. Aquat. Sci. 2291: x + 74 p.

Les saumons cohos juvéniles qui ont quitté Black Creek entre le 23 avril et le 15 juin 1993 ont été capturés et marqués par coupe de la nageoire adipeuse et insertion d'un fil codé. Au total, 56 078 saumoneaux ont ainsi été capturés à une barrière de dénombrement et 55 565 d'entre eux (99,1 %) ont été marqués et libérés en aval. Il y a eu deux crues pendant l'étude de 1993 et l'on estime que le nombre total de saumoneaux (interpolation linéaire) qui ont contourné la barrière, sans être comptés ou marqués, s'élevait à 9 093. Il est probable que d'autres saumoneaux ont pu s'échapper. Un nombre restreint d'alevins cohos ont été capturés (143) en 1993 et il a été possible d'en marquer 138 (96,5 %) par coupe de la nageoire adipeuse et fixation d'un fil codé coupé en deux. Le taux de mortalité des saumoneaux résultant de la capture et du marquage a été faible (0,36 %). Toutes les données sur les saumoneaux ont été stratifiées selon trois périodes de prélèvement. La structure calculée des âges en eau douce des saumoneaux de Black Creek est de 85,4 % de poissons d'âge 1 et de 14,6 % de poissons d'âge 2. La plupart des saumoneaux d'âge 2 (91,3 %) ont migré pendant la première période de prélèvement. Tant la longueur que le poids des saumoneaux en migration d'âge 1 ont diminué de façon significative entre la première et la deuxième périodes de prélèvement et entre la deuxième et la troisième périodes. Il n'y avait pas d'écart significatif du rapport des sexes des saumoneaux tant entre les périodes de prélèvement que dans l'ensemble des périodes réunies.

Les échappées de cohos qui ont atteint Black Creek en 1993 ont été contrôlées à l'aide d'une barrière de comptage des adultes exploitée du 22 octobre au 9 décembre de même que par marquage-recapture, dénombrement des carcasses et relevés visuels par la méthode de la surface sous la courbe réalisés en amont de la barrière du 6 au 27 décembre. La valeur des échappées d'adultes et de jeunes mâles a été estimée à l'aide de trois méthodes: une estimation de Petersen des valeurs regroupées (959 adultes et 1 502 jeunes mâles); 2) la méthode de la surface sous la courbe (847 adultes et 968 jeunes mâles) et 3) le nombre minimum (connu) de poissons en amont de la barrière de comptage (917 adultes et 1 389 jeunes mâles). Les longueurs moyennes post-orbitaire - hypural des mâles adultes, des femelles adultes et des jeunes mâles étaient, respectivement, de 43,4, 50,8 et 25,9 cm. Les femelles étaient de beaucoup plus grosses que les mâles adultes. Ces derniers étaient beaucoup plus nombreux que les femelles, le nombre total de mâles adultes (et de jeunes mâles) étant au moins cinq fois plus important que celui des femelles. Une faible majorité des adultes (55,8 %) avait passé un an en eau douce tandis que cette valeur était élevée (85,2 %) chez les jeunes mâles.

INTRODUCTION

This report presents results of the coho salmon (*Oncorhynchus kisutch*) smolt enumeration and coded-wire tagging study, and summarizes the adult coho fence count, upstream mark-recapture, and area-under-the-curve (AUC) escapement studies at Black Creek in 1993. The main objectives of the program were to:

- 1) describe the size and age distribution of the coho smolts leaving Black Creek;
- 2) insert full-length coded-wire tags (CWTs) into coho smolts and half-length CWTs into emigrant coho fry;
- 3) obtain results required to examine the relationships between physical environmental factors and smolt and adult migration; smolt migration timing and size and subsequent oceanic harvest distribution; and adult escapement and smolt production;
- 4) estimate numbers of returning salmon and to collect coded-wire tagged heads from these fish; and
- 5) collect data on length, sex, maturity, and age at return.

Achieving these objectives involved the operation of fences to monitor the downstream migration of juvenile salmonids and the upstream movement of maturing salmon, counting all migrants, sampling lengths, weights, and ages of coho, and coded-wire tagging of as large a portion of the coho smolts and emigrant fry as possible. All smolt data were stratified into the three predetermined sampling periods used in Nelson et al. (1994a) and Nelson et al. (1994b), the selection of which was based on data provided in Fielden et al. (1989), Bocking et al. (1991), and Nass et al. (1993a) to characterize the various phases of seaward migration.

STUDY STREAM

Black Creek is a low-gradient (approximately 0.6%) stream on the east coast of Vancouver Island, B.C. (Figure 1). The system is approximately 26 km long, 5-6 m wide in its middle reaches, and has a catchment area of 72.5 km². For most of its length it meanders through agricultural land, small lakes, swampy areas, and

beaver ponds. In the lower watershed, there are several tributaries including Millar Creek. Maximum discharges of $50\text{-}60\text{ m}^3\cdot\text{s}^{-1}$ have been estimated during floods. Black Creek supports populations of coho salmon, cutthroat trout (*O. clarki*), and steelhead trout (*O. mykiss*). Annual escapement estimates for coho are highly variable, ranging from as low as 749 adult spawners in 1987 to 15,000 in earlier years (Hancock and Marshall 1985; Clark and Irvine 1989; Labelle 1990). Coho spawn throughout the watershed, but the best spawning grounds are in Millar Creek, in mainstem areas adjacent to the Sturgess Road Bridge, and in the upper reaches in the vicinity of the Duncan Main logging road (Figure 1). Since 1978, and in those years when it was surveyed, the estimated coho smolt production from Black Creek has varied from a low of 29,776 in 1989 (Bocking et al. 1991) to 119,602 in 1990 (Nass et al. 1993a).

The juvenile and adult fish counting fences were located downstream of the Seaview Road bridge, in Miracle Beach Provincial Park. This location is above tidal influence. For upstream mark-recapture and AUC escapement surveys, the watershed was subdivided into six strata which contained 13 index reaches, each 250 m long (Irvine et al. 1992) (Figure 1). The locations of stratum boundaries were determined by tributary confluences and/or major transitions in stream gradient or some other habitat characteristic, and the index reaches were selected to be representative of the habitat within their stratum.

SPRING FIELD STUDIES

METHODS

Fence Operations

The Black Creek smolt fence was constructed according to methods described by Conlin and Tutty (1979) using wooden-framed panels screened with 6.4 mm mesh steel hardware cloth. It was installed and operated as per Bocking et al. (1991), and Nass et al. (1993a). Plywood holding boxes with Vexar-screened windows to allow water exchange were anchored downstream of the fence to hold sorted fish from the trap boxes. The Black Creek smolt fence and holding facilities were operated from April 23 to June 15, 1993. Two flood events during this period forced crews to open the fence (raise the drop panels) during two periods (April 26-May 3 and May 11-13). Fry traps (1 mm mesh), similar to those used by Northcote (1969), were operated between the fence and the stream margins to

monitor upstream movements of coho fry. A broomstick trap was also operated to capture upstream-migrating adult fish.

Biophysical Monitoring

Weather conditions were monitored daily. Precipitation was ranked on a scale of 0 to 5 with 0 being no precipitation and 5 being heavy precipitation. Percentage cloud cover, wind direction, and wind speed were also noted. Water stage and water temperature were recorded automatically every three hours during the entire year using a Unidata 6003 datalogger. The datalogger was equipped with a Unidata 6508b hydrostatic pressure depth probe (0 to 3 m, +/- 0.012 m) and a 6507a thermistor temperature sensor (-1.2 to 45 °C, +/- 0.2°C). The datalogger was installed approximately 200 m upstream from the Seaview Road bridge, well above the influence of the spring and fall counting fences. Output from the automated datalogger is presented in Figure 2, which illustrates the relationship of daily mean water levels and temperatures throughout 1993.

As a backup to the datalogger data, water temperatures and water levels were manually recorded during the periods of fence operation. Technicians recorded maximum, minimum, and present water temperatures ($\pm 0.5^\circ\text{C}$) at the counting fence each day between 0800 and 0900 h using a max-min thermometer. Water levels were recorded daily using two staff gauges; one gauge was located beneath the Seaview Road Bridge (adjacent to the fence sites) and the other gage was located approximately 200 m upstream at the automated datalogger station. The manually recorded water data are not presented in this report.

Trapping Efficiency

Mark-recapture trials were used to estimate the catch efficiency of the enumeration fence and trap boxes. In 1993, two groups of 100 smolts were anaesthetized using tricaine methane sulphonate (MS-222), given a unique caudal clip, and released between 100 and 200 m upstream of the fence. Throughout the entire trapping period, technicians monitored all smolts captured for recaptures from the trapping efficiency tests. All recaptures were recorded (recapture date, clip location), anaesthetized, adipose clipped, and coded-wire tagged (see **Coded-Wire Tagging** section) prior to release downstream of the fence.

Fish Counts

Each morning, all coho captured since the previous day were counted and sorted into groups based on their size. Coho smolts greater than 70 mm fork length were classified as either small (less than 120 mm in length) or large (greater than or equal to 120 mm in length). All coho less than or equal to 70 mm were categorized as fry. Any mortality due to capture, predation, holding, or tagging was recorded.

All non-coho fish migrating downstream were counted and released below the fence. We assumed that adult cutthroat or steelhead caught in the downstream traps were kelts (spawned out). All fin clips observed on non-coho species were recorded.

Biosampling

Random samples of up to 25 coho fry and 25 coho smolts were selected from each day's catch. These fish were anaesthetized in MS-222, measured to the nearest mm (fork length), and weighed using a Libra 65001 scale (± 0.1 g). Mean lengths and weights were calculated using random samples for all coho juveniles and stratified by age class and sampling period (Bocking et al. 1991; Nass et al. 1993a). Mean lengths and weights between consecutive sampling periods were compared for each age class using t-tests. A mean length and weight for the entire smolt population was calculated from random samples collected across all sampling periods.

Scale sampling procedures followed Ketchen's stratified method (Ricker 1975). During each sampling period (described below) we attempted to collect scale samples from 10 smolts in each 5 mm size class. Scale samples were not collected from coho fry. Smolts of the required sizes were selected from the catch to supplement the random samples when necessary. The calculated age-length distribution was used to determine the proportional representation of each age class within each sampling period; a chi-square test was used to detect differences between these proportions. Ages of smolts based on scale pattern analysis were reported using the European method of age designation, wherein age-1 smolts had one freshwater annulus, age-2 smolts had two freshwater annuli, etc. Scale samples were interpreted by personnel at the Department of Fisheries and Oceans Fish Ageing Laboratory in Nanaimo, B.C.

A total of 149 coho smolts from Black Creek were dissected to determine sex. Most of these fish were either trap or tag mortalities or fish sacrificed to determine CWT placement. Although the samples used for sex determination were

not taken randomly, they were collected throughout the study period to minimize potential biases due to changes in sex ratios over the period of sampling.

Coded-Wire Tagging

Coded-wire tagging was performed by experienced taggers using a Northwest Marine Technology Ltd. (NMT) Mark IV tag injector. An MS-222 bath was used to anaesthetize smolts prior to tagging. The baths were changed regularly and recovery basins were repeatedly flushed with fresh water. All tagged fish were adipose fin clipped.

Since 1988, Black Creek coho smolts have been tagged using different tag codes to differentiate subsequent recoveries by sampling period and size. In 1993, sequential coded-wire tags were used exclusively for smolts to allow the stratification of releases by date. At the beginning and end of each tag code application, tagging technicians secured at least three tags from the spool in a data book. Later, the wire was decoded to provide unique "start" and "stop" sequences for each tag code, by date. In addition, smolts greater than or equal to 120 mm (large) and smolts less than or equal to 120 mm (small) were tagged with different codes. Other data were stratified by the sampling periods used in previous years (up to May 10, May 11-June 02, and June 03 on). The majority of large and small coho were sorted by hand prior to being anaesthetized, but smolts that were close to 120 mm were sorted (measured) while under anaesthesia. The smolts from one of the size categories were then tagged while the other size category was held in a separate holding pen for tagging later in the day. This latter group of smolts included a small number of smolts that were subjected to two anaesthetic baths. No differential mortality was observed between the two size categories over a 24-hour holding period.

In total, there were seven different tag codes used for smolts at Black Creek in 1993. Coho fry were tagged with half-length CWTs, and the same tag code was used for fry tagging in all three sampling periods (Table 1). Tagging was done every day, except in a few instances when fish were held for two days before tagging. All tagged juveniles were transferred to a holding box and allowed to recover fully from the tagging operation before being released.

Tag Retention

There were eight tag retention checks performed on smolts in 1993, six for 24 hours and two for 72 hours. Approximately 100 fish were used for each test. Tag retention tests for fry were not conducted in 1993 due to the low number of fry available.

RESULTS

Biophysical Observations

Daily biophysical measurements are provided in Appendix A. Prior to fence installation, water levels were generally high and water temperatures increasing (Figure 2). The first of two flood events occurred following a substantial increase in water level on April 26. Water levels decreased for ten days following this event, then began to increase on May 6 to flood conditions on May 10. Following this second flood event, water levels decreased through the end of May, then increased moderately through mid-June (Figure 3). During the period of fence operation, water levels ranged from a maximum of 122.7 cm in late April to a minimum of 57.6 cm in late May; water temperatures ranged from a minimum of 9.9° C in late April to a maximum of 17.6° C in late May.

Trapping Efficiency

The trapping efficiency of the fence was tested twice (Table 2). On May 7, 100 coho smolts were upper caudal clipped and released upstream; a total of 89 of this release group were recaptured (89.0%). On May 14, 100 smolts were lower caudal clipped and released upstream; a total of 100 of this release group were recaptured (100.0%).

Fish Counts

Coho Smolts

Total daily catches of juvenile coho are provided in Appendix B. A total of 56,078 coho smolts were counted at the Black Creek fence between April 23 and June 15 (Table 3). During this period, there were 143 pre-tagging mortalities (0.25%) and 310 smolts (0.55%) which either escaped during handling or were released untagged due to injury or poor condition. In addition, an estimated 9,093 smolts (calculated by linear interpolation) migrated past the fence during flood events (Appendix B).

The smolt migration was roughly unimodal (Figure 4). Significant catches began following the first flood event on May 4 and continued through June 10. Peak daily catches were observed following the second flood event on May 14 and 15 (4,368 and 4,356 smolts, respectively), and on May 20 (4,549 smolts). The period of fence operation appeared to cover most of the migration, although it is likely that some number of smolts migrated past the fence site prior to the first day

of fence operation (smolts were captured on April 23, the first day of fence operation), and that some number of smolts migrated following the last day of fence operation (smolts were still leaving the system on June 15, the last day of fence operation).

Coho Fry

Daily catches of coho fry are given in Appendix B. A total of 143 downstream-migrating coho fry were caught at the fence during the study. A total of 31 upstream-migrating coho fry were captured in the fry traps below the fence; all were released above the fence.

Other Species

Daily catches of non-coho are presented in Appendix C and summarized in Table 4. Hatchery (clipped) cutthroat (classified in this report as kelts; see Methods section) were the most numerous non-coho captured², followed (in decreasing order) by cottids, stickleback, wild cutthroat kelts (no clip), wild steelhead smolts, lamprey, and wild steelhead kelts, respectively. No upstream-migrating fish were captured in the broomstick trap in 1993.

Biosampling

Age

The calculated age-length distribution for wild coho smolts leaving Black Creek is given in Table 5. Age sample data (X) includes non-random samples; the calculated age representation (Y) is based on random sampling. The calculated freshwater age structure of Black Creek smolts (from all samples) was 85.4% age 1 and 14.6% age 2, and the age ratio of all age 1:age 2 smolts was 5.9:1. The proportional representation of migrating age-2 smolts during the entire study period was highest (91.3%) during the first sampling period. When compared over the three sampling periods, the age ratio of age 1:age 2 changed from 0.8:1 in period 1, to 40.6:1 in period 2, and to 118.7:1 in period 3; the differences among these age ratios were significant ($\chi^2 = 467.7$, $df = 2$, $P < 0.001$). No scale samples were taken from fry, but it is assumed that all fry were age 0+.

² It is hypothesized that these fish were outplants to the nearby Oyster River and that they migrated from Oyster River during spring flood events in 1994, entered Black Creek from marine water, migrated upstream of the fence site either prior to the first day of fence operation and/or during periods when the fence was open (flood events), and were captured at the fence while migrating downstream.

