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Assessment of the 2009 outmigration of Coho salmon smolts from the Englishman River

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ABSTRACT

The 2009 coho smolt outmigration from the Englishman River was assessed through a mark-recapture program conducted between April 20 and June 11. Coho juveniles, migrating from the Clay Young side channel, were enumerated at a counting fence and a number of these fish were marked on each of 8 occasions, representing 5 temporal strata, during the outmigration. The movement of smolts from the Englishman River, including marked fish, was monitored using a rotary screw trap (RST) fishing in the lower river. The overall efficiency of capture during the study was 6.7%, higher than that recorded at this site in the previous year of this program.

Total smolt production in the Englishman River system in 2009 was derived using a stratified Petersen estimator, with pooling of individual strata estimates due to significant temporal variation in capture probabilities. The estimate for the Englishman system was 85,467 (95% CI 78,241- 92,692). The count of coho juveniles originating from the side channel, adjusted to incorporate that portion not sampled by the counting fence, was 36,100 individuals. This represents an unprecedented contribution of 42% of total production from the side channel.

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1.0 INTRODUCTION

In common with many other streams on the East coast of Vancouver Island, the Englishman River experienced declining escapements of coho and other anadromous species in the 1980's. This situation stimulated efforts by the DFO, local community groups and other stakeholders, to assess limitations on freshwater production and identify opportunities for mitigation. Among the limiting factors that were identified were extreme fluctuations in seasonal flows that resulted in lack of summer off-channel rearing areas, and a paucity of winter low velocity refuge areas for pre-smolts (Miller 1997). In order to address these deficiencies, the Englishman River Salmon Maintenance Plan (Hurst 1988) initiated construction of side-channel habitat in 1989 with the Weyerhaeuser Channel (then MacMillan Bloedel Ltd. Channel). A second channel, the Nature Trust Channel (then Fletcher Challenge Ltd. Channel and subsequently Timber West Channel), was constructed in 1992. In the past two years, the Community Fisheries Development Centre (CFDC), in conjunction with a number of partners, including DFO, PSC, Ministry of Transportation and Highways, BC Transmission Corp, Castaways Club, BC Conservation Foundation, BC Living Rivers Trust Fund, Habitat Conservation Trust Fund and the T.Buck Suzuki Fund constructed 3.5 km of new channel (Clay Young Channel). This provides an additional 5,000 m^2 spawning and 34,800 m^2 rearing habitat, and has the potential to boost coho smolt production by 50 – 100%.

The current study was designed to assess the 2009 output of coho smolts from the Englishman system and specifically examine the contribution of the new channel to overall production. In 2001 the Pacific Salmon Endowment Fund Society (PSEFS) mandated development of annual baseline data on coho and steelhead smolt abundances to permit assessment of trends in stock dynamics. The Englishman River Watershed Recovery Plan (ERWRP; Bocking and Gaboury 2001) initiated a series of programs to address these issues through the Community Fisheries Development Centre and local fisheries stream stewards. Directed efforts to quantify the contribution of channel coho to the Englishman system, were made in series of projects initiated in 1998, using mark-recapture. From 2002, these studies were ratified by ERWRP and funded by PSEF. In 2004 (Taylor 2004) modification to the methods used in these programs, focused on estimation of overall population size of coho smolts in the Englishman watershed, and in 2005 (Taylor 2005) a single release location, the Nature Trust channel, was the primary source of marks. That method was again used in the current study, this time using the Clay Young Channel to capture and release marked smolts.

2.0 STUDY AREA

The Englishman River flows from Mount Arrowsmith north-east for 28 km to enter the Strait of Georgia just south of Parksville, on Vancouver Island (Fig 1). It drains a watershed of approximately 324 km^2. The Englishman River primarily supports runs of coho *(O. kisutch)* and chum *(Oncorhynchus keta)*, with less numerous escapements of chinook *(O. tshawytscha)*, pink *(O. gorbuscha)*, sockeye *(O. nerka)* steelhead *(O. mykiss)*, and anadromous cutthroat trout *(O. clarki)* (Brown et al. 1977). Anadromous fish can access 15.7 km of mainstem, up to the natural barrier of the Englishman River Falls. Additional anadromous fish habitat is provided by tributaries that increase the accessible length to 31 km (Decker et al. 2003). Among these, Centre Creek is a major contributor at 5.2 km long, representing approximately 17% of the total linear habitat.

