2002 Update for the Englishman River Coho Smolt Enumeration Program

by

Jody Schick[1] and A. Scott Decker[2]*

[1]P.O. Box 524
Gibsons, BC
V0N 1V0

[2]Decker and Associates
303-533 2nd Ave, Kamloops, B.C.
V2C 3L3
decker_scott@hotmail.com

June 2003

* author to whom correspondence should be addressed

ABSTRACT

Two side-channels were constructed in the Englishman River to increase off-channel rearing habitat for juvenile coho salmon. In 2002, the numbers of coho smolt outmigrating from these channels and from the mainstem/tributary area were monitored to assess the contribution of restored habitat to overall smolt production in the Englishman River system. The mean density of outmigrating coho smolts was 2.5 times greater for the side-channel area compared to the mainstem/tributary area. While the side-channels accounted for less than 8% of total stream (by channel length), smolt outmigrants from the channels represented 16% of the estimated total smolt production for the system (7,061 smolts of 44,303 ± 4,296 smolts). These estimates should be considered minimum values because significant numbers of smolts were still being captured on June 8 when the downstream traps were removed. In 2002 an estimated 11% of the total number of smolt outmigrants from the system originated from the release of hatchery fry above a migration barrier in the Englishman River mainstem and in one of the side-channels during the summer of 2001.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPEDICES

1.0 INTRODUCTION

Since the early 1980s, concern has been voiced about declining returns of coho salmon and other anadromous species to the Englishman River (Hurst 1988). In 1988, Fisheries and Oceans Canada (DFO) began working to rehabilitate coho salmon and other salmonid populations in the Englishman River through hatchery enhancement and habitat restoration. A major initiative for coho was the construction of two side-channels to provide off-channel spawning and rearing habitat.

During 1998, 1999, and 2001, the numbers of coho smolt outmigrants from the two side-channels and from the mainstem/tributary area of the Englishman River were assessed in order to determine the contribution of the two side-channels to overall smolt production in the system (Decker et al. 2003). During these study years, total production for the system ranged from 31,005 to 50,622 smolts, with the contribution from the side-channels ranging from 15% to 25%. As part of the Englishman River Salmon Maintenance Plan (ERSMP), this monitoring program was continued in the spring of 2002. The primary objective continues to be to determine the contribution of the two side-channels to overall smolt production and to assess the health of the Englishman River coho stock. Here we present the results for 2002.

2.0 METHODS

The study design and field methods used to estimate coho smolt populations from the side-channels and the mainstem/tributary area of the Englishman River in 2002 were essentially the same as those used in 2001 (Decker et al. 2003). Here, we briefly describe the study area and methods and note any exceptions to the latter. For more detailed information refer to Decker et al. 2003.

2.1 Study area

The Englishman River is situated southwest of the City of Parksville on Vancouver Island (Figure 1). The river is about 28 km in length and drains a watershed area of 324 km^2. Mean annual discharge during 1980 to 1998 was 13.8 cms, with observed maximum and minimum discharges of 454 cms and 0.1 cms, respectively (Water Survey of Canada, unpublished data).

The Englishman River Falls, located approximately 16 km upstream of the mouth, creates a natural migration barrier to all anadromous fish. The main tributaries contributing to anadromous fish habitat are the South Englishman River (4.5 km of accessible habitat; Figure 1), Centre Creek (5.2 km accessible), Morison Creek (2.1 km accessible) and Shelley Creek (3.0 km accessible), for a total anadromous habitat in the watershed of 31 km (see Decker et al. for a map of the Englishman River watershed). The lower 8 km of the Englishman River and the accessible portions of the tributaries are low gradient (< 2%), and provide the majority of juvenile salmonid habitat.

The Englishman River sustains runs of chum *(Oncorhynchus keta)* and coho salmon *(O. kisutch*), as well as smaller runs of chinook *(O. tshawytscha)*, pink *(O. gorbuscha)*, sockeye *(O. nerka)*, steelhead *(O. mykiss)* and anadromous cutthroat trout *(O. clarki)* (Anon, 1987; Brown et al. 1977). Resident rainbow and cutthroat trout are also present in the system (Boom and Bryden 1993).

As part of the ERSMP, two side-channels were constructed in the Englishman River to provide spawning, rearing and overwintering habitat, primarily for coho salmon. The channels are located on the lower Englishman River (Figure 2), with the Timber West Channel on the north (left) bank, approximately 7 km upstream from the estuary and just below the Morison Creek confluence, and the Weyerhaeuser Channel, about 1 km downstream of that site, on the south (right) bank.

The Timber West Channel was constructed in 1992. It is approximately 1,380 m long, and provides about 11,421 m^2 of side-channel habitat interspersed with 6,288 m^2 of pond habitat, for a total wetted area of 17,709 m^2.

The original Weyerhaeuser Channel was constructed in 1989, and consisted of a 600 m long groundwater-fed channel with a wetted area of approximately 4,000 m^2. In September 1998, improvements were made to this site, including installation of a surface water intake and addition of large woody debris. Also, a new channel section and two shorter, blind channels were added. As a result of this expansion, the channel length was increased to 950 m and the wetted area to 6,000 m^2.

The above side-channels were created by excavating portions of the floodplain parallel to the river mainstem, and are protected from mainstem flooding by set-back dykes. Flow is derived from groundwater upwelling and from controlled surface water diversions from the mainstem. The channel portion of each site resembles a small, low gradient (0.5%) stream. The channels consist of roughly 80% rearing (pool) and 20% spawning (riffle) habitat. Wetted channel width ranges from 2.5 m to 20 m, and channel depth from 20 cm to 60 cm. Pool depth ranges from 0.5 m to 1.5 m. Discharge is low (< 1 cms) and relatively stable year-round. Channel substrate is composed of either native or introduced gravels (size range: 2-10 cm).

2.2 Side-channel and Center Creek smolt populations

Coho outmigrants from the Weyerhaeuser and Timber West side-channels and Center Creek, a major fish-producing tributary in the lower Englishman River, were enumerated at converging downstream weirs located in the same sites used in 2001 (Decker et al. 2003). Weirs were operated daily from April 3 to June 8. Since no weir failures or overflows were observed, we assumed 100% capture efficiency (CE) for all three weirs.

The Weyerhaeuser weir was installed about 250 m above the channel outlet (Figure 2), while the Timber West weir was installed 100 m above the channel outlet. To adjust for the number of smolts below the weirs, for each side-channel, the number of smolts captured at the weir was factored by the ratio of the total wetted area of the site (m^2) to the area of the sites above the weir (Timber West = 1.07, Weyerhaeuser = 1.3). No conversion factor was needed for counts from the Center Creek weir since it was situated just upstream of its confluence with the Englishman River.

All coho captured at the weirs were counted, and as time allowed, a portion were measured for fork length (to nearest mm). This meant that at the weirs and also the RSTs in the mainstem (see Section 2.3), length data were only collected on certain days. Thus, there was the possibility for bias in estimates of mean length for each site since daily means likely varied during the smolt migration and sampling was not in proportion to daily catches. To address this, we computed weighted means by pooling length data for each site by week, and estimating overall mean length as the average of weekly means. Based on a study by Bradford et al. (1996) that indicated that in streams of similar latitude to the Englishman River, most coho smolt at age-1, we assumed that all migrating yearling coho that we captured in the Englishman River in 2002 were smolts. This differs from previous years when a minimum fork length criteria was used to separate smolts from possible yearling parr (1998 and 1999: >79mm; 2001: > 70mm; Decker et al. 2003).