Length and Weight

The mean fork-length of the Black Creek coho smolt population was 132.4 mm and the mean weight was 25.89 g (Table 6). Individual length and weight measurements and the means of these measurements appeared to be normally distributed within sampling periods. Both the length and weight of age-1 smolts decreased significantly between both the first and second sampling period and the second and third sampling period (t-tests: lengths, $P < 0.001$ and $P < 0.02$, respectively; weights, $P < 0.001$ and $P < 0.05$, respectively). No age-3 smolts were identified in the random or non-random samples in 1993. The length-frequency distribution of successfully aged smolts is presented in Figure 5.

The mean length and weight of all fry sampled from the fence (moving downstream) was 61.6 mm and 3.20 g, respectively. A comparison of the mean lengths of sampled fry between sampling periods was not conducted in 1993 due to the low number of samples.

Sex

A total of 149 Black Creek smolts were dissected to determine sex. Males and females were observed in similar proportions over the course of the study (Table 7). There were no significant differences between male:female ratios between sampling periods and for all sampling periods combined (χ^2 , $P > 0.1$ in all cases; $df = 2$ in all cases).

Coded-Wire Tagging

Coded-Wire Tag Releases

A total of 55,625 coho smolts were coded-wire tagged using seven distinct sequential codes; a summary of specific sequences applied, by individual tag code, is provided in Appendix D. Of these tagged smolts, there were 60 known tagging-related mortalities (Table 1). A total of 140 coho fry were tagged with half-length tags, all of which were the same code. Of these tagged fry, there were two known tagging-related mortalities.

Tag Retention

Tag retention tests were performed eight times on coho smolts (six 24-h tests and two 72-h tests; Table 8). The mean tag retention rate for smolts was 98.8%. Tag retention tests were not conducted for fry in 1993 due to their low abundance.

FALL FIELD STUDIES

METHODS

Biophysical Monitoring

Biophysical conditions were monitored and recorded as described in the earlier section of the report, Spring Field Studies.

Coho Population Estimates

Counting Fence Operations

A collapsible adult counting fence was installed (Figure 1) prior to the first fall rains according to the methods and designs described in Labelle (1990) and Bocking et al. (1992). The fence was composed of a series of wood-frame panels with aluminum tube (2.5 cm diameter) insets spaced 2.5 cm apart. To increase the catch of small adult and jack (precocious male) coho, which were able to squeeze between the aluminum tubing, additional "jack panels" (mesh size 3 cm; Bocking et al. 1992) were placed on top of the main fence panels during low-flow and low-debris conditions. An aluminum-frame trap box was installed at each end of the fence; both trap boxes were operated when flows permitted.

Salmonids caught in the trap boxes at the counting fence were counted and the majority released upstream (a sample of adipose-clipped jacks was sacrificed for coded-wire tag recovery). All coho were classified as adult or jack, and the sex of each fish was recorded. All fin clips were recorded and degrees of maturity estimated (Bocking et al. 1992; Nass et al. 1993b). The orbital region of adipose-clipped adults was illuminated using a hand-held ultraviolet light and examined for the presence of a fluorescent filament tag³. Any mortalities at the fence, either naturally occurring or due to handling, were recorded.

All coho released upstream were given a uniquely numbered Ketchum No. 1 operculum tag⁴. Operculum tags were applied to fish during transfer to a canvas

³ In 1992, a study was initiated at Black Creek to determine the effectiveness of fluorescent filament tags as a visual identification mark. A total of 9,870 coho smolts were injected with filament tags during the spring field program in 1992 (see Nelson et al. 1994a).

⁴ Ketchum Manufacturing Sales Ltd., 396 Berkley Ave., Ottawa, Ont., Canada, K2A 2G6

cradle where fish were sampled for length and scales. Operculum tags were attached to specific, predetermined positions on either the left or right operculum (e.g., upper left, lower right) during flexible time periods (release groups) that corresponded roughly with pulses of fish at the enumeration fence. The rationale for the tag placement was for later determination of release group for fish captured upstream that had lost their operculum tag; the unique position of the tear on the operculum would allow positive determination of release group. The determination of release group for fish that lost their operculum tag would increase the sample size for the pooled Petersen estimate, which stratifies tag releases and recaptures by date (Arnason et al., in prep). All coho released upstream without a tag (escaped prior to tag application) were also recorded.

Mark-Recapture

In this report we refer to fish with operculum tags as tagged fish and adipose-clipped fish (fish that had been previously coded-wire tagged) as marked fish. Live coho were recovered upstream throughout the escapement period using electrofishing equipment. Most electrofishing surveys were conducted by blocking the downstream end of a recovery area with a small block net and then electrofishing the area. One person operated the block net, one person operated the electrofisher, and one or two people operated dip nets. The use of block nets greatly reduced the number of escaping coho.

All live untagged coho recovered upstream during surveys were also given a numbered operculum tag in a specific position on the operculum. Fish that had been previously operculum tagged but which had since lost their tag (identified by a tear on the operculum) were classified as primary recaptures; the position of the tear was recorded for these fish. All operculum tags applied at the counting fence were classified as primary tags; tags applied to untagged fish upstream were classified as secondary tags. In addition to a secondary tag, previously untagged fish captured upstream (referred to as "new fish") also received a single hole punch in the centre of the right operculum; this mark was applied in an attempt to positively identify recaptures of secondary tag fish that had lost their tag. Recovery effort was conducted approximately in proportion to the distribution of coho in the river as determined from the AUC stream walk surveys.

Mark-recapture estimates of escapement were generated using the pooled Petersen method. Standard errors (and confidence intervals) around the pooled Petersen were calculated using the Chapman hypergeometric model as described in Seber (1982, p. 60).

All coho captured during mark-recapture surveys were examined for operculum tags, evidence of tag loss, and the presence of a single hole punch in the operculum. Tag loss was recorded when clear evidence of tearing, due to the

former presence of an operculum tag, was observed. The tear usually appeared as a straight slit in the operculum, approximately 0.5 cm in length. The position of the tag loss on the operculum was also recorded.

Area-Under-The-Curve (AUC)

AUC escapement estimates were calculated by obtaining periodic fish population estimates, plotting these against time, and then dividing the area under these curves expressed in fish-day units by the length of time (days) fish were estimated to be alive in the areas surveyed. The first migration of fish past the enumeration fence occurred on October 22 and the last day living fish were in the system was assumed to be January 5, 1994. To obtain fish population estimates between these dates, four surveys were conducted at 13 index sites within six strata (Figure 1). An attempt was made to select index sites that included both good and marginal habitat for fish spawning and holding, and that were representative of the respective stratum as a whole (Irvine et al. 1992). Fish were counted by two observers walking upstream through each 250 m index site. The observers used wooden poles (2 m in length) to displace coho salmon hiding under cutbanks, rocks, and debris.

Five observer efficiency tests were conducted in 1993. Each test consisted of verifying the counts of a foot survey crew over a 250 m index reach with a separate electrofishing crew. These data were combined with observer efficiency measurements made at Black Creek during the previous five years. The number of fish observed (dependant variable) was assumed to be a function of the verified number of fish (counts from the electrofishing crew).

Fish populations were estimated using software described by Irvine et al. (1993) that followed the following procedure: 1) fish counts at each index site were corrected for observer efficiency; 2) the estimated mean fish density per survey site for each stratum and survey day was calculated; 3) the stratified mean density for each survey day was calculated; and 4) the stratified mean density was expanded to the stream length.

Residence time (survey life) is the average time in days that fish are present and alive in the survey area and are available to be counted by the surveyors. Residence time differs from stream life in that the latter includes time spent in other areas of the system where fish may hold but cannot be visually counted (e.g. Northy Lake, Figure 1). To estimate residence time for adult coho, one group of 100 adults were tagged (within a 24-h period) with blue Petersen disk tags⁵ (as well as operculum tags) at the counting fence and released upstream on November

⁵ Floy Tag and Manufacturing Co. Inc., 4616 Union Bay Place N.E., Seattle, WA 98105 [USA](#)

29. In an effort to estimate residence time for jack coho, one group of 100 jacks were tagged (within a 24-h period) with orange Floy FD-68 anchor tags⁶ (as well as operculum tags) at the counting fence and released upstream on November 29. Coho tagged with Petersen disk tags were subsequently observed and recorded on upstream foot surveys, and those counts were expanded and graphed to produce both total and observed tag curves, and subsequent estimates of residence time (English et al. 1992).

Age, Length, and Sex Composition

All live coho captured at the fence and during upstream surveys were measured for postorbital-hypural length and examined for fin clips, sex (adult males, females, and jacks), and maturity. Adult males and jacks were differentiated by a length delimiter of 35 cm (Bocking et al. 1992). Male coho less than 35 cm in length were closely examined for sexual dimorphic characteristics typical of spawning adult male coho (reddish sides, hooked jaws) and, for this year only, the presence of a fluorescent filament tag (filament tags were applied to migrating smolts in the spring of 1992). Scale samples (Henry 1961) were taken from random captures of "new" coho (not previously handled), both at the fence and upstream. Ages based on scale pattern analysis were reported using the European (decimal) method of age designation (e.g., 2.1), wherein the first number is the number of freshwater annuli and the second number is the number of marine annuli. Scale samples were interpreted by personnel at the Department of Fisheries and Oceans Fish Ageing Laboratory in Nanaimo, B.C.

During upstream surveys, only new coho (previously untagged) were sampled for age, length, and sex. Maturities were recorded for both newly captured coho and for recaptured fish. Sex ratios were calculated from the total recovery sample of new live fish (fence and upstream). In 1993, average lengths were calculated for all new live recoveries (pooled sample of both fence and upstream recoveries) and were stratified by sex and age (adult or jack). Separate average lengths (fence and upstream) were not calculated in 1993 because of the low number of new fish recovered upstream.

Coded-Wire Tag Recoveries

Adult and jack coho carcasses recovered were counted and the date and location of recovery, operculum tag number (if tagged), length, and any fin clips were recorded. Heads were removed from adipose-clipped carcasses, labelled with

⁶ Floy Tag and Manufacturing Co. Inc., 4616 Union Bay Place N.E., Seattle, WA 98105 USA

a unique number (E-label), and individually wrapped, and frozen. Data recorded for each carcass included date, recovery location, sex, length, maturity, any tag numbers, and other fin clips. Once counted, all carcasses were cut in half to prevent re-sampling during future surveys. Frozen heads were transferred to J. O. Thomas and Associates, Vancouver, B.C., where coded-wire tags were removed and decoded.

To determine the contribution of marked smolts from the 1992 and 1993 smolt emigrations to the 1993 escapement we used the three-step process described in Bocking (1991) and Bocking et al. (1990). Assuming that the survival of unmarked fish was equal to or greater than that of marked fish, this method estimates the minimum contribution of each tag code to the escapement.

Adipose-clipped adult males, adult females, and jacks were counted separately. The estimates of total escapement of adipose-clipped coho was based on the pooled Petersen population estimate of adults and jacks. The population estimate for all adult coho was apportioned into separate male and female population estimates using the calculated sex ratio observed in the total live recovery of new fish. Given an estimate of the total number of adipose clips for each sex and cohort escaping to the stream, the number of adipose clips for each tag code was estimated by the allocation of adipose clips to tag codes based on their relative frequency in the sample of decoded tags.

RESULTS

Biophysical Monitoring

Daily biophysical measurements are provided in Appendix E. Mean daily water temperatures and water levels during October, November, and December are presented in Figure 6. Daily water temperatures ranged from 10.3° C in late-October to 0.3° C in late November. In 1993, water levels were generally low until the end of November. A slight increase in water levels occurred on 21 October, and a second, more substantial increase occurred on 28 November. Peak water levels during the study period occurred in mid-December, and were followed by a sharp decline through the end of December.

Coho Population Estimates

Counting Fence

A summary of fence enumerations and associated operculum tag release data is provided in Appendix F. The adult counting fence was operated from October 22 through December 9. A slight increase in water level on 22 October resulted in the first pulse of fish at the fence, six adults and 123 jacks. After October 25, low water levels deterred fish through the fence for over a month; it was November 29 before the next pulse of fish was counted through the fence. This second (and final) pulse peaked on November 29 for jacks and December 1 for adults; the pulse was virtually over by December 5. Jack panels were removed on the evening of December 2 due to increasing water levels and large amounts of debris. Water levels reached flood stage on December 9, and the fence was lowered near the end of the day; the fence was not raised again during the study period. Three days prior to the flood, water levels were high and very low numbers of adult coho ($n = 3$) were observed at the fence; no jack coho were observed after December 3. Thus, due to the prolonged period of upstream passage and compressed upstream migration timing in 1993, it is likely that a very high proportion of the total run of adult coho was observed and handled at the counting fence; it is likely that some number of jack and small adult coho passed through the fence undetected following the removal of the jack panels on December 2.

Between October 22 and December 9, 903 adult and 1,414 jack coho were captured at the enumeration fence (Table 9). The daily numbers of adult and jack coho captured at the fence are illustrated in Figure 7. Upstream migration peaked on November 29 for jacks and December 1 for adults. Of all coho captured at the fence, a total of 44 jacks were sacrificed for coded-wire tag recovery, and a single adult and three jacks escaped upstream untagged during handling; the remaining adults ($n = 902$) and jacks ($n = 1,368$) were tagged with an operculum tag and released upstream.

Mark-Recapture

A summary of mark-recapture data is provided in Appendix G. Upstream mark-recapture surveys were conducted between December 6 and December 27 (Table 10). A total of 170 live adult coho and 118 live jack coho were examined upstream; of these, only one adult and six jacks were new fish (not handled at the fence). Primary recaptures (fish that had been tagged at the fence) included fish that had lost the operculum tag. Tag loss rates for primary recaptures of adults and jacks were 5.7% and 7.9%, respectively. Tag loss may have resulted from improper attachment of the tag to the operculum, and tags becoming entangled in

root wads and other debris and being torn off by the fish as it freed itself from the debris.

The various population estimates (including the minimum escapement estimate) are presented in Table 11. The minimum (known) escapement estimates of adult and jack coho above the enumeration fence in 1993 are 917 and 1,389, respectively. The minimum escapement estimates are the number of adult and jack coho released at the fence (does not include sacrifices) plus the number of "new" fish (untagged and no tag loss) handled upstream (in both the mark-recapture and carcass surveys; see Appendices F and G).

For adult coho, the pooled Petersen estimate (959) was moderately higher than the AUC estimate (847). For jack coho, the pooled Petersen estimate (1,502) was substantially higher than the AUC estimate (968).

Stream life estimates, stratified by age and sex, are provided in Table 12, and individual stream life values are presented in Appendix I. Adult stream life ranged from 1-26 d and jack stream life ranged from 1-20 d. Average stream life for jacks (16 d) was close to that for adult males (18 d). Average stream life for females was 15 d. Stream life data for Black Creek coho have been used in some previous years to generate escapement estimates using an open model (Labelle 1994). Stream life data were not used in 1993 to estimate escapement but are included in this report to be consistent with reports from previous years.

Area-Under-The-Curve

When the untransformed observer efficiency data were examined, there was increasing variability in the proportion of fish seen at higher densities, and the residuals were found to have a heteroscedastic distribution. The natural logarithmic transformation [$\ln(\text{number of fish} + 1)$] improved this situation and, therefore, regression parameters calculated on transformed data (Table 13) were used to expand the visual survey fish count data. Residence times for jack coho were not calculated in 1993 due to the low number of observations of tagged jacks (Floy tags) during visual surveys; the estimated residence time for adult coho was used to generate an AUC escapement estimate for adults and jacks.

English et al. (1992) found estimates generated using the total tag curve method were more robust than estimates generated using the observed tag curve method. We used the total residence time estimate of 8.34 d (Table 14) to generate the 1993 AUC escapement estimates for adult and jack coho (847 and 968, respectively). Figure 8 illustrates the escapement curve derived from the visual surveys conducted in index sites (adult coho only).