The two oldest side-channels provide 950 m (Weyerhaeuser) and 1,380 m (Nature Trust) of low gradient habitat in the lower 7 km of river. The Weyerhaeuser Channel is located approximately 6 km upstream from the estuary, on the south bank of the mainstem. It was constructed in 1989, primarily to create summer and winter rearing habitat for juvenile coho. The initial constructed length was 600 m: overall length was extended in 1998 and 2 spur channels were added for an overall wetted area of 6,000 m^2. The Nature Trust channel flows into the mainstem from the north bank, 1 km further upstream. It provides 17,709 m^2 of low gradient (0.5%) habitat. Both channels derive flows from groundwater upwelling as well as controlled intake of river water. In combination, these channels represent a substantial contribution to coho production in the Englishman River system, with estimates ranging from 10% (2003, Schick and Decker 2004) to 25% (1998, Decker et al. 2003). Taylor (2005) estimated that the Nature Trust channel alone produced 9.3% of the production in the Englishman River system.

In 2007 the Nature Trust channel was extended by 2.9 km, bringing the total available rearing habitat to 7.44 ha. It was expected that the contribution of smolts from the expanded channel would be substantial, based on the biostandard of 0.4 smolts m^{-2}.

3.0 METHODS

In their simplest form, the design of studies initiated in 1998 enabled an estimate of total coho smolt population size from a simple Petersen mark-recapture estimator, using catch data from two rotary screw traps (RSTs) in the lower Englishman River (Decker at al. 2003). Marks were released in conjunction with enumeration of a substantial portion of the smolt outmigration from the Nature Trust and Weyerhaeuser side-channels and, from 2001 to 2004, from Centre Creek, a natural tributary. Permutations of the design have included stratification of mark releases by release site only (1999) and with the inclusion of temporal (release period) stratification, analysed with a pooled Petersen estimator (PPE) and the use of a maximum likelihood estimator after Plante (1990) and as used by Arnason et al. (1996) in their Stratified Population Analysis System software package (SPAS). Generally, a series of estimates of population size were obtained from geographical stratification (release and recovery combinations), and, in a majority of years, the population estimates have been obtained by pooling the temporal strata (release periods).

In 2004, a modified design, based on the simple stratified M-R technique of Carlson et al. (1998) was adopted. In the following year a simplified marking protocol with associated simplified count of recoveries, resulting in reduced personnel costs, was implemented (Taylor 2005). Only one channel release site was used (Nature Trust) and 2 mark types were alternated between release strata. Two additional mark types were alternated at the upper RST site. As a result, coho captured in the lower RST had to be examined for only 4 distinct marks. This design was further modified in the present study by retaining only the lower RST site and increasing the number of mark types to four, to guard against recovery interactions among recovery strata.

3.1 Study Design

The stratified estimator described by Carlson et al. (1998) requires the application of unique mark types within designated marking periods to provide an estimate of capture probability (trap efficiency) over time, so that variation in efficiency can be addressed within the assumption of reasonable consistency in strata. This approach requires temporal stratification such that each trap efficiency trial is discretely paired with one capture period. An important element in planning is to determine the number of marks that must be released in order to achieve an appropriate level of accuracy for desired precision. Data from the 2005 study was used to generate the necessary parameters to calculate the required sample size for mark releases per stratum.