During summer 2001, an unknown number of hatchery coho fry were released in the Timber West Channel (C. Wright, pers. comm.). During our study in 2002, these fish were distinguishable from wild smolts by the presence of a clipped anal fin, thereby allowing us to generate separate population estimates for wild and hatchery origin smolts at this site.

2.3 Englishman River smolt population

The total abundance of coho smolts in the Englishman River system was estimated using the numbers of marked and unmarked coho captured in two rotary screw traps (RSTs) (Thedinga et al. 1994). These traps were 2.0 m in diameter and were situated 1.9 km (RST 1) and 4.0 km (RST 2) above the tidewater (Figure 2). Both RSTs were operated in relatively deep (> 1 m) areas of the mainstem where current velocity was relatively swift. Each RST intercepted approximately 25% of total discharge at the site. RST 1 and RST 2 commenced operation on April 17 and 3, respectively, and continued until June 8. The RSTs were fished daily and cleaned and repaired as necessary. Water temperatures were also recorded daily at RST 1 and also at the weir locations in the two side-channels and in Centre Creek (Appendix 3). Records of daily discharge for the Englishman River were obtained from Water Survey of Canada (Station 08HB002) and are provided in Appendix 4.

To obtain the ‘best estimate’ of the size of the smolt population in the Englishman River, we generated several independent mark-recapture estimates using marked populations from three different sites: the side-channels, Centre Creek and the upstream RST (RST 2) (Equations 1.1-1.7). Each group of smolts were given a unique mark by applying a tattoo to a specific fin location using a Pan-Jet dental inoculator loaded with Alcian Blue dye (Herbinger et al. 1990). At the side-channels and Centre Creek, all captured smolts that appeared healthy were marked prior to release. At RST 2 only unmarked smolts were marked prior to release. At both RSTs, we assumed that all unmarked smolts were of mainstem/tributary origin (excluding Centre Creek) since virtually all of the side-channel smolts entering the Englishman River mainstem were already marked. Therefore, we respect to the mark-recapture estimators, the unmarked population consisted of mainstem/tributary smolts only.

During summer 2001, 28,000 hatchery fry were released in the Englishman River upstream of the barrier created by the Englishman River Falls (C. Wright, pers. comm.). These coho, captured as smolts at the RSTs in 2002, were identified as being of hatchery origin by a clipped anal fin (smolts of hatchery origin from Timber West Channel were distinguishable from these by an additional side-channel mark). To estimate the number of smolts in 2002 that originated from this hatchery fry release, we factored the smolt population estimate for the mainstem/tributary area of the ~~mainstem/tributary~~Englishman River excluding marked fish from Centre Creek ~~area~~ ($N_{Mainstem/tributary}$ in equation 1.4 – N_{CC}) by the proportion of hatchery (identified by anal fin clip) smolts in the total catch of unmarked smolts (i.e, no Panjet mark) at RST 1.

2.4 Mark-recapture statistics and assumptions

For this single mark release or pooled Petersen estimate (PPE), we assumed that the recovery sample was taken without replacement, which leads to a "hypergeometric" form (Seber 1982, eq. for N* and v* on p. 60). The estimate for the number of smolts migrating past RST 1, then, would be

$$N_{RST\,1} = (M+1)(C+1) / (R+1) \qquad (1.1)$$

$$Var(N_{RST\,1}) = (M+1)(C+1)(M-R)(C-R) / (R+1)^2 (R+2) \qquad (1.2)$$

$$95\%\ CI\ (N_{RST\,1}) = \pm 1.96 \times Var\ (N_{RST\,1}) \qquad (1.3)$$

where

$N_{RST\,1}$ = number of smolts for the Englishman River system upstream of RST 1
M = number of smolts marked and released for a particular release site
C = number of marked and unmarked smolts recovered at the RST 1
R = number of marked smolts recovered at the RST 1

The estimate of the number of wild smolts that outmigrated from the entire anadromous portion of the Englishman River including the side-channels and the mainstem area downstream of the RSTs would be

$$N_{Total} = (N_{RST\,1}) \times L_{total} / L_{upstream} \qquad (1.4)$$

$$95\%\ CI\ (N_{Total}) = 95\%\ CI\ (N_{RST\,1}) \times L_{total} / L_{upstream} \qquad (1.5)$$

where

L_{total} = total anadromous length of the Englishman River system including the mainstem, tributaries, and the side-channels (33.4 km)
$L_{upstream}$ = total length of the Englishman River system upstream of RST 1 (31.5 km).

The estimate of the number of wild smolts that outmigrated from the mainstem/tributary area of the Englishman River excluding the side-channels would be

$$N_{Mainstem/tributary} = N_{Total} - N_{side\text{-}channels} \quad (1.6)$$

$$95\%\ CI\ (N_{Mainstem/tributary}) = 95\%\ CI\ (N_{Total}) \quad (1.7)$$

Separate estimates were generated for RST 1 and RST 2 using Equations 1.1-1.7 and recapture data for each of the three mark groups (side-channel, Centre Creek and RST 2) separately and combined (Table 1). Of these estimates, the "best" estimates was selected based on which combination of mark group (side-channel, Centre Creek or RST 2) and recovery site (RST 1 or RST 2) best conformed to mark-recapture assumptions (see below).

The PPE estimates depend on several important mark-recapture assumptions: no mark loss or mark induced mortality, population closure, a constant proportion of marked and unmarked recoveries, equal capture efficiency over time (the proportion of marked smolts recovered at an RST), and equal catchability of marked and unmarked smolts. Potential mark loss and marking-induced mortality were not assessed. However, in a similar study, Decker and Lewis (1999) observed that for hatchery coho smolts held in enclosures for 50 days, the estimated Pan-jet tattoo retention rate was 99%. They also found that mortality was negligible during a 24-hour period following marking. Therefore, for this study, we assumed a mark retention rate of 100% and a marking-induced mortality rate of 0%.

We examined whether the assumption of population closure was met by plotting, the histograms of daily catch totals at the side-channel weirs and the RSTs over time (Figure 3), and comparing daily numbers of smolts captured at the beginning and end of the trapping period to the numbers captured during the migration peak.

To test for constant proportions of marked to unmarked recoveries over time, the RST recovery catches were stratified into six temporal strata spanning the sampling period (Appendix 1 and 2), and the proportion of marked to unmarked smolts among temporal strata were compared (Pearson chi-square test).

We were unable to test for differences in capture efficiency over time because smolts were not differentially marked by capture period (see Arnason et al. 1996).

There is no easy way to test the assumption of equal capture efficiency for marked and unmarked smolts. We did test whether capture efficiency varied among the three mark groups since each group originated from a different part of the system, and this may have resulted in different migration timing or behaviour, which is a likely source of variation in capture efficiency. If capture efficiency was found to vary among mark groups, then we would use the mark group from RST 2 since these smolts originated from the mainstem/tributary and would likely exhibit similar migration timing and behaviour to unmarked mainstem/tributary smolts. We also examined whether migration timing differed for marked and unmarked smolts by plotting the cumulative daily proportions of coho smolts from each marked group and unmarked smolts captured at each RST (Figure 4). However, it is important to note that neither of these tests would detect a difference in capture efficiency for marked and unmarked smolts that resulted from 'trap-shy' or 'trap-happy' behaviour on the part of previously captured smolts (Seber 1982).