Age, Length, and Sex Composition

Figure 9 illustrates the length-frequency distribution of the escapement based on all live recoveries of new fish (fence plus upstream). Adult males ranged in size from 25-65 cm, (\bar{x} = 43.4 cm), females ranged from 36-67 cm (\bar{x} = 50.8 cm), and jacks ranged from 19-34 cm (\bar{x} = 25.9 cm) (Table 15). Females were significantly larger than adult males (t-test, $P < 0.001$). There were 52 adult coho (identified by CWT analysis, scale pattern analysis, external characteristics, and the presence of fluorescent filament tags) under 35 cm observed at the enumeration fence in 1993; an illustration of the length overlap for adult males and jacks is provided in Figure 10. For 1993, we did not calculate and compare mean lengths for new coho captured at the fence and during upstream recoveries because of the low number of new fish captured during upstream surveys.

The total count of new adult male coho ($n = 537$) was greater than the total count of new female coho ($n = 367$) and the difference was significant (χ^2 , $P < 0.001$). When adult and jack males were combined, the total number of all male coho (1,957) outnumbered females by more than five to one (Table 15).

The freshwater age distributions of the coho escapement are shown in Table 17. There were 79 scale samples aged successfully; however, all scale samples taken were resorbed to some extent. Results from the scale ageing analysis indicate that a slight majority of adults (55.8%) spent one year in freshwater, whereas a high proportion of jacks (85.2% spent) one year in freshwater.

Coded-Wire Tag Recoveries

A total of 660 adipose-clipped adult coho and 741 adipose-clipped jacks were observed among the total number of new fish that we handled at the fence and upstream (sacrifices included; Table 18). Based on the calculated mark rates observed in the total live recovery of new fish, (and pooled Petersen population estimate of fish above the fence), we estimate that 73.01% (700) of returning adults and 52.18% (784) of returning jacks were adipose clipped in 1993.

The percentage of smolts tagged in the springs of 1992 and 1993 that were recovered in the respective 1993 escapements of adult and jack coho varied among the tagging dates (Table 19). The total percentage of smolts tagged in 1992 that escaped to Black Creek as adults in 1993 was 1.44%. The total percentage of smolts tagged in 1993 that escaped to Black Creek as jacks in 1993 was 0.58%.

Filament Tag Recoveries

A total of 98 filament tagged adults were observed during the fall field program (all 98 were observed at the fence; none were observed on new fish upstream). From CWT decoding, we estimate that 134 filament tagged adults escaped to Black Creek (tag code 081011, Table 18).

DISCUSSION

In 1993, CWT releases of coho smolts totalled 55,565; this number was 99.1% of the total number of smolts observed at the enumeration fence (56,078). Although the period of fence operation appeared to cover a high proportion of the smolt migration, the fence was topped by high water on two occasions. The total estimated number of smolts that past the fence site undetected during these flood events was 9,093.

In general, migrating smolts were in good condition in 1993; the mean length (132.4 mm) of sampled smolts was high in comparison with previous years (68.4% of the smolts sampled were greater than or equal to 120 mm). Mortalities due to trapping and tagging were low for smolts (0.36%). Coho fry were observed infrequently and in low numbers at the enumeration fence in 1993. A total of 143 fry were observed at the fence, of which 138 (96.5%) were released tagged.

The majority of all age-2 smolts that migrated downstream in 1993 passed the fence site early in the migration. When compared across the three sampling periods, the age ratio of age 1:age 2 increased from 0.8:1 (Period 1) to 40.6:1 (Period 2) to 118.7:1 (Period 3).

The 1993 fall field studies at Black Creek were very successful. The minimum (known) numbers of adult and jack coho above the counting fence accounted for 95.6% and 92.5%, respectively, of the pooled Petersen escapement estimates. These figures indicate that the majority of the returning fish were counted and sampled for sex, length, and adipose-clip status. The above-fence escapement estimate (pooled Petersen) for all coho in 1993 was 2,461, of which 959 were adults (39%) and 1,502 were jacks (61%).

The AUC escapement estimate for adults was 11.7% less than the pooled Petersen estimate for adults. The AUC estimate for jacks was 35.5% less than the respective pooled Petersen estimate; AUC escapement estimates for jacks have

been low in most previous years (Irvine et al. 1992). We may overestimate the efficiency of observing jacks which would result in an insufficient expansion of the data and produce a consistent low bias in the escapement estimates for jacks. In addition, we have always assumed that the residence time for jacks was the same as for adults, and this is probably not a valid assumption.

We statistically tested for differences in length between adult male and female coho and found females to be significantly longer. This is consistent with previous studies at Black Creek (Bocking et al. 1992; Nass et al. 1993b; Nelson et al. 1994a; Nelson et al. 1994b). In the field, all male coho greater than or equal to 35 mm in length (postorbital-hypural) were classified as adult males. The 35 cm length delimiter for jacks was determined by analyzing the lengths of successfully decoded (CWT) returning coho. There were 52 adult male coho under 35 cm in length identified at the enumeration fence in 1993; this number is higher than in previous years.

The estimated proportion of returning adults that spent two years in freshwater (42.3%) is higher than in recent years: 1992 = 8.8% (Nelson et al. 1994a); 1991 = 5.0% (Nelson et al. 1994b); 1990 = 26.3% (Nass et al. 1993a); but similar to the proportion of two-year freshwater adults observed in 1989 (43.5%; Bocking et al. 1992). The high majority of smolts that left Black Creek in 1992 were reported to be freshwater age 1 (91.2%; Nelson et al. 1994a), whereas only 55.8% of the adults that returned in 1993 were freshwater age 1. Given the discrepancy in the freshwater age representation for the 1992 smolt year, we are concerned with the validity of the aging results for both studies.

We calculated the percentage of migrating smolts in 1992 and 1993 which returned to spawn as adults or jacks in 1993, respectively, by dividing the estimated escapement of adipose clips, stratified by sex, by the number of smolts tagged (adipose clipped) and released in the respective migrating year. The number of smolts tagged and released in 1992 and 1993 was 50,073 and 55,565, respectively. The estimated adult escapement of adipose clips (pooled Petersen estimate, $n = 700$) represented 1.44% of the smolts released in 1992. The estimated jack escapement of adipose clips ($n = 784$) represented 0.58% of the smolts released in 1993.

It is likely that some smolts migrated prior to the first day of fence operation, and that some smolts were downstream of the fence site when the fence was erected. The difference in the mark rate at release in 1993 (99.4%) and the mark rate of jacks at return in 1993 (52.2%) is likely attributable to some combination of the following reasons: 1) that the total number of smolts estimated to have migrated undetected (unmarked) during flood events in 1993 ($n = 9,093$) is an underestimate; 2) that a substantial number of smolts or fry migrated out of the

system before and/or after the period of fence operation; and 3) that significant straying might be occurring from unmarked stocks.

1993 was the ninth consecutive year that Black Creek coho smolts were counted and coded-wire tagged and accurate escapement estimates were obtained. As the primary indicator for wild coho in the Strait of Georgia, data from this study form an integral part of the coho stock assessment process. Our knowledge of the production dynamics and spawning escapement requirements of coho increased considerably with the collection of information in 1993.

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TABLES

Table 1. Coded-wire tag release data for Black Creek juvenile coho, by size group, 1993.

Size group ¹	Tag code	Tagging dates	No. tagged	Tag morts	No. released tagged ²	No. released untagged ³
<u>Small</u>						
	081835	04/23 - 05/18	8265	4	8261	57
	080141	05/19 - 05/22	8305	9	8296	11
	080143	05/23 - 05/27	9759	34	9725	26
	080144	05/28 - 06/15	6433	4	6429	24
		Subtotal	32762	51	32711	118
<u>Large</u>						
	081834	04/23 - 05/15	8760	2	8758	153
	081836	05/16 - 05/20	9589	3	9586	12
	080142	05/21 - 06/15	4514	4	4510	27
		Subtotal	22863	9	22854	192
<u>Grand total (smolts)</u>			55625	60	55565	310
<u>Fry</u>						
	0201010311	05/15 - 06/15	140	2	138	1

Note: all small and large (smolt) tag codes are for sequential coded-wire tags

¹small is < 120 mm; large is > = 120 mm

²not corrected for tag loss; total tag loss was 1.193% for smolts (see Table 8)

³No. released untagged = known escapees + fish released due to poor condition

Table 2. Results of trap efficiency tests conducted at Black Creek, 1993.

Date of release	Number smolts released	Fin clip	Number recovered	Date of last recovery	Percent recovered
05/07	100	upper caudal	89	05/10	89.0
05/14	100	lower caudal	100	05/20	100.0

Table 3. Coho smolt catches by tagging period at Black Creek, 1993. Mortalities include smolts killed by trapping and predation.

Sampling period	Smolt size ¹		Total (S+L)	Pre-tagging mortalities	Number released untagged ²	Number available for tagging
	Small	Large				
04/23 - 05/10	4106	215	4321	45	103	4173
05/11 - 06/02	18737	30877	49614	79	201	49334
06/03 - 06/15	274	1869	2143	19	6	2118
Total	23117	32961	56078	143	310	55625

¹small is < 120 mm; large is > = 120 mm

²No. released untagged = known escapees + fish released due to poor condition

Table 4. Total number of non-coho fish caught at the Black Creek smolt enumeration fence, April - June 1993. All fish were captured moving downstream.

Species	Life stage ¹	Total number caught
Steelhead	smolt (W)	111
	kelt (W)	9
Cutthroat	smolt (W)	43
	kelt (H)	827
	kelt (W)	176
Cottids	-	522
Lamprey	-	26
Stickleback	-	233

¹H = hatchery (fin clip observed); W = wild (no clips observed)

Table 5. Age-length distribution of Black Creek coho smolts, by sampling period, 1993. Age representation was determined according to Ketchen's stratified subsampling method (Ricker 1975, p. 67).

Sampling period	Size class (mm)	Age sample (X)	Age groups in (X)		Length sample (Y)	Calculated age representation in (Y)	
			1	2		1	2
<u>04/23 - 05/10</u>							
	< 80	1	1	0	0	0.0	0.0
	80-84	1	1	0	0	0.0	0.0
	85-89	0	0	0	0	0.0	0.0
	90-94	0	0	0	0	0.0	0.0
	95-99	2	2	0	0	0.0	0.0
	100-104	1	1	0	1	1.0	0.0
	105-109	3	3	0	0	0.0	0.0
	110-114	4	4	0	3	3.0	0.0
	115-119	2	1	1	11	5.5	5.5
	120-124	7	7	0	8	8.0	0.0
	125-129	5	3	2	10	6.0	4.0
	130-134	9	8	1	13	11.6	1.4
	135-139	7	6	1	18	15.4	2.6
	140-144	5	4	1	24	19.2	4.8
	145-149	9	5	4	33	18.3	14.7
	150-154	11	2	9	33	6.0	27.0
	155-159	8	3	5	43	16.1	26.9
	160-164	6	0	6	32	0.0	32.0
	> = 165	23	2	21	33	2.9	30.1
	Total	104	53	51	262	113	149
			Percent of length sample (Y)			43.1	56.9
<u>05/11 - 06/02</u>							
	< 80	0	0	0	0	0.0	0.0
	80-84	0	0	0	0	0.0	0.0
	85-89	0	0	0	0	0.0	0.0
	90-94	2	2	0	3	3.0	0.0
	95-99	6	6	0	5	5.0	0.0
	100-104	7	7	0	25	25.0	0.0
	105-109	9	9	0	58	58.0	0.0
	110-114	8	8	0	90	90.0	0.0
	115-119	8	8	0	102	102.0	0.0
	120-124	7	7	0	71	71.0	0.0
	125-129	9	8	1	43	38.2	4.8
	130-134	8	8	0	42	42.0	0.0
	135-139	7	7	0	21	21.0	0.0
	140-144	8	7	1	20	17.5	2.5
	145-149	6	4	2	13	8.7	4.3
	150-154	4	4	0	7	7.0	0.0
	155-159	0	0	0	0	0.0	0.0
	160-164	0	0	0	0	0.0	0.0
	> = 165	0	0	0	0	0.0	0.0
	Total	89	85	4	500	488	12
			Percent of length sample (Y)			97.7	2.3

Table 5. Age-length distribution of Black Creek coho smolts, by sampling period, 1993. Age (cont.) representation was determined according to Ketchen's stratified subsampling method (Ricker 1975, p. 67).

Sampling period	Size class (mm)	Age sample (X)	Age groups in (X)		Length sample (Y)	Calculated age representation in (Y)		
			1	2		1	2	
<u>06/03 - 06/15</u>								
	< 80	0	0	0	25	25.0	0.0	
	80-84	0	0	0	7	7.0	0.0	
	85-89	1	1	0	1	1.0	0.0	
	90-94	2	2	0	1	1.0	0.0	
	95-99	3	3	0	3	3.0	0.0	
	100-104	6	6	0	17	17.0	0.0	
	105-109	4	4	0	38	38.0	0.0	
	110-114	8	8	0	100	100.0	0.0	
	115-119	7	7	0	82	82.0	0.0	
	120-124	9	9	0	60	60.0	0.0	
	125-129	6	6	0	16	16.0	0.0	
	130-134	10	7	3	4	2.8	1.2	
	135-139	2	1	1	2	1.0	1.0	
	140-144	3	2	1	1	0.7	0.3	
	145-149	0	0	0	0	0.0	0.0	
	150-154	0	0	0	0	0.0	0.0	
	155-159	1	1	0	0	0.0	0.0	
	160-164	2	2	0	1	1.0	0.0	
	> = 165	0	0	0	1	1.0	0.0	
	Total	64	59	5	359	356	3	
			Percent of length sample (Y)				99.3	0.7
	Grand total	257	197	60	1121	958	163	
			Percent of total length sample (Y)				85.4	14.6

(X) = random and non-random samples

(Y) = random samples only

Table 6. Means and standard deviations for lengths and weights of Black Creek smolts, by age and sampling period, 1993. Data from successfully aged random samples only.

Age	Sampling period	Fork length (mm)			Weight (g)		
		N	Mean	SD	N	Mean	SD
1	04/23 - 05/10	30	137.6	15.8	30	28.27	9.70
	05/11 - 06/02	78	123.8	15.4	78	21.59	8.52
	06/03 - 06/15	43	117.3	12.1	43	18.41	6.86
	Total age-1 ¹	151	124.7	16.2	151	22.01	8.96
2	04/23 - 05/10	42	159.1	12.5	41	39.65	13.04
	05/11 - 06/02	4	141.8	9.3	4	31.03	6.34
	06/03 - 06/15	0	-	-	0	-	-
	Total age-2 ¹	46	157.6	13.1	45	38.88	12.79
Grand total (all ages) ²		197	132.4	20.8	196	25.89	12.22

¹total means and standard deviations are calculated from pooled data across sampling periods

²total means and standard deviations are calculated from pooled data from both age groups across sampling periods

Table 7. Sex ratios and mean lengths of Black Creek coho smolts, by sampling period, 1993.

Sampling period	Sex	Proportion (%)	Sample size	Mean length (mm)	SD length (mm)
04/23 - 05/10	Male	51.0	25	135.2	22.8
	Female	49.0	24	131.2	19.3
05/11 - 06/02	Male	43.9	36	114.0	10.4
	Female	56.1	46	113.5	11.5
06/03 - 06/15	Male	44.4	8	106.0	7.3
	Female	55.6	10	101.7	13.0
Total ¹	Male	46.5	69	120.8	19.3
	Female	53.5	80	117.3	17.3

¹total means and standard deviations are calculated for pooled data across all sampling periods

Table 8. Coded-wire tag retention and loss rates for Black Creek juvenile coho, 1993.

Life stage	Date	Hours held	Sample size	Number tags lost	Tag retention (%)	Tag loss (%)
Smolts						
	05/05	24	100	3	97.0	3.000
	05/07	24	104	1	99.0	0.962
	05/18	24	114	0	100.0	0.000
	05/25	24	105	4	96.2	3.810
	05/27	24	108	0	100.0	0.000
	05/28	72	104	2	98.1	1.923
	06/05	72	100	0	100.0	0.000
	06/08	24	103	0	100.0	0.000
		Total	838	10	98.8	1.193

Table 9. Total number of coho captured and released at the Black Creek enumeration fence, 1993.

Category	Number captured	Number sacrificed for sampling	Number released		
			Tagged	Untagged	Total
Adults	903	0	902	1	903
Jacks	1414	44	1368	2	1370

Table 10 Summary of foot survey and electrofishing efforts at Black Creek, by date and stratum, 1993.