3.1.1 Calculation of mark releases

An appropriate goal for the level accuracy and precision was based on the recommendation of Robson and Regier (1964) for fairly accurate management work: an acceptable level of error is ±25% to be exceeded not greater than 5% of the time (α=0.05). Since a large number of smolts were expected to be available from Clay Young Channel in 2009, smolts numbers were not anticipated to be a limiting factor in any but the initial and final strata. Consequently, the total relative error (r_h) was set at

±15% for 95% precision and the calculated number of marks required to achieve this target was considered to be a minimum for the program.

Strata totals from the 2005 migration were used to estimate the proportion of the population encountered in each time period (ϕ_h) : a total of 5 strata were anticipated for 2009, given a provisional program duration of April 17 to June 7. These were 5%, 22%, 38%, 29% and 7%. A conservative capture efficiency of 5% was assumed for the RST, corresponding to the measured rate in 2005. Assuming a constant relative error (i.e. $r_1 = r_2 = ... = r_L$) then the expected stratum relative error (r_t) was estimated to be 28% from:

$$r_h = \frac{r_t}{\sqrt{\sum_{h=1}^{L} \phi_h^2}} \qquad (1)$$

and the number of marks required for release per stratum was calculated from:

$$M_h = \frac{K}{e_h(100)} \qquad (2)$$

where K is a constant described by the power function y=3E+6x$^{-1.8893}$ constructed for α=0.05 from data given in Carlson et al. (1998). A minimum of 1,059 marked fish is then required for release in each stratum.

3.1.2 Estimation method

The common Petersen estimator for population size, incorporating the Chapman (1951) modification for small sample bias, was used to provide an estimate of the overall population, including marked smolts, from release catch and recapture data. This estimator compensates for the tendency of the simple Petersen to overestimate the true population, particularly at low sample sizes, but requires recaptures to exceed 7 in a given stratum (Robson and Regier 1964). Strata estimates are from:

$$\hat{N}_h = \frac{(n_h + 1)(M_h + 1)}{m_h + 1} - 1 \qquad (3)$$

where

$\hat{N}_h$ = estimate of population size for stratum h

M_h = number of marked smolts in stratum h

n_h = number of smolts in the RST catch in stratum h

m_h = number of recaptured marks in stratum h

Total smolt abundance is given by:

$$\hat{N} = \sum_{h=1}^{L} \hat{N}_h \qquad (4)$$

Given that predicted release of marks plus total catches in any RST was expected to be less than the anticipated population of smolts, the result is an approximately unbiased estimate.

The tally of marked smolts from RST catches represents sampling without replacement and, hence, the distribution of m_h for ranges of M_h and n_h, is hypergeometric. However, for populations greater than 100, simpler distributions, such as the binomial and normal, are satisfactory approximations (Robson and Regier 1964). Given the very large smolt population size, the normal approximation to the variance for $\hat{N}_h$ is adequate, in the form:

$$\mathrm{v}(\hat{N}_h) = \frac{(M_h + 1)(n_h + 1)(M_h - m_h)(n_h - m_h)}{(m_h + 1)^2 (m_h + 2)} \qquad (5)$$

and the overall variance is:

$$v(\hat{N}) = \sum_{h=1}^{L} v(\hat{N}_h) \qquad (6)$$

(see Seber 1982:p60 for conditions to satisfy an approximately unbiased estimate of variance).

Approximate 95% confidence limits for $\hat{N}$ are:

$$\pm 1.96\sqrt{v(\hat{N})} \qquad (7)$$

Consistency in the capture efficiency of the RSTs through time was examined using a χ^2 contingency test. Randomness of the marking sample was tested by comparing the frequency distributions of marked and unmarked coho in size classes of 10mm (65 – 135mm), using a $\chi 2$ goodness of fit test after Seber (1982: p74). Similarly, size selective catchability was tested by comparing the distributions for recaptured and not recaptured smolts ($\chi 2$ Seber 1982: p71).