3.0 RESULTS AND DISCUSSION

During the study periods in 2002, daily water temperatures in the Englishman River mainstem ranged from 3°C to 12°C (Appendix 3), while daily temperatures in the side-channels and Centre Creek were often 1-3°C warmer. Discharge in the lower Oyster River during the study ranged from 2 to 66 m^3/s, declining over the length of the study period (Appendix 4). Daily coho smolt catch at the RSTs was not strongly correlated with either discharge or temperature ($R < 0.5$ for all cases).

3.1 Side-channel and Center Creek smolt populations

In 2002, the numbers of coho smolts captured at the Timber West and Weyerhaeuser side-channel weirs were 4,926 and 1,401, respectively. When these estimates were extrapolated to include the area between the weirs and confluence with the Englishman River mainstem, the population estimates for the Weyerhaeuser channel and Timber West channels were 1,825 smolts (1,921 smolts/km) and 5,283 smolts (3,828 smolts/km), respectively (Table 2). Total smolt abundance for the two side-channels in 2002 (7,108; Table 2) was within the range in smolt abundance observed for the side-channels during the 1998, 1999 and 2001 study years (5,893 - 8,339 smolts; Decker et al. 2003). The estimate of the number of smolts outmigrating from Center Creek was 6,236, which was double the estimate in 2001 (3,828 smolts; Decker et al. 2003).

The assumption of population closure appeared to be reasonably well met for the Center Creek and Timber West Channel weirs, but less so for the Weyerhaeuser Channel weir. The shape of the daily catch histograms for the Center Creek and Timber West weirs suggests that the majority of smolts outmigrated past these sites during the sampling period (Figure 3). However, despite a strong trend of decreasing daily catch near the end of the sampling period for these two locations, only at the Center Creek weir did daily catches approach minimal levels (< 10 smolts/day) by the end of trapping. The histogram of daily catch totals for the Weyerhaeuser weir did not indicate a clear migration peak or a sustained decrease in numbers towards the end of the sampling period, which made it uncertain how well the assumption of population closure was met. These results suggest that our smolt population estimates for the Weyerhaeuser Channel, and to a lesser extent, the Timber West Channel, are likely biased low.

3.2 Mainstem/tributary smolt population

Weighted means for smolt fork length varied from 82 mm at Centre Creek to 91 mm at Timber West Channel and RST 2 (Figure 5), but differences among sites were not significant (ANOVA, Bonferroni-adjusted pair-wise comparison, $P > 0.05$ for all cases). Observed mortality was at or below 1% for the RSTs for all the trapping sites.

For each mark group, a summary of the number of smolts marked and then recaptured at each RST is provided in Table 1 along with total catches and unadjusted PPE population estimates (i.e., $N_{RST\ 1}$ in Equation 1.1) derived from these numbers. For estimates using recaptures from the upstream RST (RST 2), there was no significant difference between the side-channel (39,931; 95% CI: ± 2,452 smolts) and Center Creek (37,916 ± 2,229 smolts) mark groups considering the overlapping 95% confidence intervals. Also, there was no significant difference in RST capture efficiency for the two marked groups (Center Creek 12%, side-channels 13%; Fishers exact test, $p = 0.08$; Table 1). This allows for the numbers of marked smolts from two locations to be combined to estimate smolt numbers at this RST. The estimate of the total number of outmigrating smolts using both mark groups and recaptures from RST 2 was 38,891 ± 1,488 smolts. Using both mark groups, the precision of the estimate increased to ±4% from the ± 6% achieved when using each mark group individually (Table 1).

For estimates using recaptures from the downstream RST (RST 1), there was no significant difference between estimates using the side-channel (48,319 ± 3,410 smolts; Table 1) and the Center Creek mark groups (47,084 ± 3,310 smolts), but the estimate using smolts marked at RST 2 was significantly lower than the other two (41,783 ± 4,051). There was no significant difference in RST capture efficiency for the three mark groups (Pearson Chi-square, $\chi^2 = 5.25$, df = 2, $p = 0.07$). However, a plot of the cumulative daily proportions of smolts captured at RST 1 (Figure 4) suggests that unmarked fish from the mainstem/tributary area began migrating in substantial numbers earlier than did marked smolts from the three release sites (side-channel, Centre Creek, RST 2). This is also evident in the daily catch histograms for each site (Figure 3): in early May an initial pulse of smolts was observed at RST 1, but not at the other sites. The assumption of constant proportions of marked to unmarked smolts over time was not met at either RST 1 or RST 2 (~~jody, chi-square values??????, or if not, just P < 0.05 for both cases??~~$P < 0.05$ for all cases; Table 1). At the RSTs, the proportion of smolts from the various mark groups (RST 1: side-channel, Centre Creek and RST 2 mark groups; RST 2: side-channel and Centre Creek mark groups;) increased steadily over the course of the study period (Appendices 1 and 2).

Although there was no way of confirming this, we judged that different migration timing may have led to a difference in capture efficiency for marked and unmarked smolts at RST 1. Therefore, we selected the population estimate obtained using marked mainstem/tributary smolts from RST 2 and the recapture data from RST 1 as the “best” estimate. This was done because, compared to the other two groups, migration timing for the RST 2 mark group appeared closer to that for unmarked smolts at RST 1 (Figure 4).

When the estimate using smolts marked at RST 2 (41,783) was extrapolated to include the portion of the mainstem downstream of RST 1, the total number of coho smolts for the Englishman River system in 2002 was 44,303 (± 4,296; Table 2). Subtracting from this total the estimated number from the side-channels (7,108), gave a smolt estimate for the mainstem/tributary area of 37,195 (± 4,296) or 1,200 smolts·km^{-1} (Table 2). This is within the range of previous years' (1998, 1999, 2001) estimates of total smolt production for the mainstem/tributary area (25,192 to 42,927 smolts; Decker et al. 2003). In 2002 an estimated 16% (95% CI: 14.6% to 17.8%) of total number smolts that outmigrated from the Englishman River system originated from the Timber West and Weyerhaeuser side-channel habitats. This is also comparable to previous years when the two side-channels contributed an estimated 15% to 25% of total smolt numbers (Decker et al. 2003).

The mark-recapture estimates of smolt abundance for mainstem/tributary area and the total Englishman River system were relatively precise (±12% and ±10%, respectively; Table 2). This was achieved through reasonably good capture efficiency (11%; Table 1) at the recovery site (RST 1) and a large number of marked smolts (3,015; Table 1). However, for two reasons, these estimates may be somewhat biased. First, as mentioned above there was a notable difference in migration timing for marked and unmarked smolts, even when only marked mainstem/tributary smolts from RST 2 were considered (Figure 4). Second, the assumption of population closure was not met for either of the two RSTs. The smolt migration occurred relatively late in 2002 compared to previous years (see Decker et al. 2003), and as a result, total catches remained at 80-100 smolts and 50-80 smolts/day at RST 1 and RST 2, respectively (Figure 3), in the final week (June 1-8) of trapping. In a plot of cumulative fish captured over time, population closure would be indicated by considerable flattening of the slope prior to the end of trapping. However, the slope of marked and unmarked captures at RST 1 and RST 2 remained steep (Figure 4). A lack of population closure at the two side-channel weirs (Figure 3) may also have contributed to underestimation of the whole river smolt population. Nevertheless, even though the estimates of total smolt abundance may be biased, the estimate of the proportion of smolts from the side-channels may not because a lack of population closure was apparent for both the mainstem and the side-channel traps.