Date	Stratum ¹	Method ²	Distance sampled (m)
12/06	F	FS	250
12/06	D	FS	250
12/06	D	EF	350
12/07	D	FS	250
12/15	F	EF	250
12/16	D	EF	650
12/16	D	FS	500
12/17	F	FS	500
12/17	E	FS	500
12/18	D	FS	750
12/19	C	FS	500
12/19	B	FS	500
12/19	A	FS	500
12/20	F	EF	500
12/20	F	FS	500
12/21	D	EF	400
12/21	C	EF	250
12/21	D	FS	750
12/21	C	FS	500
12/22	E	FS	500
12/23	F	EF	500
12/23	B	FS	500
12/23	A	FS	500
12/27	F	EF	250

¹see Figure 1 for stratum locations

²FS = foot survey; EF = electrofishing survey

Table 11. Escapement estimates for adult and jack coho for Black Creek, 1993.

Estimator	Category	N	Lower 95% CL	Upper 95% CL
<u>Pooled Petersen</u>				
	Adult	959	920	998
	Jack	1502	1417	1587
<u>AUC¹</u>				
	Adult	847	N/A	N/A
	Jack	968	N/A	N/A
<u>Minimum (above fence)²</u>				
	Adult	917	N/A	N/A
	Jack	1389	N/A	N/A

¹confidence limits not calculated for AUC because of non-random sampling

²the minimum (known) escapement above the fence is the number of fish released at the fence plus the number of new fish (untagged and no tag loss) handled upstream (both live and dead)

Table 12. Stream life values for coho salmon at Black Creek, November - December, 1993.

Category	Sex	n	Stream life (days)		
			Range	Mean	SD
Adult					
	Male	10	6-24	18	5.1
	Female	18	1-26	15	7.6
	Combined (M + F)	28	1-26	16	7
Jack					
	Male	6	1-20	16	7.3

Table 13. Parameters for linear and log-linear ($\ln + 1$) regressions between the number of adult or jack coho observed during visual surveys and the number seen or captured during electrofishing surveys conducted at Black Creek from 1987 - 1993.

Category	n ¹	Linear			Log-linear		
		Slope	Constant	r ²	Slope	Constant	r ²
Adults	50	0.884	-0.711	0.92	1.018	-0.276	0.90
Jacks	42	0.565	0.550	0.64	0.876	-0.133	0.73

¹n = the number of observer efficiency tests performed when at least one fish was seen or captured.

Table 14. Residence time (survey life) estimates, in days, for Black Creek coho, 1993.

Blue tags	
Total curve	8.34
Observed curve	4.84

Table 15. Summary of length data from new¹ live coho captured at the enumeration fence and upstream at Black Creek, 1993.

Category	Sample size			Length (cm) ²		
	Fence	Upstream	Total	Range	Mean	SD
Adult males	531	1	532	25 - 65	43.4	6.75
Females	364	0	364	36 - 67	50.8	5.74
Jacks	1408	6	1414	19 - 34	25.9	2.40

¹"new fish" are fish not previously handled at the enumeration fence and are identified by the absence of an operculum tag or tag scar

²postorbital-hypural length

Table 16. Sex ratios and chi-square results for new¹ live coho captured at the enumeration fence and upstream at Black Creek, 1993.

Adult males only				Adult males and jacks			
Number adult males	Number adult females	Ratio M:F	Chi- square	Number adult males and jacks	Number adult females	Ratio (M+J):F	Chi- square
537	367	1.46	31.59	1957	367	5.33	1086.45

Note: critical value of chi square = 3.84 (df = 1) in all cases

¹"new fish" are fish not previously handled at the enumeration fence and are identified by the absence of an operculum tag or tag scar

Table 17. Freshwater age distribution of returning adult and jack coho at Black Creek, 1993, as determined from scale pattern analysis.

	Freshwater age							Total aged	Total sampled
	Adults				Jacks				
	1	2	3	Total	1	2	Total		
Number	29	22	1	52	23	4	27	79	129
Percent	55.8	42.3	1.9		85.2	14.8			

Table 18. Estimates of total escapement of adipose-clipped coho to Black Creek, 1993.

Category	Sample size ¹ (A)	Adipose clips ¹ (B)	Mark rate (%) (C = B/Ax100)	Population estimate ² (D)	Percent of population sampled (E = A/Dx100)	Total estimated adipose clips (F = B/AxD)
Male	537	390	72.6	570	94.3	414
Female	367	270	73.6	389	94.3	286
(M + F)	904	660	73.0	959	94.3	700
Jack	1420	741	52.2	1502	94.5	784
Total	2324	1401	60.3	2461	94.4	1484

¹from all new live fish handled at the fence and upstream; includes fish sacrificed at the fence

²population estimates from the pooled Petersen population model (Table 11); adult male and female estimates are derived using the adult male:female ratio in the live sample (composition was 59.4% adult male and 40.6% female)

Table 19. Contribution of 1992 and 1993 coho smolt migrations, by tag code and tagging dates, to the 1993 escapement to Black Creek.

1993 ADULTS															
Smolt year	CWT code ¹	Tagging dates	Size at release (mm)	Decoded adipose clips			Estimated adipose clips ²			No. Smolts		Contribution to escapement			Smolt to 1992 adult ⁵ escapement (percent) ⁶
				M	F	T	M	F	T ³	Clipped	Unclipped	M	F	T ⁴	
1992	081007	04/13 - 06/13	<120	7	6	13	99.9	57.2	157.1	8351	5	100	57	157	1.88
	081832	05/16 - 06/18	<120	2	0	2	28.6	0.0	28.6	1791	6	29	0	29	1.59
		Total		9	6	15	128.5	57.2	185.7	10142	11	129	57	186	1.83
	081008	04/13 - 04/29	>=120	0	8	8	0.0	76.3	76.3	9549	15	0	76	76	0.80
	081009	04/30 - 06/18	>=120	3	3	6	46.1	28.6	74.7	8763	5	46	29	75	0.85
	081833	05/16 - 06/18	>=120	1	1	2	15.4	9.5	24.9	1472	14	16	10	25	1.69
		Total		4	12	16	61.5	114.4	175.9	19784	34	62	115	176	0.89
	081010	05/01 - 05/20	(all)	11	6	17	169.1	57.2	226.3	10277	9	169	57	226	2.20
	081011	05/01 - 05/20	(all)	5	6	11	76.9	57.2	134.1	9870	4	77	57	134	1.36
		Total		16	12	28	246.0	114.4	360.4	20147	13	246	114	361	1.79
		Total decoded		29	30	59	414	286	700	50073	58	436	286	723	1.44
		Strays		0	0	0									
		No data		360	240	600									
		No pin		1	1	2									
	Lost pin		0	0	0										
	Total observed		390	271	661										

Table 19. Contribution of 1992 and 1993 coho smolt migrations, by tag code and tagging dates, to the 1993 escapement to Black Creek. (cont.)

1993 JACKS																
Smolt year	CWT code	Tagging dates	Size at release (mm)	Decoded adipose clips			Estimated adipose clips ²			No. Smolts		Contribution to escapement			Smolt to 1992 jack escapement (percent) ⁶	
				M	F	T	M	F	T ³	Clipped	Uncipped	M	F	T ⁴		
1993	081835	04/23 - 05/18	<120	3	0	3	46.1	0.0	46.1	8261	57	46	0	46	0.56	
	080141	05/19 - 05/22	<120	2	0	2	30.7	0.0	30.7	8296	11	31	0	31	0.37	
	080143	05/23 - 05/27	<120	2	0	2	30.7	0.0	30.7	97725	26	31	0	31	0.03	
	080144	05/28 - 06/15	<120	0	0	0	0.0	0.0	0.0	6429	24	0	0	0	0.00	
	Total				7	0	7	107.6	0.0	107.6	114282	94	108	0	108	0.09
	081834	04/23 - 05/15	>= 120	29	0	29	445.8	0.0	445.8	8758	153	454	0	454	5.09	
	081836	05/16 - 05/20	>= 120	11	0	11	169.1	0.0	169.1	9586	12	169	0	169	1.76	
	080142	05/21 - 06/15	>= 120	4	0	4	61.5	0.0	61.5	4510	27	62	0	62	1.36	
	Total				44	0	44	676.4	0.0	676.4	22854	192	685	0	685	2.97
	Total decoded				51	0	51	784	0	784	137136	286	793	0	793	0.58
	Strays				0	0	0									
	No data				688	0	688									
No pin				3	0	3										
Lost pin				0	0	0										
Total observed				742	0	742										

abbreviations are: M = male, F = female

¹1992 CWT release data from Nelson et al. (1994a)

²total decoded estimated adipose clips are from Table 18

³calculated from observed adipose clips totals

⁴calculated from estimated adipose clips totals

⁵male and female combined

⁶escapement is defined as the number of fish that escaped the marine fisheries and returned to Black Creek

FIGURES

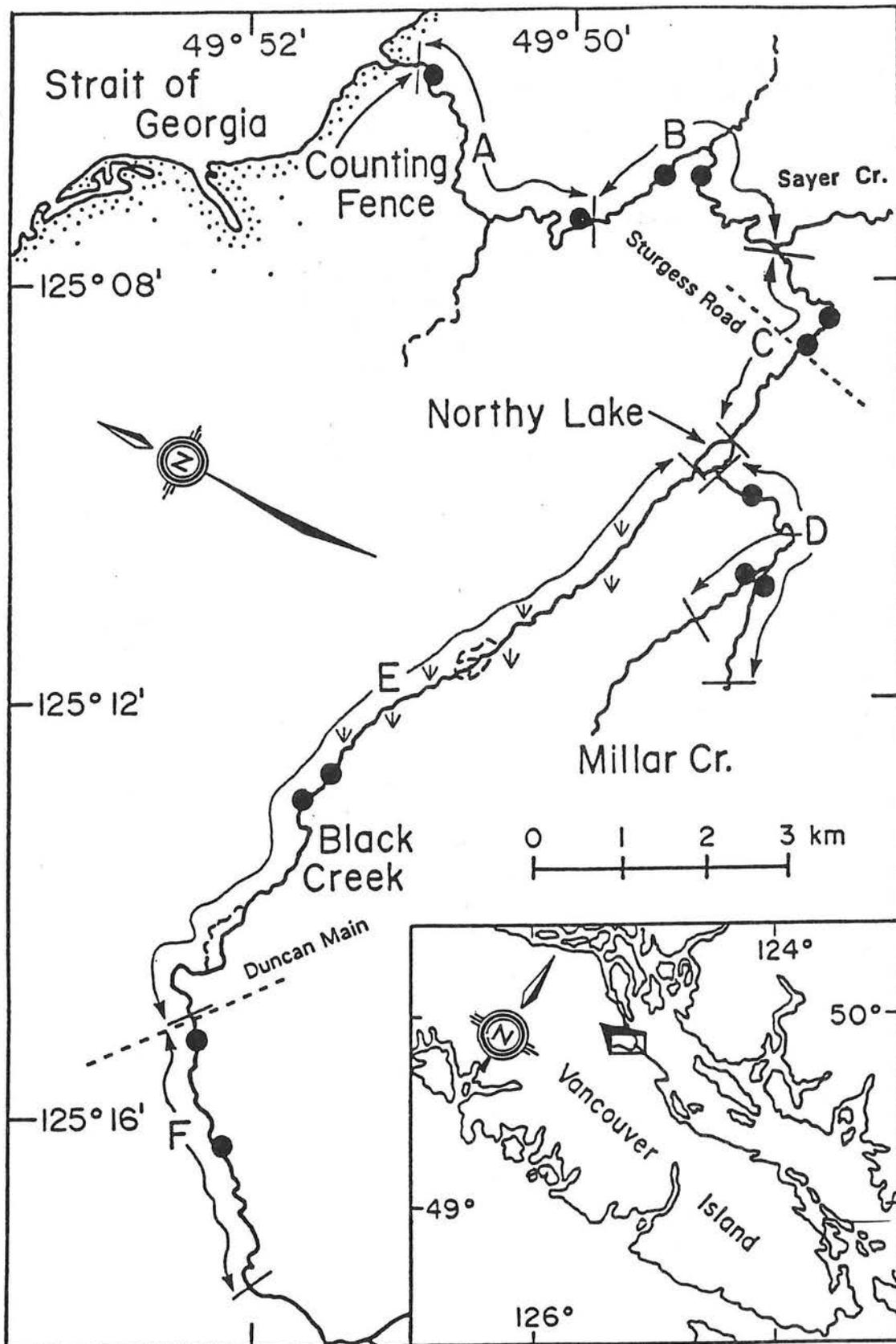


Figure 1. Map of Black Creek study area, showing location of smolt and adult counting fences, upstream recovery strata (A-F), and index reaches (identified by black dots).

BLACK CREEK 1993

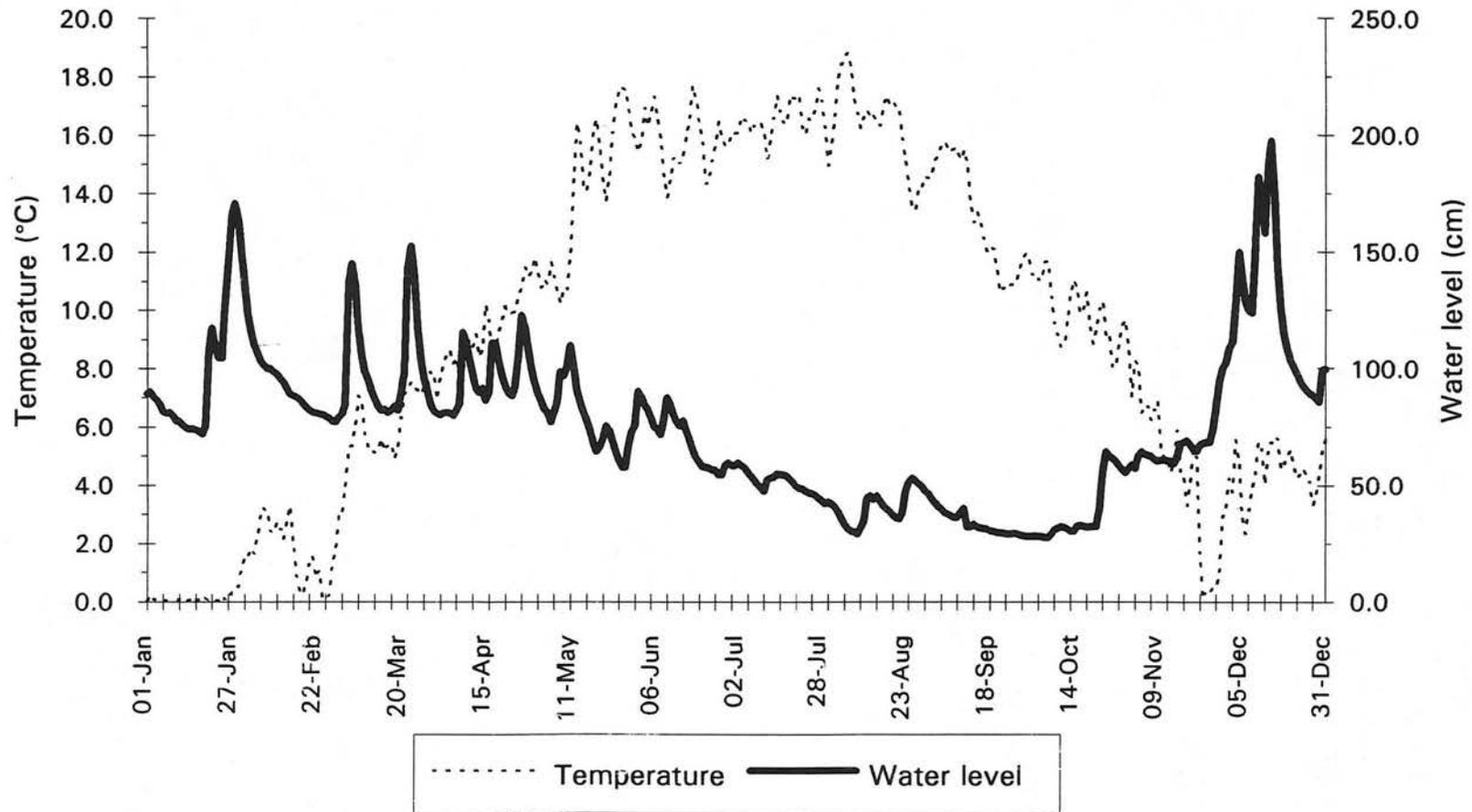


Figure 2. Water temperatures and levels at Black Creek, 1993. Data are daily means of records logged every three hours on the automated datalogger located 200 m upstream of the Seaview Road Bridge.