3.1.3 Channel smolts capture and marking

Coho smolts (all juvenile coho > 65 mm were considered to be smolts) were captured for marking from Clay Young Channel, using a converging downstream weir: a description of the construction and operation of the weir is given by Decker et al. (2003). Marking was performed on healthy smolts using a Pan Jet dental inoculator (Herbinger et al. 1990) to apply a sub-dermal tattoo of Alcian Blue dye to a fin. Three distinct marks, chosen for maximum visibility, were applied during the study: upper caudal fin, anal fin, lower caudal fin and a caudal left pectoral fin combination. Marking commenced as soon after the RSTs were installed and fishing as numbers at the counting fence permitted. Provisional sampling periods were established before the study started but these were adjusted to accommodate the minimum required mark releases and flow conditions in the mainstem. The weir was operated from April 15 to June 9, with marking conducted for a variable number of days in each period, based on smolt abundance: total catches and mark releases are provided in Appendix 1. The intent was for all marks released in each period to have moved through the system to the upper RST before further marks were released. Therefore, marking was concentrated at the beginning of each period to ensure that each release was discretely paired with one capture period. On days when marking was not conducted, smolts were either held in a flow-through holding box or the weir was closed. This box was also used to estimate mortality of marked smolts in each release stratum: at least 100 smolts were held for 24 hr after which they were checked for mortalities.

Weir integrity was maintained from an early stage in coho migration, throughout the project until cessation of movement and, consequently, the total smolt count closely reflects population size for the channel.

All species collected at the weir were identified and tallied: this included steelhead salmon (*O. mykiss*) which were also enumerated at the mainstem sampling site (Appendix 2). At least 100 coho smolts were measured for fork length (mm) in each marking period. During periods when coho movement was very high, a sub-sample of smolts was measured, but measurements were made on each sample date to minimize bias from sporadic sampling. A systematic procedure, based on a fixed sampling interval, i.e. every 4^{th} or 5^{th} fish, was used to sample randomly. Water temperatures were collected daily at each weir and at the RST location (Appendix 3).

3.1.4 Mainstem Sampling

A rotary screw trap (RST), 2 m in diameter, was installed in the Englishman River mainstem to trap juvenile coho migrating downstream and assess the mark-unmarked proportions of the migration. The trap was installed in, approximately, the same location as in 2005, along the east side of a wide gravel bar: trap location was adjusted in this general vicinity to improve catches in the first recovery period. The total discharge sampled was estimated at 25% of the east channel. The portion of the smolt migration that moved through the channel on the west side of the gravel bar was unsampled.

All smolts captured in the RSTs were tallied daily by species and mark/unmark type (Appendix 4). All smolts with a mark originating from Clay Young Channel were measured for fork length (mm) at both sites. Unmarked smolts were also measured; sub-sampling was performed on large catches.

4.0 RESULTS AND DISCUSSION

4.1 Clay Young Channel mark application

Due to an unseasonably cold spring, coho smolt movement from the channel, and also in the mainstem Englishman River, did not commence as early as was anticipated and the initial marking stratum start was delayed until April 27. The average channel temperature between April 20 and 27 was 7.0^0C, compared with 9.5^0C in 2005 (Taylor 2005), while the mainstem temperature was also slightly colder: 7.4^0C, compared with 8.3^0C over the same period. Subsequently, during the study, water temperature in the side-channel ranged from 6^0C to 16^0C (Appendix 3) slightly warmer on average (10.3^0C) than the mainstem (7 - 14^0C mean 10.0^0C).

The total count of juvenile coho from the Clay Young Channel was 35,160 individuals, of which 7,539 were marked for population estimation. Smolt densities were very high (approximately 8,580 km^{-1}), far exceeding the range of estimates provided by Marshall and Britton (1990) for coastal streams (1990: 363 – 3018 km^{-1}). The previous highest recorded density of 5,451 $smolts.km^{-1}$ occurred in the Nature Trust Channel in 1998 (Decker et al. 2003). In contrast, the 2004 and 2005 smolt densities in the Nature Trust Channel were 4,270 km^{-1} and 2,865 km^{-1}, respectively (Taylor 2005). Natural smolt density in Centre Creek in 2004 was 1,259 $smolts.km^{-1}$, higher than that in Weyerhaeuser Channel (799 $smolts.km^{-1}$).