We were unable confirm that the capture efficiency was constant at each RST throughout the sampling period since smolts were not marked by release period. However, we speculate that capture efficiency was relatively constant, due to the relatively constant river discharge during May and June (Appendix 4) when the bulk of the migration occurred. Fluctuation in discharge is a common source of variation in RST capture efficiency (Roper and Scarnecchia 1996; Irvine et al. 1996). Moreover, in other studies where a stratified estimator (Darroch 1961) was used to address violations of the assumptions constant proportions and equal capture efficiency, the stratified estimates were not significantly different from those derived from the non-stratified Petersen estimator used here (Dempson and Stansbury 1991; Schwarz and Dempson 1994; Decker et al. 2003: Decker and Lewis 2000). This suggests the Petersen estimator may be robust to violation of these two assumptions.

3.2 Smolt production from hatchery fry releases

Of the 4,926 smolts captured at the Timber West weir, 911 (17%) were originated from the release of hatchery fry in Timber West Channel the previous year (Table 2). Fry-to-smolt survival could not be estimated for the released fry because the fry were not counted before release.

Based on the proportion of hatchery coho smolts captured at RST 1 that were not marked as being captured at Center Creek, the side-channels or RST 2 (14.2%), factored by the smolt population estimate for the mainstem/tributary area (27,944 smolts excluding Centre Creek and marked smolts from RST 2) the estimated number of smolts that originated from the release of 28,000 hatchery fry upstream of the barrier in the Englishman River mainstem was 3,968 (Table 2). Fry-to-smolt survival for smolts from this hatchery release was an estimated 14.2%, which was comparable to a range of survival estimates reported by Tripp and McCart (1983) for a fry stocking experiment above migration barriers in two small streams on southern Vancouver Island. Overall, in 2002, an estimated 5,307 of the 44,303 (11.0%) outmigrating smolts from the Englishman River system originated from hatchery fry releases in 2001.

4.0 CONCLUSIONS AND RECOMMENDATIONS

In 2002, an estimated 44,303 (95% CI: ± 4,296) coho smolts outmigrated from the Englishman River system; 7,108 (16%) of these smolts originated from two constructed side-channels that represented less than 8% of total habitat in the stream (by channel length). These estimates should be considered minimum values because downstream trapping likely ended prior to the completion of the smolt migration. As well, an estimated 11% of the total number of smolt outmigrants originated from hatchery fry releases in 2001. These results suggest that constructed side-channels in the Englishman River were readily colonized by both wild spawners and released hatchery fry, and that side-channel outmigrants contributed substantially to overall smolt production in the system. However, in order to state unequivocally that side-channel development has increased the overall smolt production in the system, a long-term monitoring program would have to be conducted before and after enhancement. This was not possible for the Englishman River. Nevertheless, our study indicates that the construction of two side-channels in the Englishman River has affected the distribution of coho production. If it is assumed that coho smolt production in the Englishman River is limited by overwintering habitat, then it is reasonable to suggest that overall coho productive capacity of the system has been increased as a result of side-channel construction.

For future smolt trapping programs in the Englishman River, we make the following recommendations:

1. Smolt marking should be stratified by release period so that a stratified mark-recapture estimator (Darroch 1961) can be used. This can be done with little extra cost or effort when using Pan-jet marking techniques. Without stratified marking, there is no means of determining whether failure to meet the assumption of constant capture efficiency over time has biased the population estimates.

2. At each site, downstream trapping should be scheduled so that it spans the period of major smolt movement (i.e., includes the period when the catch per day exceeds 10-20 smolts at each weir or RST).

3. If hatchery fry or smolt releases are to occur, all fish should be marked (to identify them as hatchery fish) and counted prior to release to allow for estimates of hatchery fry-to-smolt survival and hatchery contribution to overall smolt production. Furthermore, the size and timing of releases should be integrated into the ERSMP so that hatchery supplementation can be balanced with objectives for wild coho restoration.

5.0 ACKNOWLEDGEMENTS

Mel Sheng administered and assisted with the design of the study. Clay Young of the Community Fisheries Development Centre of Central Vancouver Island coordinated the field crew and assisted in the administration of the program. Bob Brown, Mike Edwards, Matt McKay, and Jeffrey Young collected the field data and performed the strenuous task of constructing and disassembling the downstream traps. We appreciate the generosity and co-operation of Mike Gieringer and Yvonne Taylor who provided access to several trapping sites through their land.

6.0 REFERENCES

Arnason, A.N., C.W. Kirby, C.J. Swartz, J.R, Irvine. 1996. Computer analysis of data from stratified mark-recovery experiments for estimation of salmon escapements and other populations. Can. Tech. Rep. Fish. Aquat. Sci. 2106.

Bradford, M. J., G. C. Taylor, and J. A. Allan. 1996. Empirical review of coho salmon smolt abundance and the prediction of smolt production at the regional level. Tran. Amer. Fish. Soc. 126:49-64.

Darroch, J.N. 1961. The two-sample capture-recapture census when tagging and sampling are stratified. Biometrika 48: 241-260.

Decker, S., and G. Lewis. 2000. Fish response to increased minimum flows and habitat restoration in the Coquitlam River: a five-year review. Unpublished report prepared for B.C. Hydro Power Facilities, Burnaby, B.C., December 2000: 40 p.

Decker, A.S., M.J. Lightly and A.A. Ladwig. In Press . The contribution of two constructed side-channels to coho salmon smolt production in the Englishman River. Can. Tech. Rep. Fish. Aquat. Sci.

Dempson, J.B., and D.E. Stansbury. 1991. Using partial counting fences and a two-sample stratified design for mark-recapture estimation of an Atlantic salmon smolt population. N. Amer. J. Fish. Manage. 11: 27-37.

Herbinger, C.M., G.F. Newkirk and S.T. Lanes. 1990. Individual marking of Atlantic salmon: evaluation of cold branding and jet injection of Alcian Blue in several fin locations. J. Fish. Biol. 36: 99-101.

Hurst, R. 1988. Englishman River salmon maintenance plan. Department of Fisheries and Oceans. Unpublished internal report.

Irvine, J.R., Y. Miyakoshi, H. Hayano, M. Fujiwara, K. Sugiwaka, M. Miyamoto, and M. Nagata. 1996. Assessment of hatchery origin and wild masu salmon (*Oncorhynchus masou*) smolts in the Masuhoro River, 1996. Scientific Reports of the Hokkaido Fish Hatchery 50:1-16.

Roper, B., and D.L. Scarnecchia. 1996. A comparison of trap efficiencies for wild and hatchery age-0 chinook salmon. N. Amer. J. Fish. Mange. 16: 214-217.

Seber, G.A.F. 1982. The estimation of animal abundance. 2nd ed. Griffin, London.

Schwarz, C.J., and J.B. Dempson. 1994. Mark-recapture estimation of a salmon smolt population. Biometrics 50: 98-108.

Tripp, D., and P. McCart. 1983. Effects of different coho stocking strategies on coho and cutthroat trout production in isolated headwater streams. Can. Tech. Rep. Fish. Aquat. Sci. 1212: 176 p.

Table 1. Summary of the number of coho smolts marked (M) at the Center Creek and side-channel weirs (Weyerhaeuser and Timber West) and RST 2, the total number of smolts recovered at RST 1 and RST 2 (C), the number of marked smolts recovered (R), and the capture efficiency for each mark group. Also shown are the pooled Peterson estimates of the number of smolts that passed each RST based on each mark group and 95% confidence intervals. Tests of equal proportions refer to the probability that the proportion of marked and unmarked smolts were constant among the six recovery periods (*P*).