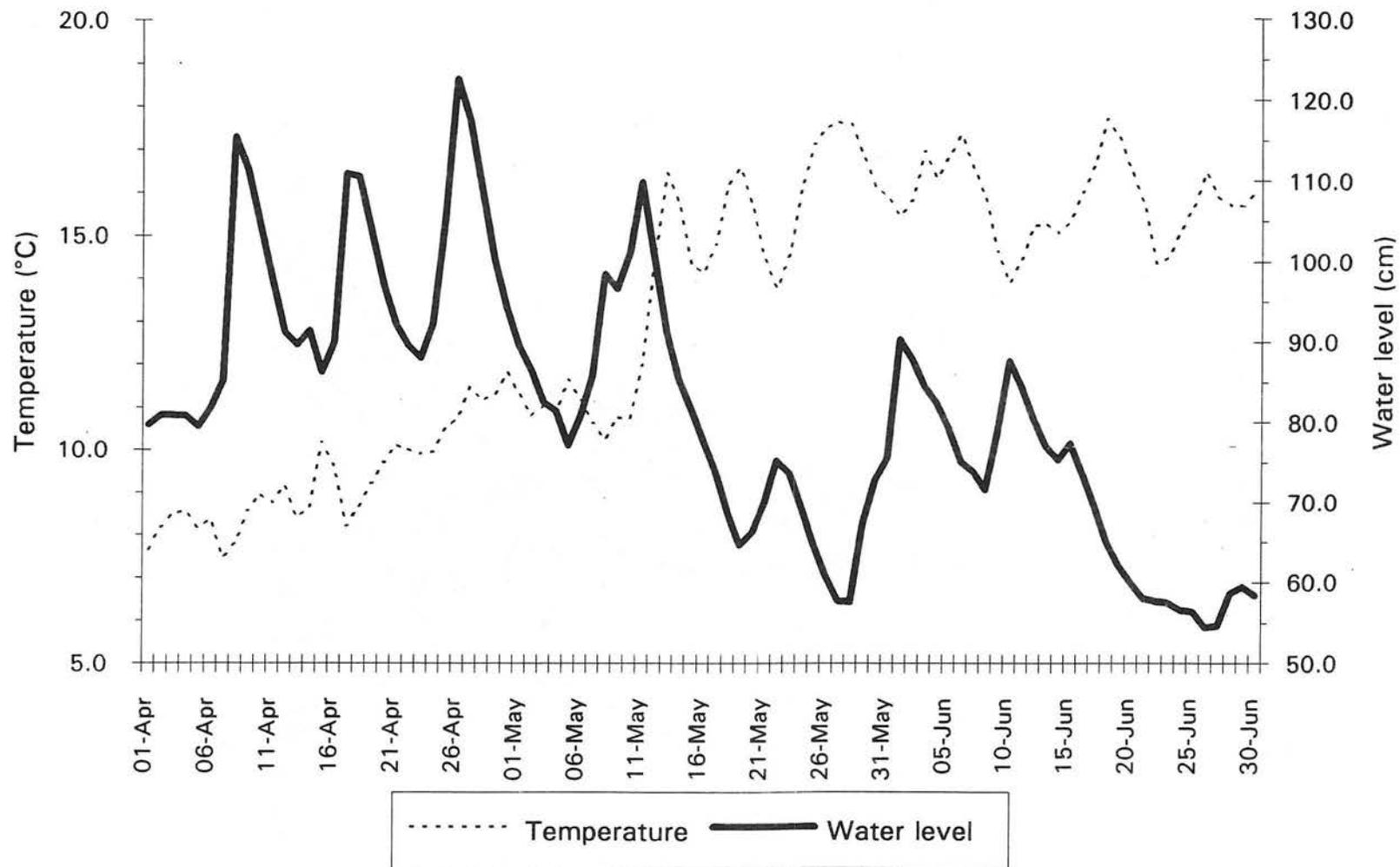


Figure 3. Water temperatures and levels at Black Creek during April, May, and June, 1993. Data are daily means of records logged every three hours on the automated datalogger located 200 m upstream of the Seaview Road Bridge.

COHO SMOLTS 1993

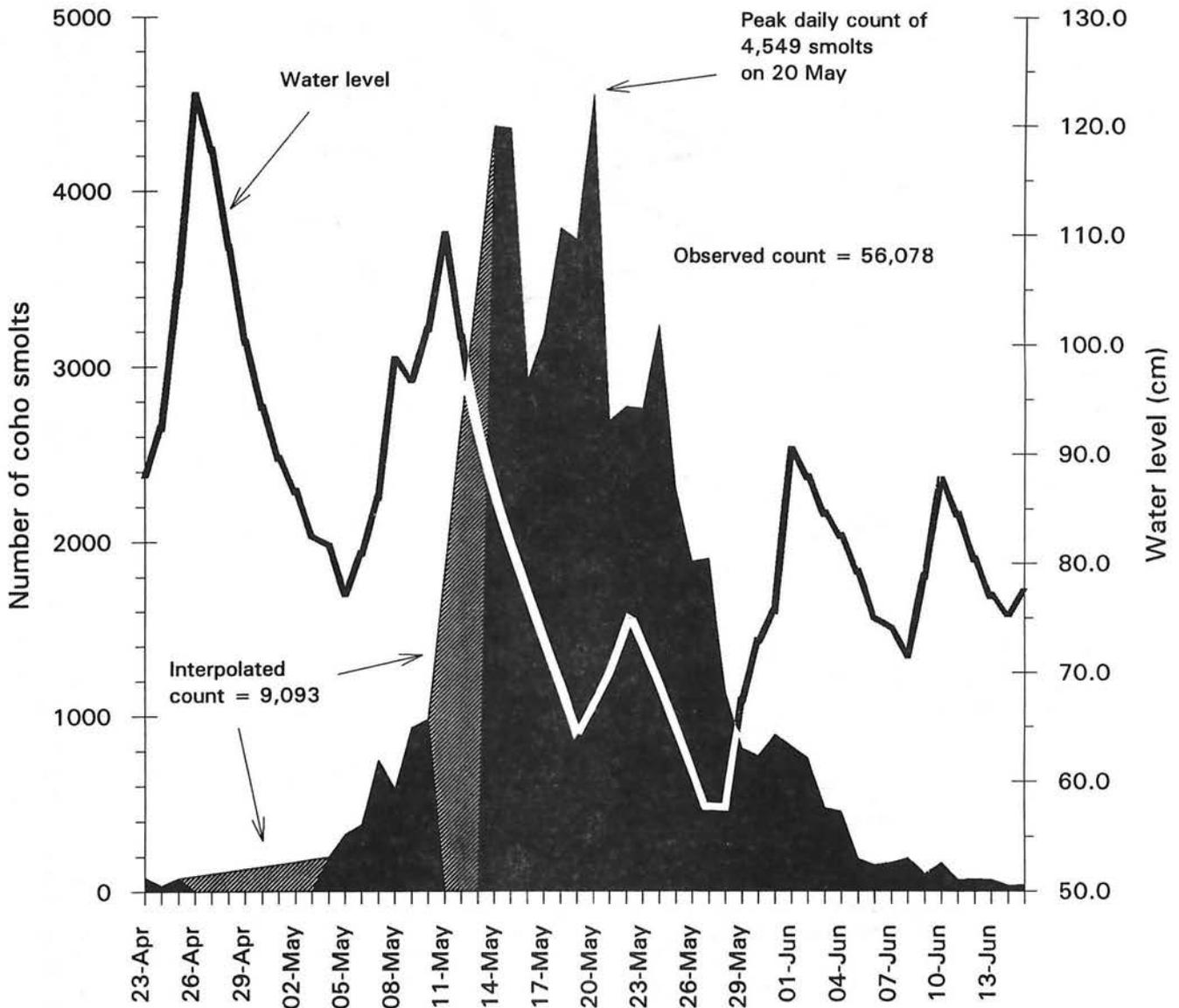


Figure 4. Total daily catches and interpolated numbers (during floods) of coho smolts at the enumeration fence, and associated water levels, by date, at Black Creek, 1993.

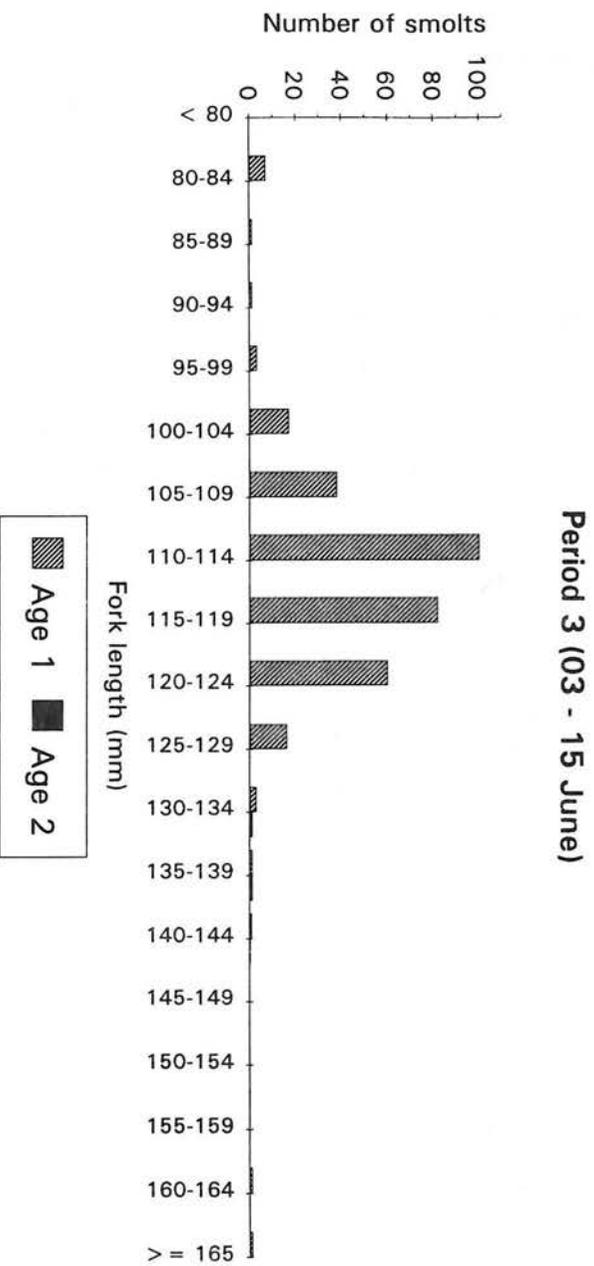
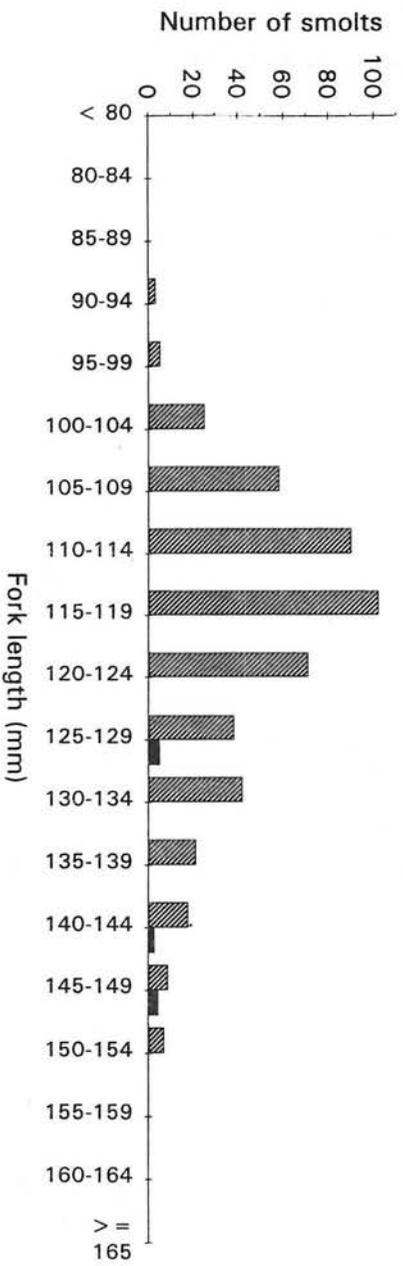
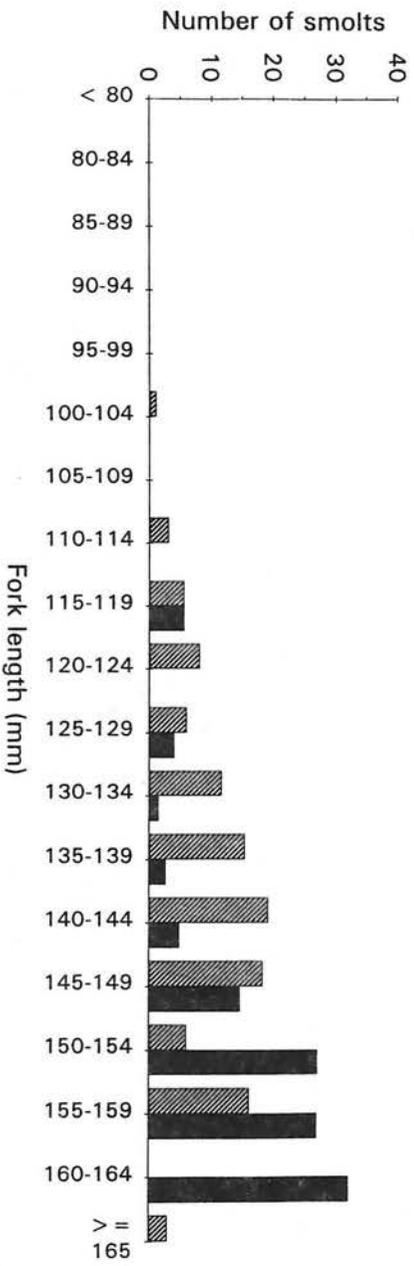


Figure 5. Calculated age-length representation of age-1 and age-2 coho smolts, by sampling period, at Black Creek, 1993. (Data from Table 5.)

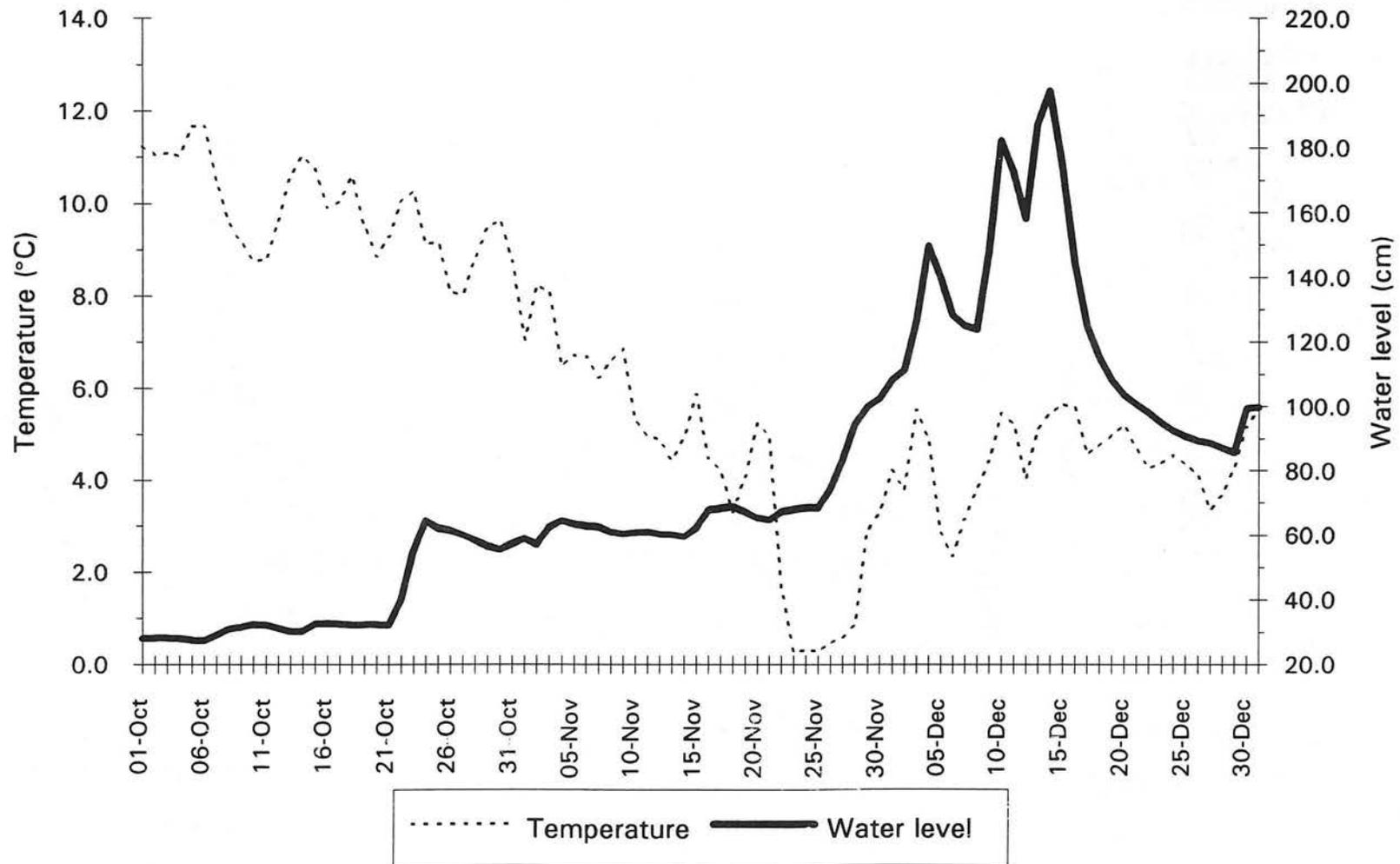


Figure 6. Water temperatures and levels at Black Creek during October, November, and December, 1993. Data are daily means of records logged every three hours on the automated datalogger located 200 m upstream of the Seaview Road Bridge.