No mortalities occurred in 24 hour retention tests and the total number of marked smolts released from the channel, between April 27 and June 3 was 7,539: releases by mark type and period are provided in Appendix 1. Totals of 506 upper caudal, 266 anal, 511 lower caudal/left pectoral and 276 lower caudal marked smolts were measured during the program. Mean fork lengths for these groups is given in Table 1, the mean for all mark types was 91.9 mm (SD 11.5).

Although marking and release of coho from Clay Young Channel was periodic, daily smolt migration from the channel was counted and is illustrated in Fig. 2. Peak migration occurred on May 23, with a count of 3,014 smolts: 40% of the total migration from the channel (14,152 smolts) was recorded between May 22 and 28 (Appendix 1). Movement had dropped to low levels by June 8 and no further catches were recorded after June 9. Figure 3 illustrates the cumulative proportional catches from the channel and in the RST and documents the agreement between mark releases and mainstem movement as well as the end of migration: the step pattern in the channel migration reflects the pattern of mark application.

4.2 RST capture and mark recovery

The RST was fished between April 20 and June 11 with only one period during which no catches were made: high discharge levels prevented fishing on May 5 (Figure 4) and resulted in damage to the RST. This occurred early in the study when low numbers of smolts were migrating in the mainstem; consequently, the effect on the period estimate was small. Capture probability only decreased to 6.0% from 6.7% (Table 2), a minor fluctuation. Over the course of the study a total of 5,964 smolts, were captured, including 507 marks from 7,539 releases (Table 2). The overall capture efficiency was 6.7% (values ranged from 4.8% to 9.6%), higher than anticipated in pre-study planning, and higher than in the 2005 study (mean 5.1%, range 3.2% to 7.3%, Taylor 2005). The total number of captures, 2.3 times the total in 2005 (Taylor 2005), suggests that the overall migration of smolts was much greater in the present study than in 2005.

Capture probabilities from the RST demonstrated significant temporal variation (Pearson chi-square, $\chi 2 = 40.1$, $df = 4$, $p < 0.001$). Consequently, the data could not be pooled over all periods to provide a Petersen estimate since the lack of temporal consistency suggests that such an estimate would incorporate substantial bias. Instead, the individual period estimates were summed to provide an overall population estimate for the Englishman system. The component estimates, with associated statistics, are presented in Table 2.

The estimate of total smolt numbers, including the channel population, is 85,467 (95% CI 78,241- 92,692); the associated error for this estimate (coefficient of variation 4.3%) far lower than that targeted in the planning exercise. Increased precision stemmed from the higher capture probabilities from the RST in conjunction with the larger than required release of marks from the channel in most periods.

In previous years (Decker et al. 2003), adjustment was made to correct for the unsampled mainstem population, below the lower of the two RSTs. This was also performed on the 2004 estimates (Taylor 2004), although with some reservations, since a simple correction factor requires a direct proportionality between smolt production and lineal distance throughout the Englishman River. The lower river contains proportionately less quality rearing habitat and is likely to be less productive than upstream (Mel Sheng pers. comm.). While the potential error from such an expansion factor would have a small effect on an unbiased estimate, it has not been applied in this study.

The overall contribution of smolts from the Clay Young Channel was estimated by assuming that the areal density of smolts produced by the unsampled portion of the Clay Young channel was not widely different from the upstream section. The total area of the sidechannel is 74,353 m^2 and 1,955 m^2 was located downstream of the counting fence location. Therefore, the total potential production originating in the sidechannel was

36,100 smolts. The adjusted count of smolt output from the Clay Young Channel indicates that 42 % of the total smolt migration from the Englishman River was generated by this area. This represents a very substantial increase over the contributions from the Weyerhaeuser and Nature Trust sidechannels in previous years. At their most productive, these channels have contributed 26% of the estimates population for the system (Decker et al. 2000). The current program illustrates the continuing importance of constructed channel habitat to overall coho smolt production in the Englishman River system and the ability of side-channel restoration techniques to drive overall system recovery.