				Capture	Pooled Peterson estimate				Test of equal prortions	
Mark group	M	C	R	Efficiency (R/M)	N smolts	SE	CI (±)	CI (%)	Chi-square value	*P*
RST 2										
All locations	12,457	4,866	1,558	0.13	38,891	759	1,488	4%	311	< 0.01
Center Creek	6,171	4,866	752	0.12	37,916	1,137	2,229	6%	155	< 0.01
Side-channels	6,286	4,866	806	0.13	39,931	1,251	2,452	6%	115	< 0.01
RST 1										
All locations	15,435	4,654	1,547	0.10	46,416	915	1,793	4%	495	< 0.01
RST 2	3,015	4,654	335	0.11	41,783	2,067	4,051	10%	32	< 0.01
Center Creek	6,159	4,654	608	0.10	47,084	1,689	3,310	7%	226	< 0.01
Side-channels	6,279	4,654	604	0.10	48,319	1,740	3,410	7%	170	< 0.01

Table 2. Summary of estimated coho numbers, 95% CI, densities and proportion of total Englishman River smolt run for the Timber West and Weyerhaeuser side-channels, Center Creek, Englishman River mainstem and tributaries, and the entire Englishman River system. Smolt numbers for the Englishman River are based on pooled Peterson estimates using smolts marked at RST 2 and recaptured at RST 1.

Site	Length (km)	Area (m^2)	Estimation method	N smolts	CI (+/-)	CI %	Smolt density /km	Smolt density /m^2	% of smolt run
Timber West (hatchery)[2]	1.38	17,709	Count	1,215	-	-	881	0.07	-
Timber West (total)	1.38	17,709	Count	5,283	-	-	3,828	0.30	12%
Weyerhaeuser	0.95	6,000	Count	1,825	-	-	1,921	0.30	4%
Side-channels total	2.4	23,709	Count	7,108	-	-	2,962	0.30	16%
Center Creek	5.2		Count	6,236	-	-	1,199	-	14%
Mainstem/tributary[1]	31.0		Peterson	37,195	4,296	12%	1,200	-	84%
Upper Englishman (hatchery)[2]	-		Peterson	3,968	-	-	-	-	-
Total system	33.4		Peterson	44,303	4,296	10%	1,326	-	100%

[1] Includes smolt numbers from Center Creek
[2] Estimated number of smolts resulting from the release of hatchery fry in the Timber West side-channel or in the Englishman River mainstem upstream of an anadromous barrier

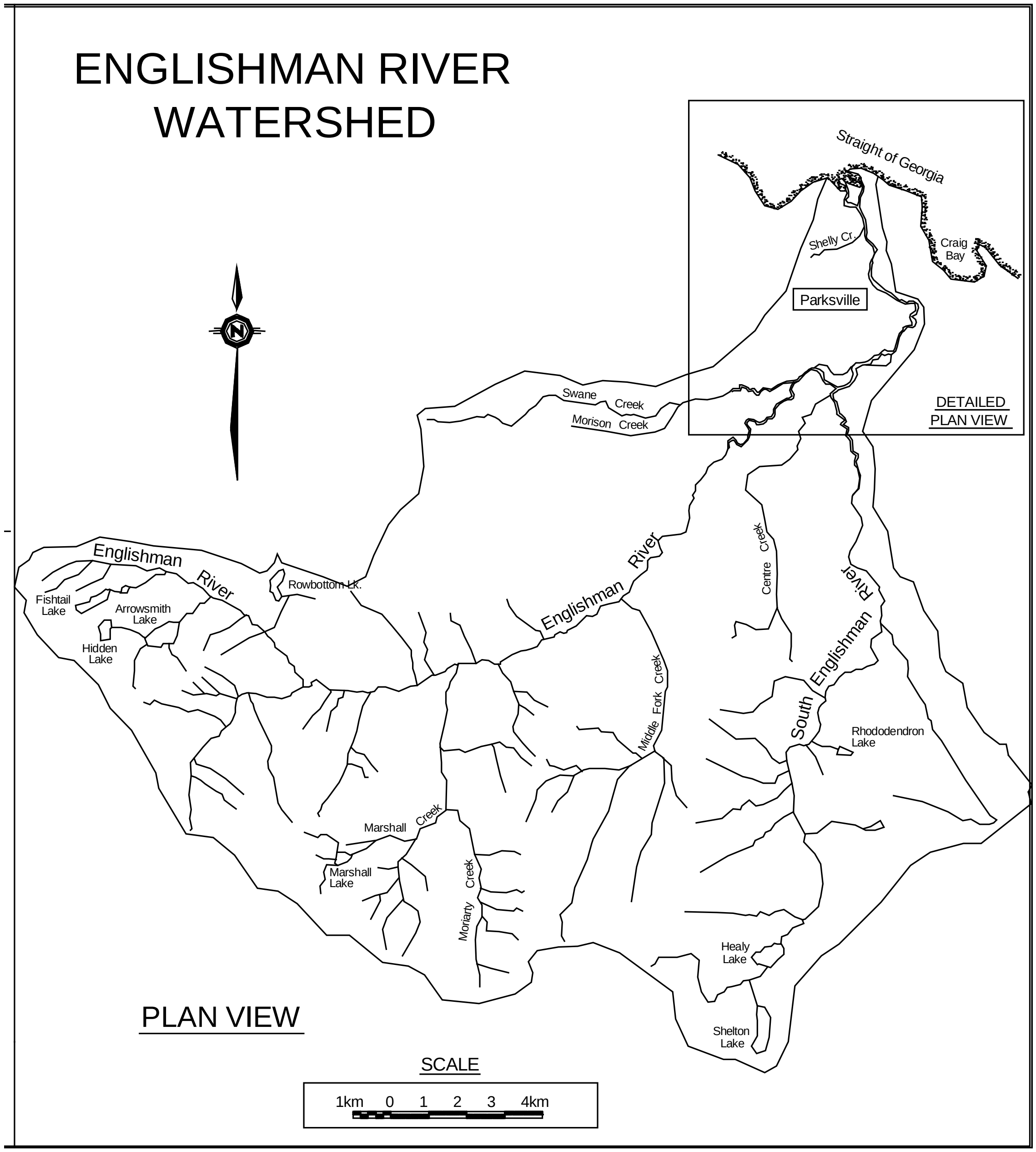


Figure 1. Map of the Englishman River watershed.