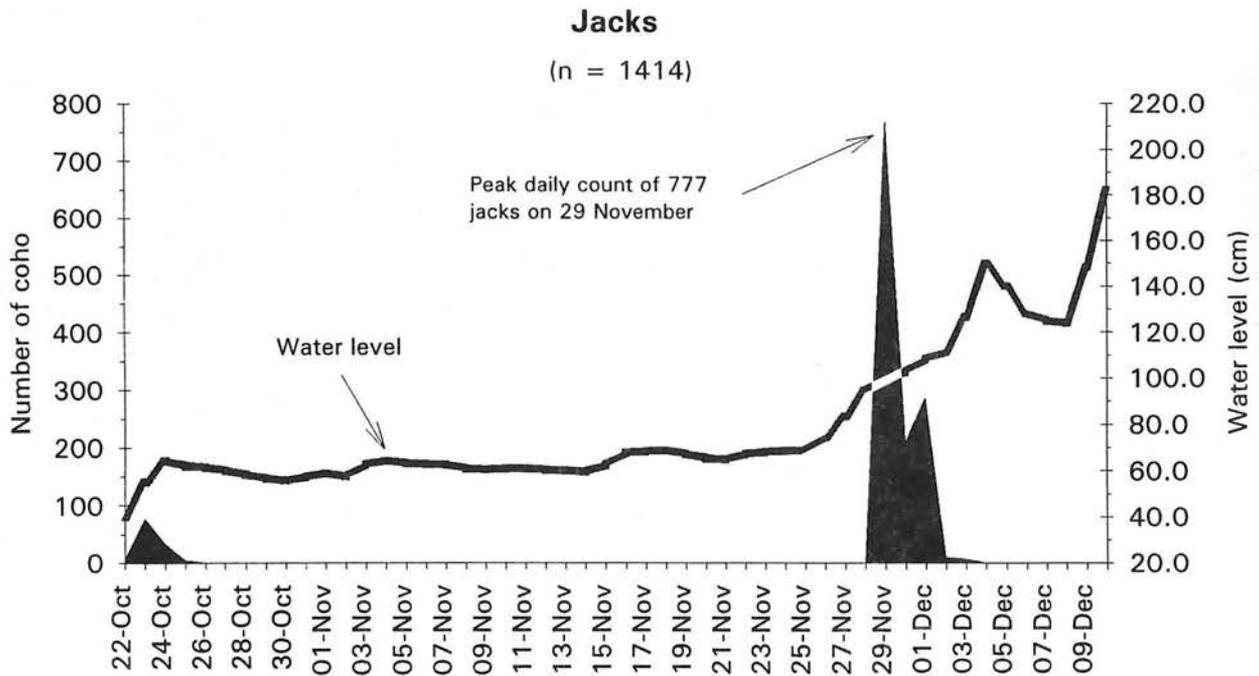
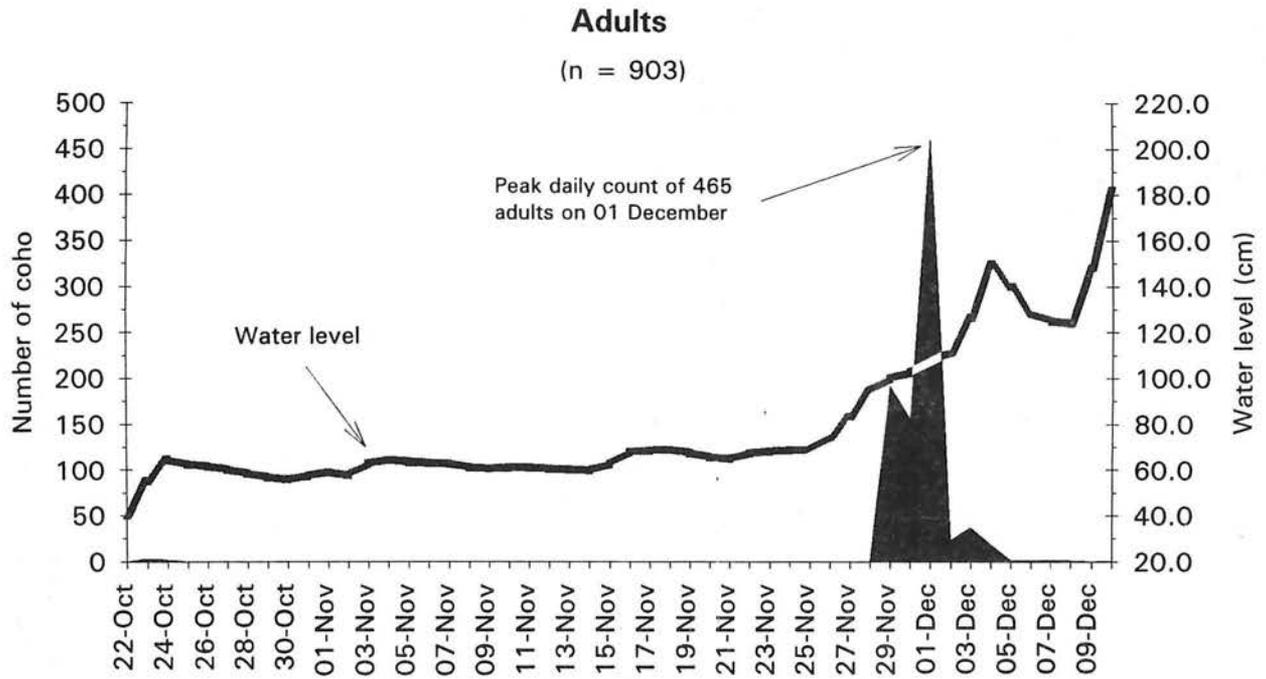


Figure 7. Daily fence counts of adult and jack coho salmon, and associated water levels, by date, at Black Creek, 1993.

ESCAPEMENT CURVE

GRAPH INFO

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FISH TYPE:
ADULT COHO

SIS METHOD

AUC:
7064

ESCAPEMENT
ESTIMATE:
847

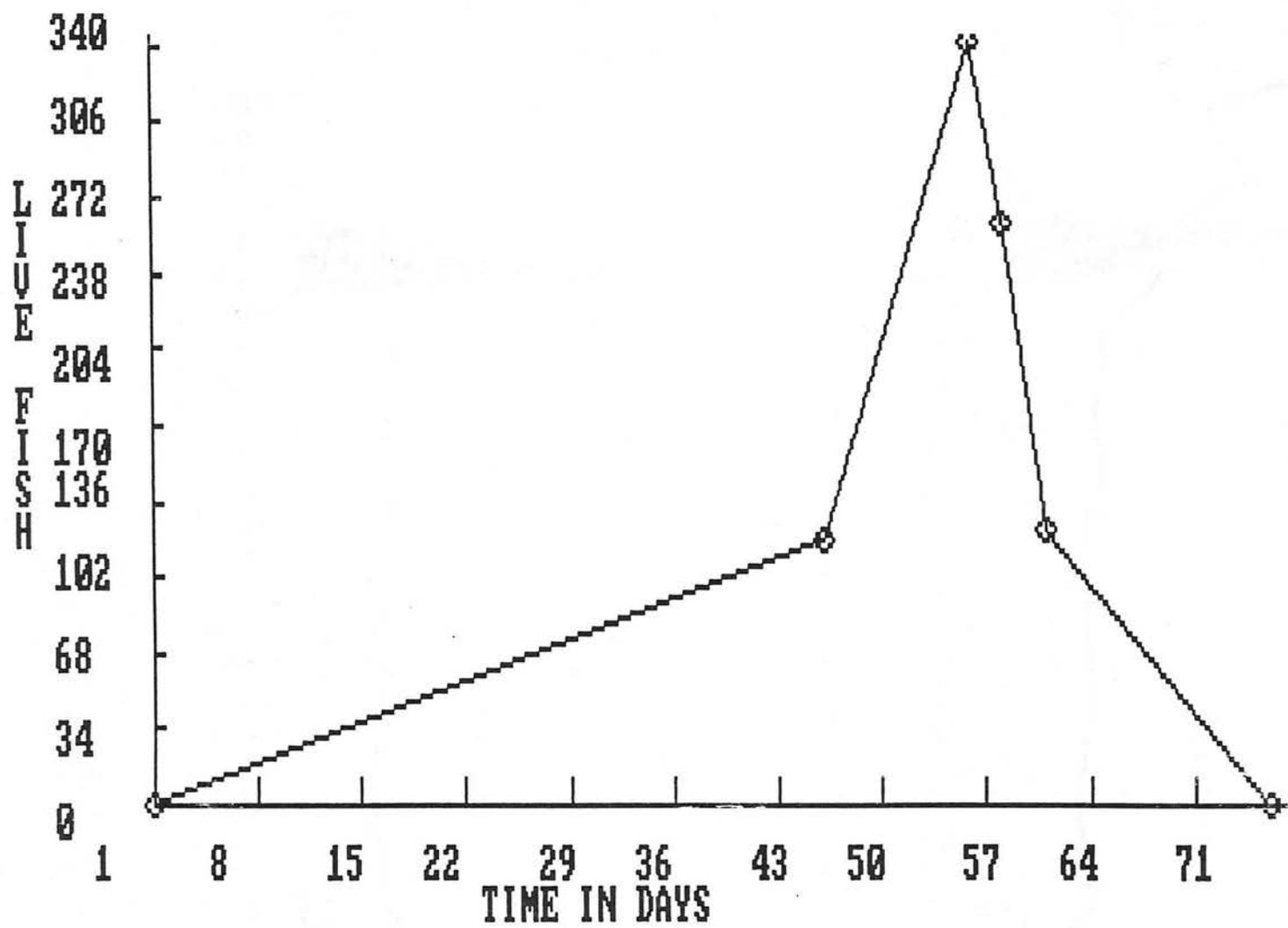
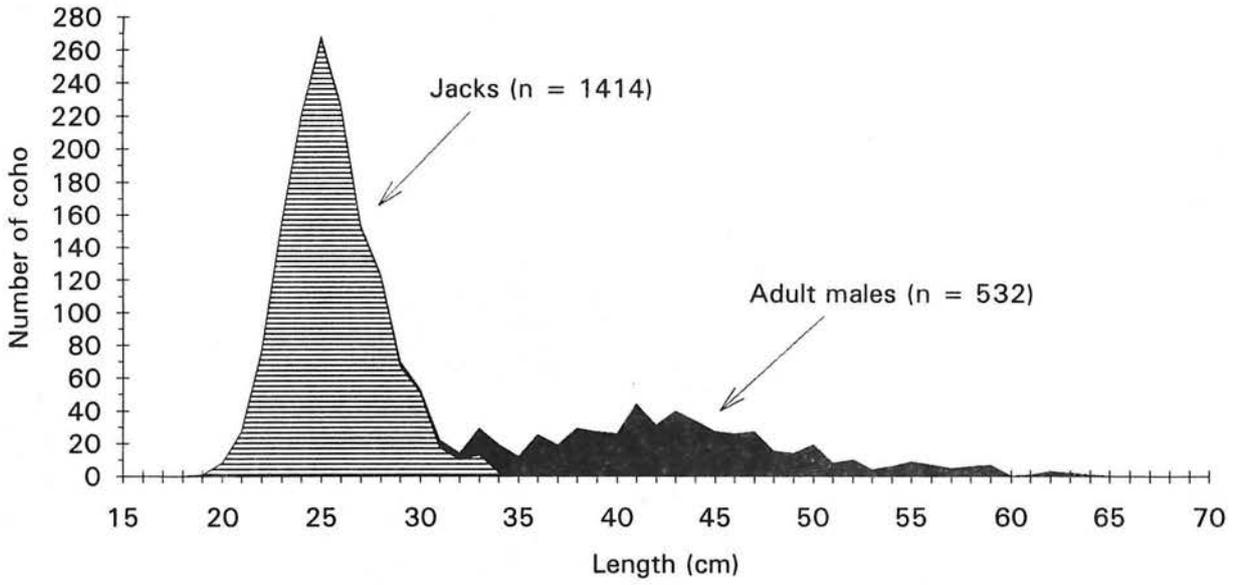


Figure 8. Escapement curve determined from AUC surveys of live coho salmon at Black Creek, 1993 (numbers of live coho versus time). Day 1 is October 22, 1993. Illustration produced using software described in Irvine et al. (1993).

Jacks and adult males



Females

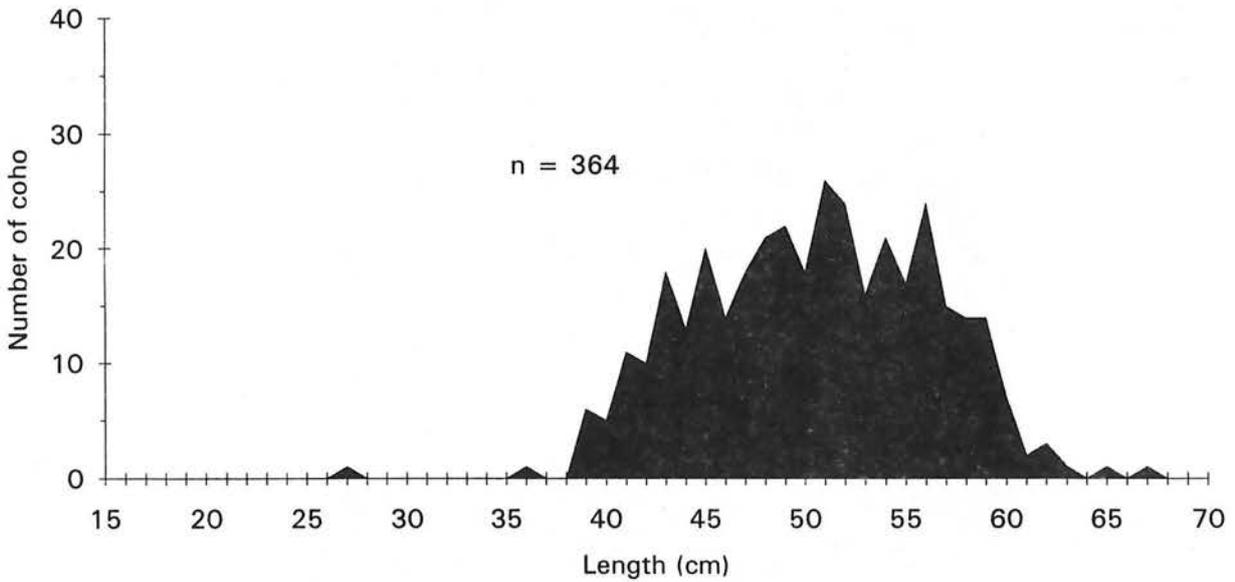


Figure 9. Length-frequency distributions for returning coho salmon at Black Creek, 1993, from all live recovery data of new fish.