4.3 Sources of bias in the population estimates

A number of assumptions are required to be fulfilled for the unbiased estimation of population size using a Petersen estimator (e.g. see Seber 1982, Arnason et al. 1996). Of these, marking mortality was assessed during the program and was found to be zero in the short term (24 hrs), field examination of marking and recovery efforts indicated that marks were applied correctly and visibly and that marks were being correctly identified in RST catches, and equal catchability in the marking sample was assured by marking a substantial portion (21%) of the population of Clay Young Channel. It was assumed that the distance between release and recovery sites (approximately 6 km to the RST) would ensure random mixing between marked and unmarked fish, which allows considerable latitude in mark and recovery sampling methods (Schwarz and Taylor 1998). The use of only one recapture location and four mark types greatly reduced the complications of earlier studies and the overall population estimate was minimally affected by hydrological events.

The use of stratification is important in avoiding the assumption of constant capture and movement probabilities for all fish that can potentially create significant bias in pooled Petersen estimates. Ideally, catchability should remain stable throughout the study, although most capture gear displays size selectivity (Ricker 1975) which may introduce temporal variation. However, temporal stratification can minimize bias by compensating for events such as fluctuations in discharge or variation in size of migrants over time (Carlson et al. 1998). In addition, the use of two distinct capture methods (fence and rotary trap) was expected to minimize bias from capture selectivity, if for example, migration from Clay Young Channel was found to be size dependent with respect to time (Seber 1982; p86). Unlike the 2005 Englishman River data where early mark releases were less catchable than those later in the program, the capture probabilities were quite similar over most strata, except for the final period (4.8%). Fork lengths of smolts captured in the RST in these periods was not significantly different (ANOVA Bonferroni adjusted pair-wise comparisons $p>0.05$ in all cases) although there was a slight trend to smaller average fork length in periods 1 through 4 (Figure 5). Comparisons of the size classes of marked versus unmarked smolts indicate the marked population was random with respect to size in the first two marking periods (Pearson $\chi 2 = 2.04$, df = 4, p = 0.84, $\chi 2 = 4.43$, df = 4, p = 0.49), but not in the subsequent three (Pearson $\chi 2 = 17.03$, 85.5, 27.0, df = 4, $p < 0.01$ in all cases) when marked fish tended to be smaller than the average unmarked smolt (Figure 6b). There was very close agreement between the distributions of fork lengths of marked and unmarked smolts collected in the RST. However, a goodness of fit test on recaptured versus not recaptured smolts showed significant size selectivity by the trap (Pearson $\chi 2 = 22.1$, df = 6, $p < 0.01$), likely as a function of the high power of the test (Carlson et al. 1998) given the large numbers of measurements (n= 2,534). In any event, increased catchability of a segment of the migration does not necessarily produce bias in the stratum estimates. Since the marked releases constitute a random sample, the recovery sample can be selective as long as this is independent of mark status (Seber 1982).