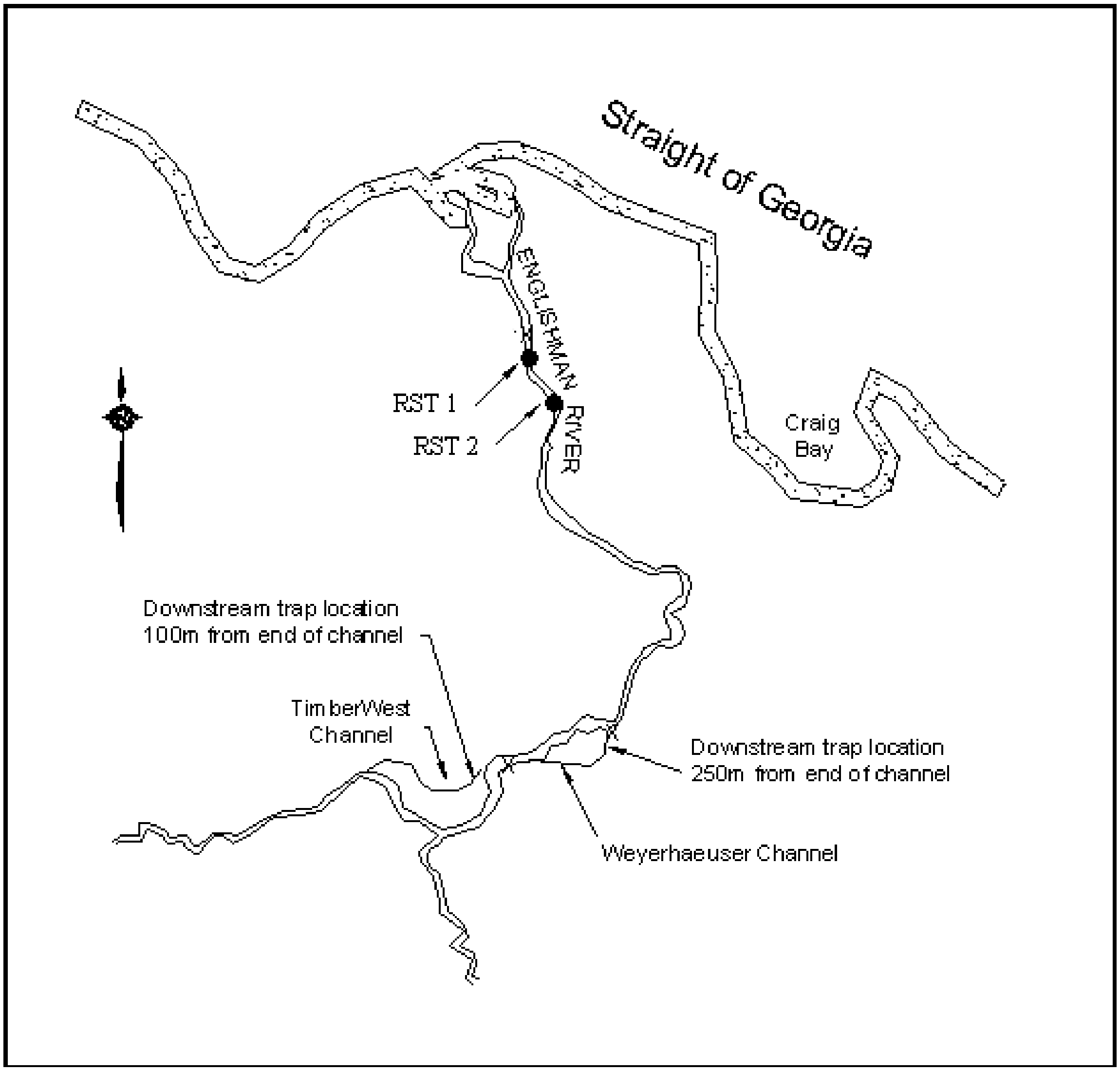


Figure 2. Map of the lower Englishman River showing the location of two rotary screw traps (RST) in the mainstem and two constructed side-channels and the downstream trap (weir) locations for these sites.

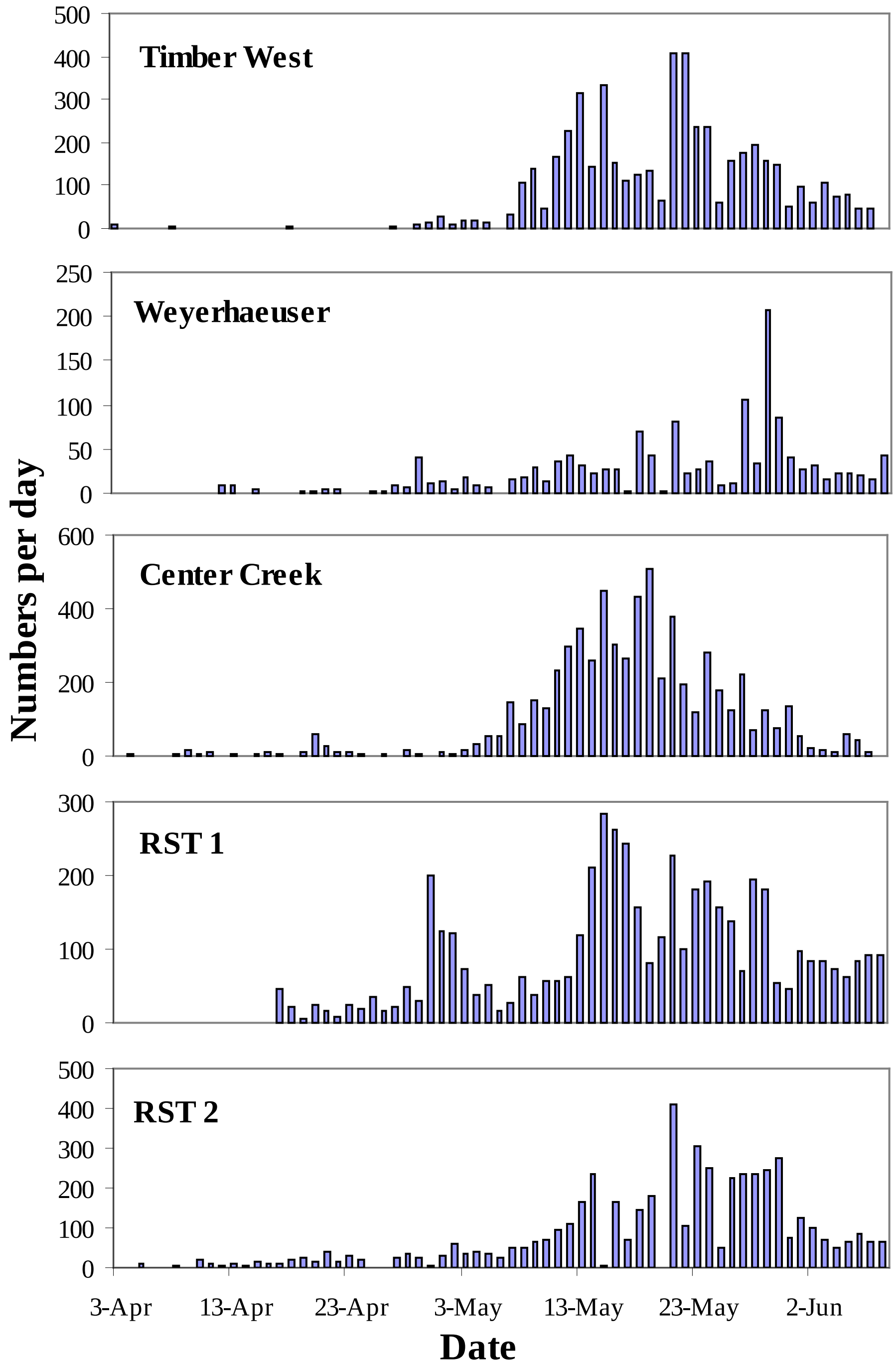


Figure 3. Daily catches of coho smolts at the Timber West and Weyerhaeuser side-channel weirs, Center Creek weir and rotary screw traps positions 1.9 km (RST 1) and 4 km (RST 2) above tidewater on the English River.