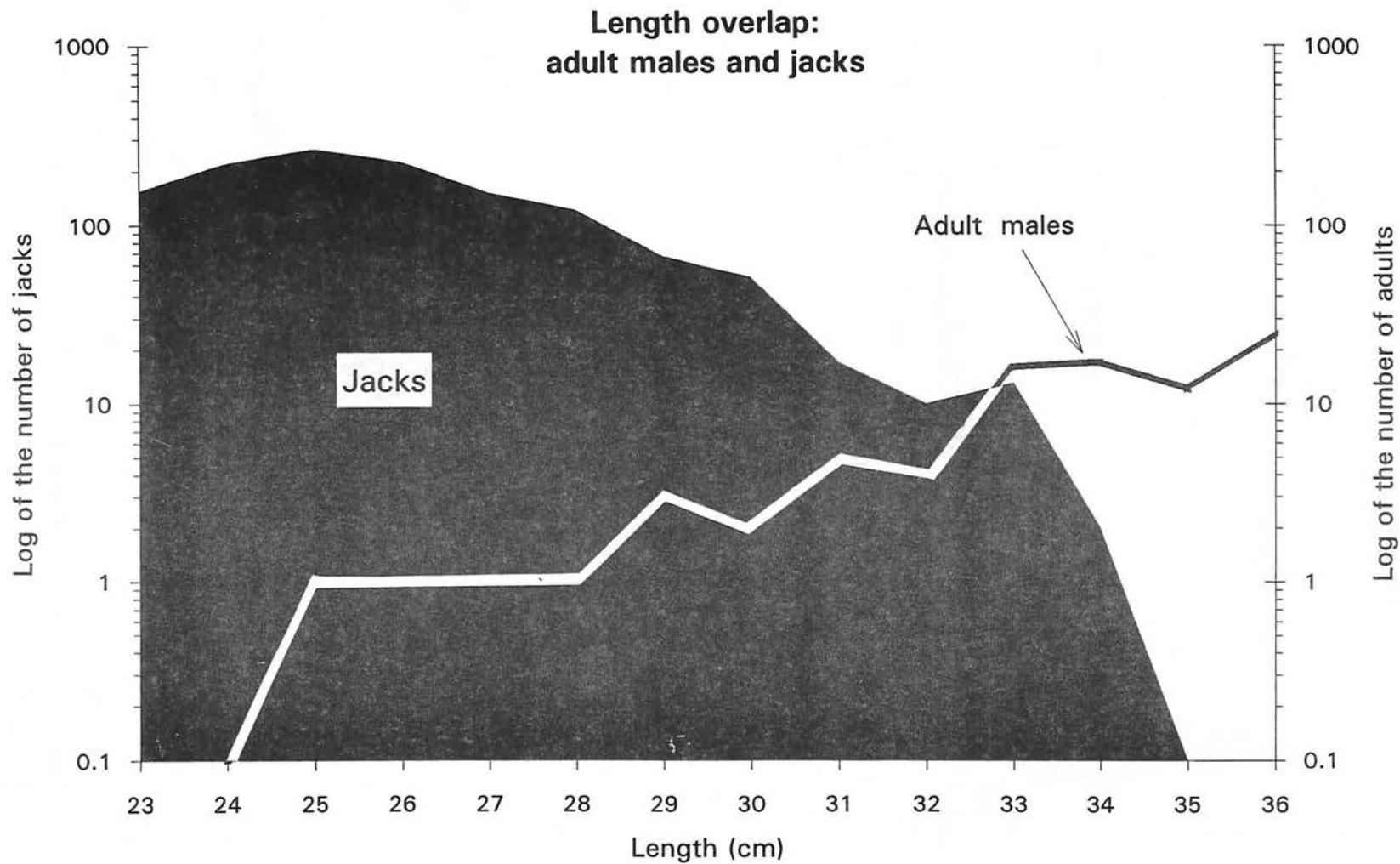


Figure 10. Illustration of length overlap of adult male and jack coho at Black Creek, 1993. Age data for adult males less than 35 cm in length (postorbital-hypural length) are from successful scale and coded-wire tag analyses.

Appendix A

Biophysical data for Black Creek, April 23 - June 15, 1993.

Appendix A. Biophysical data for Black Creek, April 23 - June 15, 1993. Temperature and water level data are daily means of records logged every three hours on the automated datalogger located 200 m upstream of the Seaview Road Bridge. Time entries indicate the time of day when records for rain, wind direction, wind speed, and cloud cover were recorded.

Date	Time (24 h)	Water Temperature (°C)	Water level (cm)	Rain (0-5)	Wind direction	Wind speed (km/h)	Cloud cover (%)
04/23/93	10:00	9.9	88.1	1	SE	10	100
04/24/93	08:00	10.0	92.4	1	SE	5	100
04/25/93	07:00	10.5	105.5	4	SE	30	100
04/26/93	08:00	10.7	122.7	0	N	10	50
04/27/93	09:00	11.5	117.7	0		0	20
04/28/93	09:00	11.2	108.9	1	SE	5	100
04/29/93	09:00	11.3	100.2	0		0	25
04/30/93	09:00	11.8	94.2	0	NW	15	40
05/01/93	10:00	11.3	89.6	1	SE	5	100
05/02/93	10:00	10.8	86.6	0			20
05/03/93	08:00	11.1	82.6	2	SE	5	100
05/04/93	08:00	10.9	81.5	0			40
05/05/93	08:00	11.6	77.2	2			100
05/06/93	08:00	11.2	80.9	1	SE	10	100
05/07/93	08:00	10.6	85.9	3	SE	10	100
05/08/93	08:00	10.2	98.6	0		0	100
05/09/93	08:00	10.8	96.8	0		0	100
05/10/93	07:00	10.7	101.4	3	SE	5	100
	Mean	10.9	95.0				
	Max	11.8	122.7				
	Min	9.9	77.2				
05/11/93	09:00	12.0	109.9	0	NW	10	40
05/12/93	09:00	14.5	100.7	0	NW	15	0
05/13/93	09:00	16.4	91.1	0	NW	10	10
05/14/93	08:00	15.8	85.5	0	SE	10	40
05/15/93	08:00	14.3	81.6	0		0	80
05/16/93	08:00	14.1	77.6	0		0	70
05/17/93	08:00	14.8	74.0	0		0	25
05/18/93	08:00	16.2	68.6	0		0	20
05/19/93	08:00	16.6	64.7	0	SE	5	95
05/20/93	08:00	15.6	66.4	1	SE	10	99
05/21/93	08:00	14.4	70.1	0		0	80
05/22/93	08:00	13.8	75.3	0		0	30
04/23/93	08:00	14.5	73.8	0		0	10
05/24/93	08:00	16.1	69.4	0		0	5
05/25/93	08:00	17.1	64.7	0		0	5

Appendix A. Biophysical data for Black Creek, April 23 - June 15, 1993. Temperature and water level data are daily means of records logged every three hours on the automated datalogger located 200 m upstream of the Seaview Road Bridge. Time entries indicate the time of day when records for rain, wind direction, wind speed, and cloud cover were recorded.

Date	Time (24 h)	Water Temperature (°C)	Water level (cm)	Rain (0-5)	Wind direction	Wind speed (km/h)	Cloud cover (%)
05/26/93	08:00	17.5	60.8	0		0	15
05/27/93	08:00	17.6	57.8	0		0	5
05/28/93	08:00	17.6	57.6	1	SE	5	100
05/29/93	08:00	16.9	67.4	1		0	100
05/30/93	08:00	16.1	72.9	1	SE	5	100
05/31/93	08:00	15.9	75.6	2			100
06/01/93	08:00	15.4	90.4	0		0	100
06/02/93	08:00	15.8	87.9	0	SE	10	65
	Mean	15.6	75.8				
	Max	17.6	109.9				
	Min	12.0	57.6				
06/03/93	08:00	16.9	84.5	1	SE	10	100
06/04/93	08:00	16.3	82.5	0			77
06/05/93	08:00	16.8	79.2	0			7
06/06/93	08:00	17.3	75.2	0		0	60
06/07/93	08:00	16.6	73.9	0			93
06/08/93	08:00	15.9	71.6	0			52
06/09/93	08:00	14.6	78.8	3	SE	30	100
06/10/93	08:00	13.9	87.6	0	SE	10	35
06/11/93	08:00	14.4	84.4	0		0	15
06/12/93	08:00	15.2	80.4	0		0	2
06/13/93	08:00	15.3	77.0	0			61
06/14/93	08:00	15.0	75.4	2			100
06/15/93	08:00	15.3	77.4	1			100
	Mean	15.7	79.1				
	Max	17.3	87.6				
	Min	13.9	71.6				

Appendix B

Catches of juvenile coho at the Black Creek counting fence,
by date, 1993.

Appendix B. Catches of juvenile coho at the Black Creek counting fence, by date, 1993. Underlined numbers in italics are derived from linear interpolation.

Capture date	Total fry catch ¹	Total smolt catch ¹	Total pre-tag fry morts ²	Total pre-tag smolt morts ²	Total No. fry released untagged ³	Total No. smolt released untagged ³	No. fry available for tagging ⁴	Total No. smolts available for tagging ⁴
04/23/93	0	81	0	4	0	0	0	77
04/24/93	0	32	0	1	0	1	0	30
04/25/93	0	74	0	0	0	0	0	74
04/26/93	<u>0</u>	<u>87</u>	Drop panels opened at 07:30 on 04/25/93 during flood.					
04/27/93	<u>0</u>	<u>101</u>						
04/28/93	<u>0</u>	<u>114</u>						
04/29/93	<u>0</u>	<u>127</u>	A total of 1072 smolts were estimated to have migrated past the fence from 04/25 to 05/03					
04/30/93	<u>0</u>	<u>141</u>						
05/01/93	<u>0</u>	<u>154</u>						
05/02/93	<u>0</u>	<u>167</u>						
05/03/93	<u>0</u>	<u>181</u>	Fence repaired and fishing at 15:00 on 05/03/93.					
05/04/93	0	194	0	4	0	0	0	190
05/05/93	0	323	0	1	0	0	0	322
05/06/93	0	378	0	5	0	2	0	371
05/07/93	0	743	0	2	0	100	0	641
05/08/93	0	584	0	3	0	0	0	581
05/09/93	0	933	0	8	0	0	0	925
05/10/93	0	979	0	17	0	0	0	962
05/11/93	<u>0</u>	<u>1826</u>	Water over fence at 15:00 on 05/10/93 during flood.					
05/12/93	<u>0</u>	<u>2674</u>	A total of 8021 smolts were estimated to have migrated from 05/10 to 05/13					
05/13/93	<u>0</u>	<u>3521</u>	Fence repaired and fishing at 15:00 on 05/13/93.					
05/14/93	0	4368	0	5	0	102	0	4261
05/15/93	3	4356	0	5	0	3	3	4348
05/16/93	5	2918	0	6	0	2	5	2910
05/17/93	2	3186	0	6	0	1	2	3179
05/18/93	1	3786	0	21	0	1	1	3764
05/19/93	3	3723	0	12	0	8	3	3703
05/20/93	0	4549	0	3	0	7	0	4539
05/21/93	2	2687	0	3	0	6	2	2678
05/22/93	0	2767	0	2	0	4	0	2761
05/23/93	0	2758	0	3	0	12	0	2743

Appendix B. Catches of juvenile coho at the Black Creek counting fence, by date, 1993. Underlined numbers in italics (cont.) are derived from linear interpolation.

Capture date	Total fry catch ¹	Total smolt catch ¹	Total pre-tag fry morts ²	Total pre-tag smolt morts ²	Total No. fry released untagged ³	Total No. smolt released untagged ³	No. fry available for tagging ⁴	Total No. smolts available for tagging ⁴
05/24/93	3	3235	0	3	0	6	3	3226
05/25/93	9	2299	1	1	0	5	8	2293
05/26/93	4	1885	0	0	0	16	4	1869
05/27/93	10	1903	0	2	0	7	10	1894
05/28/93	3	1136	0	1	0	8	3	1127
05/29/93	17	812	0	0	0	2	17	810
05/30/93	11	771	0	4	0	2	11	765
05/31/93	7	892	0	0	0	2	7	890
06/01/93	3	826	0	2	0	3	3	821
06/02/93	4	757	0	0	0	4	4	753
06/03/93	4	472	0	4	0	1	4	467
06/04/93	9	455	1	2	0	4	8	449
06/05/93	0	182	0	0	0	0	0	182
06/06/93	6	151	0	5	0	0	6	146
06/07/93	8	164	0	1	0	0	8	163
06/08/93	6	187	0	1	0	0	6	186
06/09/93	6	98	0	3	0	0	6	95
06/10/93	2	163	0	3	0	0	2	160
06/11/93	2	67	0	0	0	0	2	67
06/12/93	2	69	0	0	0	0	2	69
06/13/93	2	64	0	0	0	1	2	63
06/14/93	3	33	0	0	0	0	3	33
06/15/93	6	38	0	0	1	0	5	38
Total ⁵	143	53078	2	143	1	310	140	55625

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¹total catch = No. tagged + total pre-tag morts + No. escapees + No. released untagged

²total pre-tag morts = trap morts + pred morts + sacs

³total No. released untagged = No. released untagged (due to poor condition) + No. escapees

⁴No. available for tagging = total catch - pre-tag morts - No. released untagged

⁵does not include 9093 smolts estimated to have migrated during flood periods

Appendix C

Catches of non-coho fish at the Black Creek counting fence,
by date, 1993.

Appendix C. Catches of non-coho fish at the Black Creek counting fence, by date, 1993.

Date	Steel-head fry	Steel-head parr	Steel-head smolt no addipose	Steel-head smolt no clip	Steel-head adult no addipose	Steel-head adult no clip	Steel-head kelt no addipose	Steel-head kelt no clip	Cut-throat fry	Cut-throat parr	Cut-throat smolt no addipose	Cut-throat smolt no clip	Cut-throat adult no addipose	Cut-throat adult no clip	Cut-throat kelt no addipose	Cut-throat kelt no clip	Cottids	Lamprey	Stickle-back
04/23/93	0	0	0	0	0	0	0	1	0	0	0	0	0	0	5	3	17	0	3
04/24/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	4	8	0	5
04/25/93	0	0	0	4	0	0	0	1	0	0	0	1	0	0	12	10	13	0	1
05/04/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	2	9	0	1
05/05/93	0	0	0	7	0	0	0	1	0	0	0	1	0	0	31	8	14	0	2
05/06/93	0	0	0	4	0	0	0	0	0	0	0	4	0	0	22	8	16	0	0
05/07/93	0	0	0	2	0	0	0	0	0	0	0	0	0	0	36	11	7	0	1
05/08/93	0	0	0	14	0	0	0	0	0	0	0	3	0	0	32	20	7	0	1
05/09/93	0	0	0	9	0	0	0	0	0	0	0	0	0	0	14	9	7	0	1
05/10/93	0	0	0	10	0	0	0	0	0	0	0	2	0	0	24	10	14	0	4
05/14/93	0	0	0	6	0	0	0	0	0	0	0	0	0	0	36	6	11	0	2
05/15/93	0	0	0	8	0	0	0	0	0	0	0	1	0	0	50	8	10	0	7
05/16/93	0	0	0	5	0	0	0	0	0	0	0	0	0	0	34	7	27	0	0
05/17/93	0	0	0	6	0	0	0	0	0	0	0	0	0	0	48	13	13	0	5
05/18/93	0	0	0	6	0	0	0	1	0	0	0	1	0	0	77	14	19	0	4
05/19/93	0	0	0	6	0	0	0	0	0	0	0	1	0	0	95	18	12	1	2
05/20/93	0	0	0	8	0	0	0	3	0	0	0	0	0	0	46	5	17	1	2
05/21/93	0	0	0	4	0	0	0	0	0	0	0	1	0	0	45	4	16	5	4
05/22/93	0	0	0	1	0	0	0	0	0	0	0	2	0	0	27	3	7	2	4
05/23/93	0	0	0	3	0	0	0	1	0	0	0	1	0	0	12	1	8	0	1
05/24/93	0	0	0	2	0	0	0	0	0	0	0	1	0	0	18	1	12	1	5
05/25/93	0	0	0	1	0	0	0	0	0	0	0	1	0	0	21	3	12	0	3
05/26/93	0	0	0	0	0	0	0	0	0	0	0	1	0	0	30	1	20	0	3
05/27/93	0	0	0	1	0	0	0	0	0	0	0	9	0	0	25	2	26	1	2
05/28/93	0	0	0	1	0	0	0	1	0	0	0	7	0	0	23	0	26	1	0
05/29/93	0	0	0	0	0	0	0	0	0	0	0	2	0	0	6	0	33	1	3
05/30/93	0	0	0	0	0	0	0	0	0	0	0	1	0	0	5	1	27	3	4
05/31/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	22	1	5
06/01/93	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	3	13	0	3
06/02/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	7	0	3
06/03/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	12	0	9
06/04/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	11	1	8
06/05/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	1	2
06/06/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	5	2	2

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Appendix C. Catches of non-coho fish at the Black Creek counting fence, by date, 1993.
(cont.)