A basic assumptions that is required to be satisfied for an unbiased estimator is that the population is closed, resulting in a non-zero probability of capture of animals from the initial (capture) strata in one of the final (recovery) strata. Ideally, to satisfy the assumption of population closure, sampling must start at the beginning of the outmigration and continuing past the point of movement of marked animals. Unfortunately, due to the late initiation of smolt movement, this could not be completely satisfied, although in the final days of the program catches were extremely low: fewer than 50 fish were caught in each of the last three days of sampling. Continued movement of smolts past the recovery site results in failure of the slope of the RST cumulative abundance plot in Figure 3 to level out. The lowest capture probability value in the study (0.048) occurred in the final period, under lower discharge conditions (Figure 4), which may have lowered the rate of migration of smolts. Earlier in the program stratum recaptures were complete in 5 days (Figure 7), however, in the final period marks were recorded over an 11 day period and recaptures were made on the final sampling date. Consequently, additional marks may have moved past the recovery site after sampling ended. Given the small numbers involved, it is expected that bias from this source would be small.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The estimate of the 2009 smolt outmigration is 85,467 (95% CI 78,241- 92,692) of which 35,900 smolts originated from Clay Young Channel. The program substantially improved on the design objective of ±15% accuracy (±8.5% with 95% confidence). This resulted from the availability of large numbers of smolts from the channel to increase the mark releases in a majority of time strata, combined with a higher than predicted capture efficiency by the RST. However, while the RST capture efficiency was higher than in 2005, the current mean value of 6.7% is lower than the 10% recommended by Carlson et al. (1998). In order to compensate for the possibility of low capture efficiency, the number of marks released should continue to be maximized in future programs, at least to the level required to generate an error of ±10% to be exceeded not greater than 5% of the time. This would require fewer marks than the totals released in two of the strata in the present study and availability of smolts for marking should not present any difficulty at the current level of channel production.

Previous studies have estimated the contribution of sidechannel smolt production to the Englishman River system to lie between 15% (1999) and 25% (1998) (Decker et al.

2003). The unenhanced Nature Trust Channel alone contributed 14% in 2004 and 9% in 2005, Taylor 2005). However, these levels of production pale in comparison with the 2009 estimate of 41% of overall production based on a counted population of 35,160 smolts that moved out of the Clay Young Channel (42% when the uncounted portion of channel production is included). The areal density of smolts from the section of the channel delimited by the fence was 0.43 smolts.m^{-2}; very similar to the 0.4 smolts.m^{-2} recorded from the shorter channel in 1998 (Decker et al. 2003). However, the potential for even larger outmigration is suggested by comparison with production of 0.69 smolts.m^{-2} reported from a series of constructed sidechannels in the Pacific Northwest by Koning and Keeley (1997): a value in excess of 1.0 smolts.m^{-2} is referenced in a meta analysis by Rosenfeld et al. (2008) as was an unusual value of 3.25 smolts.m^{-2} but most densities in stream habitat were much lower.

6.0 ACKNOWLEDGEMENTS

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Table 1. Summary of coho smolt fork length (mm) by mark type measured at the Clay Young Channel and from the RST captures. Mark types correspond to marking strata, with upper caudal marks released in periods 1, 3 and 5.

Site	Mark	n	mean FL	min FL	max FL	SD
Clay Young	UC[1]	746	90.6	65	134	11.7
	A[2]	266	98.3	72	138	10.6
	UC/lp[3]	511	93.4	67	125	10.9
	LC[4]	276	88.6	70	121	10.0
	All marks	1799	92.2	65	138	11.4
RST	UC	245	88.1	65	122	9.6
	A	86	95.4	70	115	10.4
	UC/lp	17	91.2	75	108	11.2
	LC	201	85.7	62	108	12.9
	NM[5]	2014	90.6	60	135	10.0
	All marks	549	88.0	62	122	9.3
	All smolts	2563	90.1	60	135	9.9

[1] UC = upper caudal fin, [2] A = anal fin, [3] UC/lp = upper caudal /left pectoral, [4] LC = lower caudal, [5] NM = no mark

Table 2. Periodic estimates of population size derived from recovery sampling by the rotary screw trap. Capture probabilities (trap efficiencies) are provided by release period.

Release end date	Catch	Marked Releases	Recaptures	Population Estimate	lower 95% CL	upper 95% CL	CV	capture probability
4-May	204	405	27	2973	3942	2003	16.6	6.7%
14-May	947	1633	98	15647	18460	12834	9.2	6.0%
22-May	1710	1501	94	27052	32142	21962	9.6	6.3%
30-May	2363	2000	192	24510	27651	21368	6.5	9.6%
11-Jun	740	2000	96	15286	18038	12534	9.2	4.8%
Total	5964	7539	507	**85,467**	**92,692**	**78,241**	4.3	6.7%