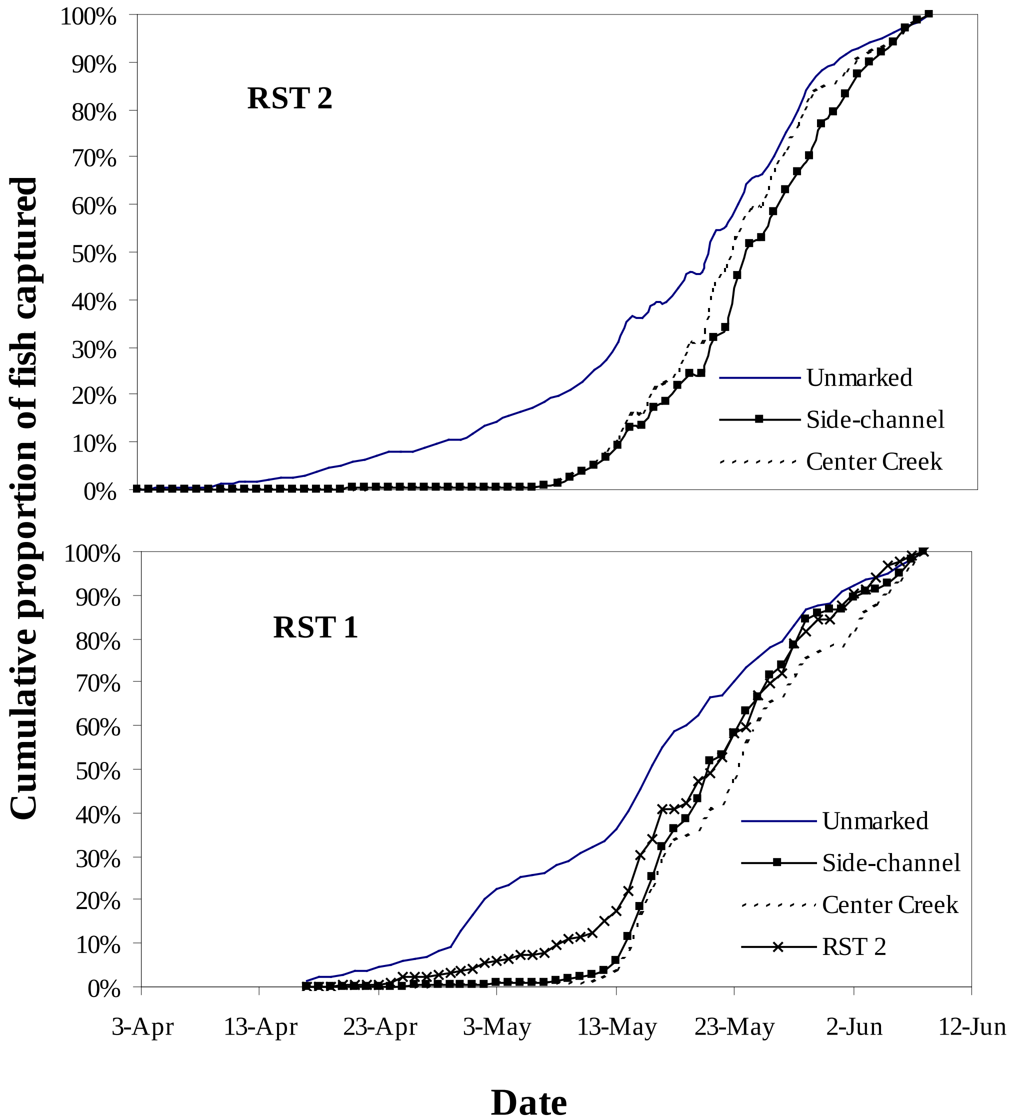


Figure 4. Cumulative daily proportions of coho smolts marked at either the side-channel or Center Creek weirs, RST 2 (RST 1 captures only) and unmarked that were captured at captured at the rotary screw traps situated 4 km (RST 2) and 1.9 km (RST 1) upstream of tidewater on the Englishman River.

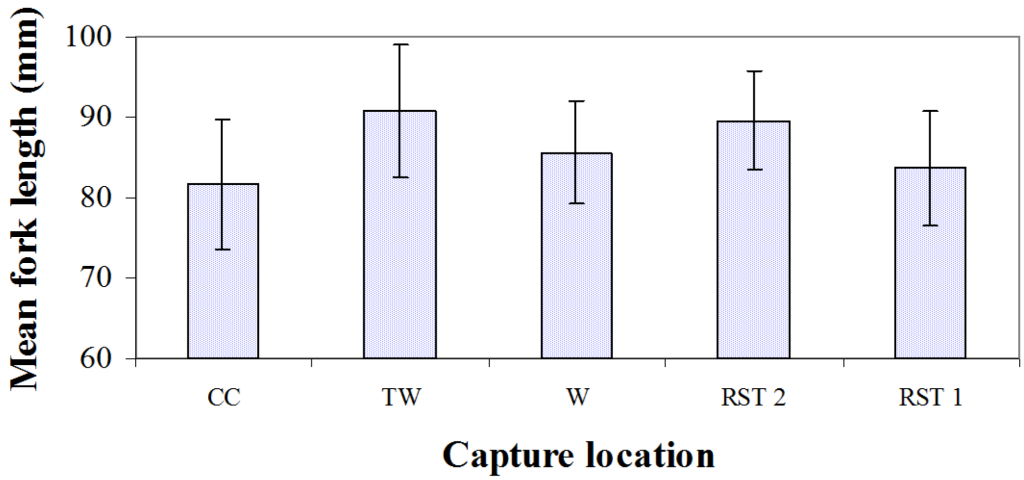


Figure 5. Weighted mean fork length of coho captured at downstream weirs in Center Creek (CC), Timber West (TW) and Weyerhaeuser (W) side-channels, and unmarked smolts captured at two rotary screw traps situated 1.9 (RST 1) and 4 km (RST 2) upstream of tide-water on the Englishman River. Error bars represent 95% confidence intervals.

Appendix 1. Numbers of coho smolts marked and released (M), numbers of marked and unmarked smolts recovered, percentages of marked smolts recovered (capture efficiency), and the proportion of catch that were marked in each of the 6 recovery periods (strata) for the lowermost rotary screw trap (RST 1) 1.9 km upstream of tide-water on the Englishman River.

A. Side-channel

		Recovery period						
		1	2	3	4	5	6	
	M	3-April 29-April	30-April 11-May	12-May 18-May	19-May 25-May	26-May 1-June	2-June 8-June	Capture efficiency
Marked	6,279							
Marked recovereis		4	14	201	183	122	80	0.10
Total catch		313	778	1,338	994	690	541	
Untagged Fish		309	764	1,137	811	568	461	
Proportion of marked recoveries		1%	2%	15%	18%	18%	15%	

B. Center Creek

		Recovery period						
		1	2	3	4	5	6	
	M	3-April 29-April	30-April 11-May	12-May 18-May	19-May 25-May	26-May 1-June	2-June 8-June	Capture efficiency
Marked	6,159							
Marked recovereis		3	5	197	169	102	132	0.10
Total catch		313	778	1,338	994	690	541	
Untagged Fish		310	773	1,141	825	588	409	
Proportion of marked recoveries		1%	1%	15%	17%	15%	24%	

C. RST 2

		Recovery period						
		1	2	3	4	5	6	
	M	3-April 29-April	30-April 11-May	12-May 18-May	19-May 25-May	26-May 1-June	2-June 8-June	Capture efficiency
Marked	3,015							
Marked recovereis		11	30	95	89	69	41	0.11
Total catch		313	778	1,338	994	690	541	
Untagged Fish		302	748	1,243	905	621	500	
Proportion of marked recoveries		4%	4%	7%	9%	10%	8%	