Date	Steel-head fry	Steel-head parr	Steel-head smolt no adipose	Steel-head smolt clip	Steel-head adult no adipose	Steel-head adult clip	Steel-head kelt no adipose	Steel-head kelt clip	Cut-throat fry	Cut-throat parr	Cut-throat smolt no adipose	Cut-throat smolt clip	Cut-throat adult no adipose	Cut-throat adult clip	Cut-throat kelt no adipose	Cut-throat kelt clip	Cottids	Lamprey	Stickle-back
06/07/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	10	1	6
06/08/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	6	0	16
06/09/93	0	0	0	1	0	0	0	0	0	0	0	1	0	0	5	0	4	2	6
06/10/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	8
06/11/93	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3	0	9
06/12/93	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	20
06/13/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	13
06/14/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	0	18
06/15/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	3	0	35
Total	0	0	0	111	0	0	0	9	0	0	0	43	0	0	827	176	522	26	233

Appendix D

Summary of sequential coded-wire tag applications,
by smolt period, tag code, and smolt size,
at Black Creek, 1993

Appendix D. Summary of sequential coded-wire tag applications, by smolt period¹, tag code, and smolt size, at Black Creek, 1993.² D3 and D4 are the data-3 and data-4 values as read from coded-wire tags; sequence numbers are the numeric values associated with the D3 and D4 values.

Date	Period ¹	Tagcode	Size ³	D3,D4 (s,e) ⁴	Sequence (s,e) ⁴
4/23/93	1	08-18-34	LG	01,68 s	135 s
5/10/93				60,91 e	5229 e
5/14/93	2	08-18-34	LG	61,67 s	5250 s
5/15/93				125,32 e	11071 e
5/16/93		08-18-36	LG	01,57 s	209 s
5/19/93				111,112 e	9567 e
5/20/93	3	08-18-36	LG	111,75 s	9586 s
5/20/93				115,35 e	11970 e
5/21/93		08-01-42	LG	01,115 s	162 s
6/15/93				35,57 e	7889 e
4/23/93	1	08-18-35	SM	90,59 s	13869 s
5/10/93				93,77 e	13449 e
5/14/93	2	08-18-35	SM	92,73 s	13425 s
5/18/93				22,23 e	3557 e
5/19/93		08-01-41	SM	01,63 s	213 s
5/19/93				25,47 e	2250 e
5/20/93	3	08-01-41	SM	25,19 s	2274 s
5/22/93				115,123 e	11949 e
5/23/93		08-01-43	SM	90,9 s	13838 s
5/27/93				09,70 e	1915 e
5/28/93		08-01-44	SM	02,108 s	439 s
6/15/93				111,57 e	9518 e

¹ smolt periods, used for additional between-year analyses, are as follows:

- Period 1 (through May 10);
- Period 2 (May 11-19); and
- Period 3 (May 20 on)

² a complete listing of 1993 sequential coded-wire tag releases at Black Creek, by date, is available from:

R. E. Bailey
 Biological Sciences Branch
 Department of Fisheries and Oceans
 Pacific Biological Station
 Nanaimo, B.C. V9R 5K6

³ SM = small (<120 mm); LG = large (>=120 mm)

⁴ s = start; e = end

Appendix E

Biophysical data for Black Creek, October 22 - December 09, 1993.

Appendix E. Biophysical data for Black Creek, October 22 - December 09, 1993. Temperature and water level data are daily means of records logged every three hours on the automated datalogger located 200 m upstream of the Seaview Road Bridge. Time entries indicate the time of day when records for rain, wind direction, wind speed, and cloud cover were recorded.

Date	Time (24 h)	Water Temperature (°C)	Water level (cm)	Rain (0-5)	Wind direction	Wind speed (km/h)	Cloud cover (%)
10/22/93	1430	10.0	40.1	1		0	100
10/23/93	0800	10.3	55.1	2	SE	10	100
10/24/93	0800	9.1	64.4				15
10/25/93	0800	9.2	62.2				25
10/26/93	0800	8.1	61.5	0			70
10/27/93	0800	8.0	60.2				30
10/28/93	0800	8.8	58.4	1			100
10/29/93	0800	9.5	56.6	1			100
10/30/93	0800	9.7	55.6	0		0	100
10/31/93	0800	8.8	57.3				10
11/01/93	1000	7.1	58.9				50
11/02/93	1000	8.2	57.2	0	SE	10	100
11/03/93	0800	8.1	62.6	0			10
11/04/93	1000	6.5	64.4	0			25
11/05/93	1000	6.7	63.4	0			80
11/06/93	1000	6.7	62.9	0	NW	10	20
11/07/93	1000	6.2	62.6	0			40
11/08/93	0900	6.6	61.1	0			95
11/09/93	1000	6.8	60.3	0	N	10	99
11/10/93	1100	5.3	60.9	0			5
11/11/93	0900	5.0	61.1	0			40
11/12/93	1100	4.9	60.3	0			20
11/13/93	1000	4.4	60.2	0	NW	10	5
11/14/93	1200	4.9	59.4	0	S	15	85
11/15/93	0800	5.9	62.3	0			25
11/16/93	0900	4.5	67.7	0			10
11/17/93	1000	4.2	68.3	0			20
11/18/93	1000	3.3	68.8	0			70
11/19/93	1000	4.1	67.3	0			98
11/20/93	0900	5.2	65.4	0			100
11/21/93	0900	4.9	64.7	0			50
11/22/93	0900	1.7	67.2	0	NW	10	0
11/23/93	1000	0.3	67.9	0			70
11/24/93		0.3	68.5				
11/25/93	0900	0.3	68.5	0			17
11/26/93	1030	0.5	74.4	0			89
11/27/93	1030	0.6	83.3	2	SE	10	100
11/28/93	0800	0.9	94.5	1	SE	10	100
11/29/93	0730	2.9	100.0	1	SE	5	100

Appendix E. Biophysical data for Black Creek, October 22 - December 09, 1993. Temperature and water level data are daily means of records logged every three hours on the automated datalogger located 200 m upstream of the Seaview Road Bridge. Time entries indicate the time of day when records for rain, wind direction, wind speed, and cloud cover were recorded.

Date	Time (24 h)	Water Temperature (°C)	Water level (cm)	Rain (0-5)	Wind direction	Wind speed (km/h)	Cloud cover (%)
11/30/93	0830	3.3	102.4	3	SE	10	100
12/01/93	0800	4.2	108.4	1	SE	10	100
12/02/93	0800	3.8	111.3	0			100
12/03/93	0800	5.5	126.4	0	SE	5	98
12/04/93	0830	4.9	149.7	0	SE	10	0
12/05/93	0800	2.9	139.9	0	NW	5	65
12/06/93	0830	2.4	128.2	0		5	100
12/07/93		3.2	125.0				
12/08/93	0800	3.8	123.9	1		0	100
12/09/93	0700	4.4	148.1	0			98
	Mean	5.2	77.1				
	Max	10.3	149.7				
	Min	0.3	40.1				

Appendix F

Black Creek fence counts and associated operculum tag release data
for returning adult and jack coho salmon, by date, 1993.

Appendix F. Black Creek fence enumerations and associated operculum tag release data for returning adult and jack coho salmon, by date, 1993.

Date	Number captured	Number adipose clipped	Number filament tagged	Number sacrificed	Number released untagged	Number released tagged
Males						
10/23/93	2	2	0	0	0	2
11/29/93	128	92	11	0	0	128
11/30/93	97	74	13	0	0	97
12/01/93	262	192	28	0	0	262
12/02/93	10	9	1	0	0	10
12/03/93	20	10	1	0	0	20
12/04/93	14	10	2	0	0	14
12/05/93	1	0	0	0	0	1
12/07/93	1	0	0	0	0	1
12/08/93	1	0	0	0	0	1
Total	536	389	56	0	0	536
Females						
10/23/93	1	1	0	0	0	1
10/24/93	2	1	0	0	0	2
11/29/93	64	49	8	0	0	64
11/30/93	59	42	8	0	1	58
12/01/93	203	154	20	0	0	203
12/02/93	14	11	2	0	0	14
12/03/93	17	8	3	0	0	17
12/04/93	5	3	1	0	0	5
12/05/93	1	1	0	0	0	1
12/06/93	1	0	0	0	0	1
Total	367	270	42	0	1	366

Appendix F. Black Creek fence enumerations and associated operculum tag release data for (cont.) returning adult and jack coho salmon, by date, 1993.

Date	Number captured	Number adipose clipped	Number filament tagged	Number sacrificed	Number released untagged	Number released tagged
Jacks						
10/22/93	7	6	0	2	0	5
10/23/93	78	52	0	36	0	42
10/24/93	34	20	0	0	0	34
10/25/93	4	2	0	0	0	4
11/29/93	777	391	0	0	1	776
11/30/93	210	99	0	3	1	206
12/01/93	287	157	0	2	0	285
12/02/93	10	6	0	0	0	10
12/03/93	7	4	0	1	0	6
Total	1414	737	0	44	2	1368

Appendix G

Summary of mark-recapture data for coho salmon collected upstream
of the counting fence at Black Creek, 1993.

Appendix G. Summary of mark-recapture data for coho salmon collected upstream of the counting fence at Black Creek, 1993. Operculum tags were applied to all new fish and tag loss fish prior to release. Data presented are for live fish only.

Date	No. captured	No. new fish ¹	No. new fish ¹ adipose clipped	No. new fish ¹ filament tagged	No primary recaptures ²	No secondary recaptures ³	No. sacrificed	No. released
Males								
12/06/93	3	0	0	0	3	0	0	3
12/15/93	54	0	0	0	54	0	0	54
12/16/93	8	0	0	0	8	0	0	8
12/20/93	30	0	0	0	30	0	0	30
12/23/93	15	1	1	0	14	0	0	15
12/27/93	8	0	0	0	8	0	0	8
Total	118	1	1	0	117	0	0	118
Females								
12/06/93	8	0	0	0	8	0	0	8
12/15/93	17	0	0	0	17	0	0	17
12/16/93	6	0	0	0	6	0	0	6
12/20/93	12	0	0	0	12	0	0	12
12/21/93	4	0	0	0	4	0	0	4
12/23/93	5	0	0	0	5	0	0	5
Total	52	0	0	0	52	0	0	52
Jacks								
12/06/93	8	0	0	0	8	0	0	8
12/15/93	47	3	2	0	44	0	0	47
12/16/93	9	0	0	0	9	0	0	9
12/20/93	36	3	2	0	32	1	0	36
12/21/93	2	0	0	0	2	0	0	2
12/23/93	7	0	0	0	7	0	0	7
12/27/93	9	0	0	0	9	0	0	9
Total	118	6	4	0	111	1	0	118

¹new fish are fish captured upstream of the fence that do not possess an operculum tag or tag scar (tag loss)

²primary recaptures are fish that were initially counted and tagged at the fence (includes tag loss fish)

³secondary recaptures are recaptures of fish that were initially counted and tagged upstream of the counting fence (new fish)

Appendix H

Recovery data for coho salmon recovered as carcasses
in Black Creek, by date, 1993.

Appendix H. Recovery data for coho salmon recovered as carcasses in Black Creek, by date, 1993.

Date	Number recovered	Number new fish ¹ recovered	Number new fish ¹ ad clipped	Number new fish ¹ filament	Number primary recaptures ²	Number secondary recaptures ³	Number new recovered below fence	Number recovered below fence ad clipped
Male								
12/05/93	1	0	0	0	1	0	0	0
12/06/93	1	0	0	0	1	0	0	0
12/15/93	1	0	0	0	1	0	0	0
12/16/93	1	0	0	0	1	0	0	0
12/18/93	1	0	0	0	1	0	0	0
12/20/93	3	0	0	0	3	0	0	0
12/23/93	1	0	0	0	1	0	0	0
12/27/93	3	0	0	0	2	0	0	0
Total	12	0	0	0	11	0	0	0
Female								
12/04/93	1	0	0	0	1	0	0	0
12/05/93	1	0	0	0	1	0	0	0
12/07/93	1	0	0	0	1	0	0	0
12/09/93	2	0	0	0	2	0	0	0
12/15/93	1	0	0	0	1	0	0	0
12/16/93	1	0	0	0	1	0	0	0
12/17/93	1	0	0	0	0	0	0	0
12/19/93	5	1	1	0	4	0	0	0
12/20/93	1	0	0	0	1	0	0	0
12/21/93	3	0	0	0	3	0	0	0
12/22/93	1	0	0	0	1	0	0	0
12/23/93	1	0	0	0	1	0	0	0
12/27/93	1	0	0	0	1	0	0	0
Total	20	1	1	0	18	0	0	0

Appendix H. Recovery data for coho salmon recovered as carcasses in Black Creek, by date, 1993.
(cont.)

Date	Number recovered	Number new fish ¹ recovered	Number new fish ¹ ad clipped	Number new fish ¹ filament	Number primary recaptures ²	Number secondary recaptures ³	Number new recovered below fence	Number recovered below fence ad clipped
Jacks								
11/26/93	1	1	1	0	0	0	0	0
11/30/93	1	0	0	0	1	0	0	0
12/07/93	1	1	0	0	0	0	0	0
12/16/93	1	0	0	0	1	0	0	0
12/19/93	2	0	0	0	2	0	0	0
12/20/93	1	0	0	0	1	0	0	0
12/21/93	1	0	0	0	1	0	0	0
Total	8	2	1	0	6	0	0	0

¹new fish are fish captured upstream of the fence that do not possess an operculum tag or tag scar (tag loss)

²primary recaptures are fish that were initially counted and tagged at the fence (includes tag loss fish)

³secondary recaptures are recaptures of fish that were initially counted and tagged upstream of the counting fence (new fish)

Appendix I

Stream life values for individual coho salmon
recovered as carcasses in Black Creek, 1993.

Appendix I. Stream life values for individual coho salmon recovered as carcasses in Black Creek, 1993.

Sex	Date tagged	Date recovered	Days dead	Stream life (days)
M	11/29/93	12/05/93		6
M	11/29/93	12/20/93	1	20
M	11/29/93	12/23/93		24
M	11/30/93	12/15/93		15
M	12/01/93	12/16/93	1	14
M	12/01/93	12/18/93		17
M	12/01/93	12/20/93		19
M	12/01/93	12/20/93		19
M	12/01/93	12/20/93		19
M	12/04/93	12/27/93		23
F	11/29/93	12/09/93		10
F	11/29/93	12/15/93		16
F	11/30/93	12/19/93		19
F	11/30/93	12/21/93		21
F	11/30/93	12/21/93		21
F	12/01/93	12/16/93	2	13
F	12/01/93	12/19/93		18
F	12/01/93	12/19/93		18
F	12/01/93	12/20/93	2	17
F	12/01/93	12/21/93		20
F	12/01/93	12/22/93		21
F	12/01/93	12/23/93		22
F	12/01/93	12/27/93		26
F	12/02/93	12/04/93	1	1
F	12/02/93	12/19/93		17
F	12/03/93	12/05/93		2
F	12/03/93	12/09/93	1	5
F	12/04/93	12/07/93		3
J	11/29/93	11/30/93		1
J	11/29/93	12/16/93	2	15
J	11/29/93	12/19/93		20
J	11/29/93	12/21/93	2	20
J	11/30/93	12/19/93		19
J	11/30/93	12/20/93	2	18

Abbreviations are: M = male; F = female; J = jack