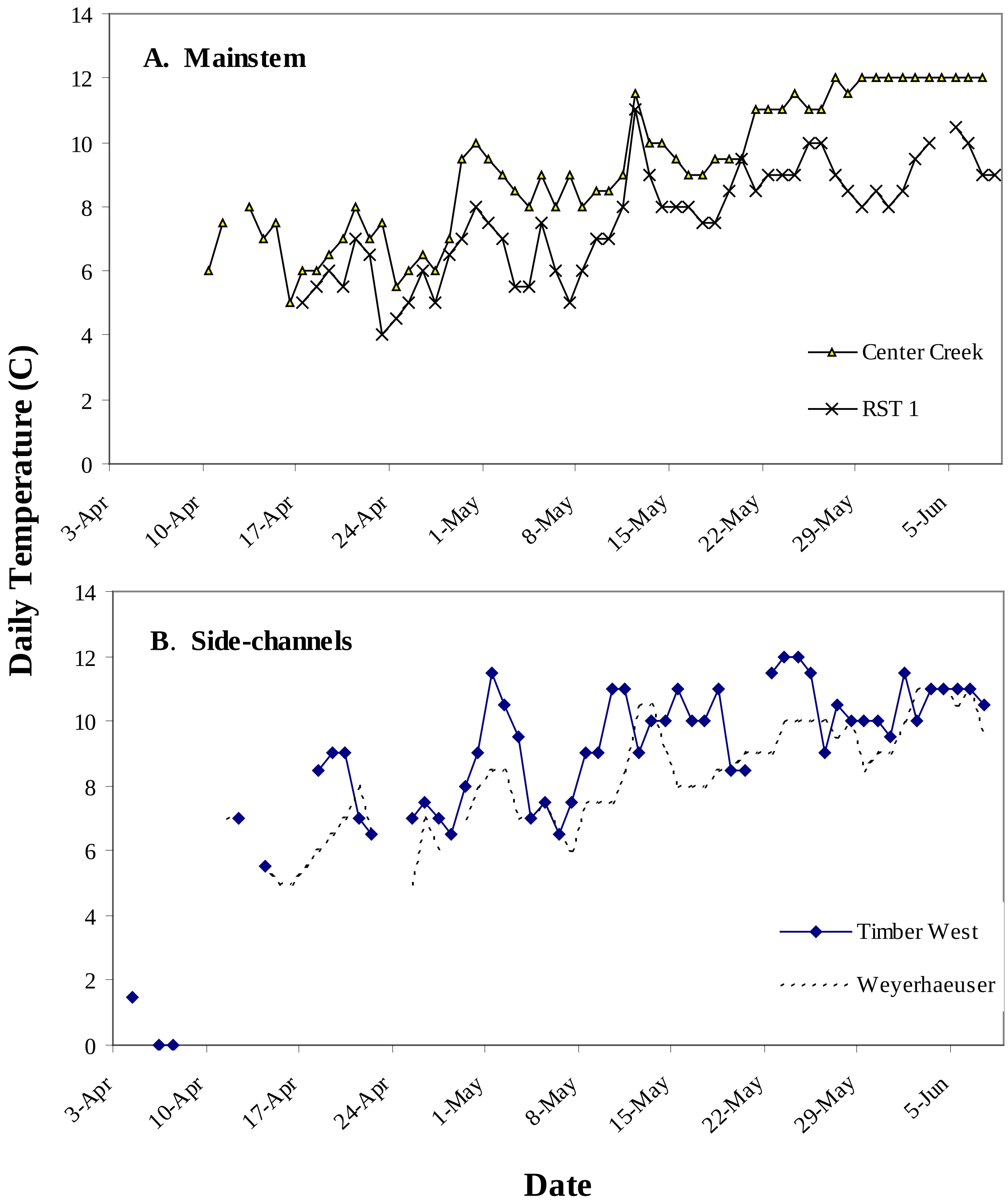
Appendix 2. Numbers of coho smolts marked and released (M), numbers of marked and unmarked smolts recovered, percentages of marked smolts recovered (capture efficiency), and the proportion of marked smolts recovered in each of the 6 recovery periods (strata) for recaptures of the two mark groups (A. Side-channel, B. Center Creek) at the rotary screw trap (RST 2) located 4.0 km upstream of tide-water on the Englishman River.

A. Side-channel

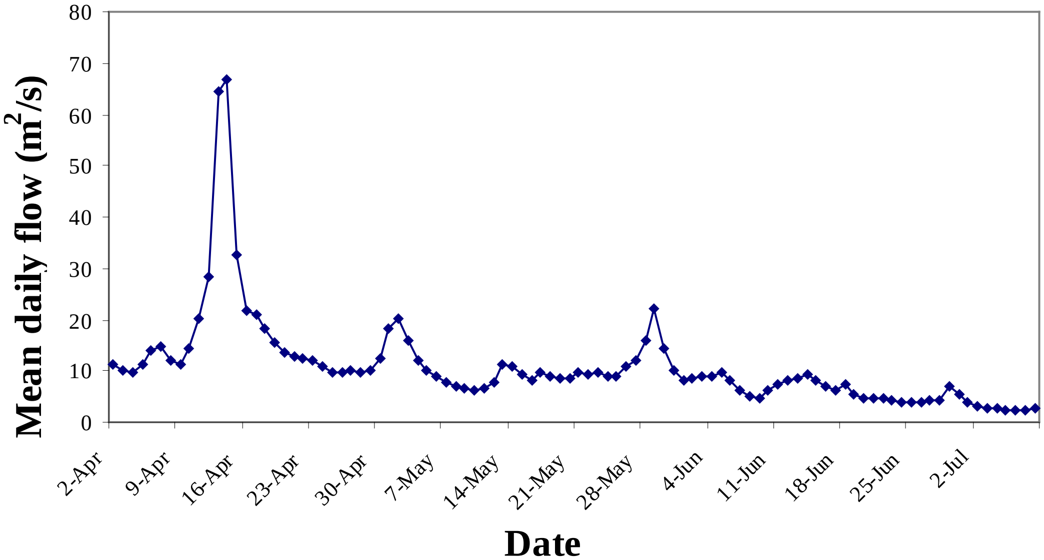
		Recovery period						
		1	2	3	4	5	6	
	M	3-April 29-April	30-April 11-May	12-May 18-May	19-May 25-May	26-May 1-June	2-June 8-June	Capture efficiency
Marked	6,286							
Marked recoveries		2	40	133	253	242	136	0.13
Total catch		351	563	856	1,302	1,293	501	
Untagged Fish		349	523	723	1,049	1,051	365	
Proportion of marked recoveries		1%	7%	16%	19%	19%	27%	

B. Center Creek

		Recovery period						
		1	2	3	4	5	6	
	M	3-April 29-April	30-April 11-May	12-May 18-May	19-May 25-May	26-May 1-June	2-June 8-June	Capture efficiency
Marked	6,171							
Marked recoveries		2	41	147	262	212	88	0.12
Total catch		351	563	856	1,302	1,293	501	
Untagged Fish		349	522	709	1,040	1,081	413	
Proportion of marked recoveries		1%	7%	17%	20%	16%	18%	



Appendix 3. Water temperatures at two mainstem/tributary locations of the Englishman River (A. Mainstem) and at the two side-channel habitats (B. Side-channels).



Appendix 4. Mean daily flows in the Englishman River during trap and weir operation in 2002 (WSC Station 08HB002).