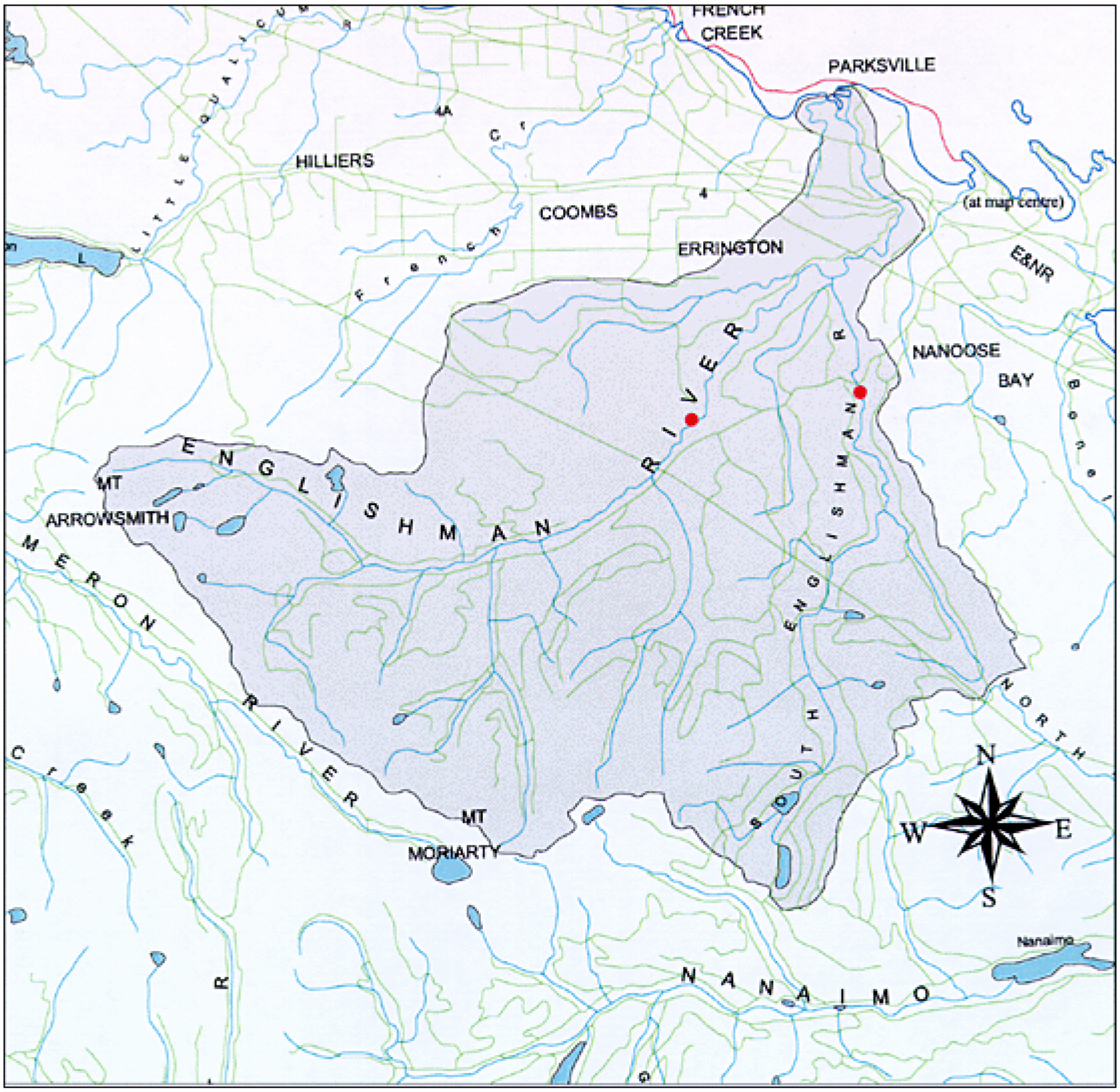


Figure 1. Map of the Englishman River watershed. Anadromous barriers are shown as red dots.

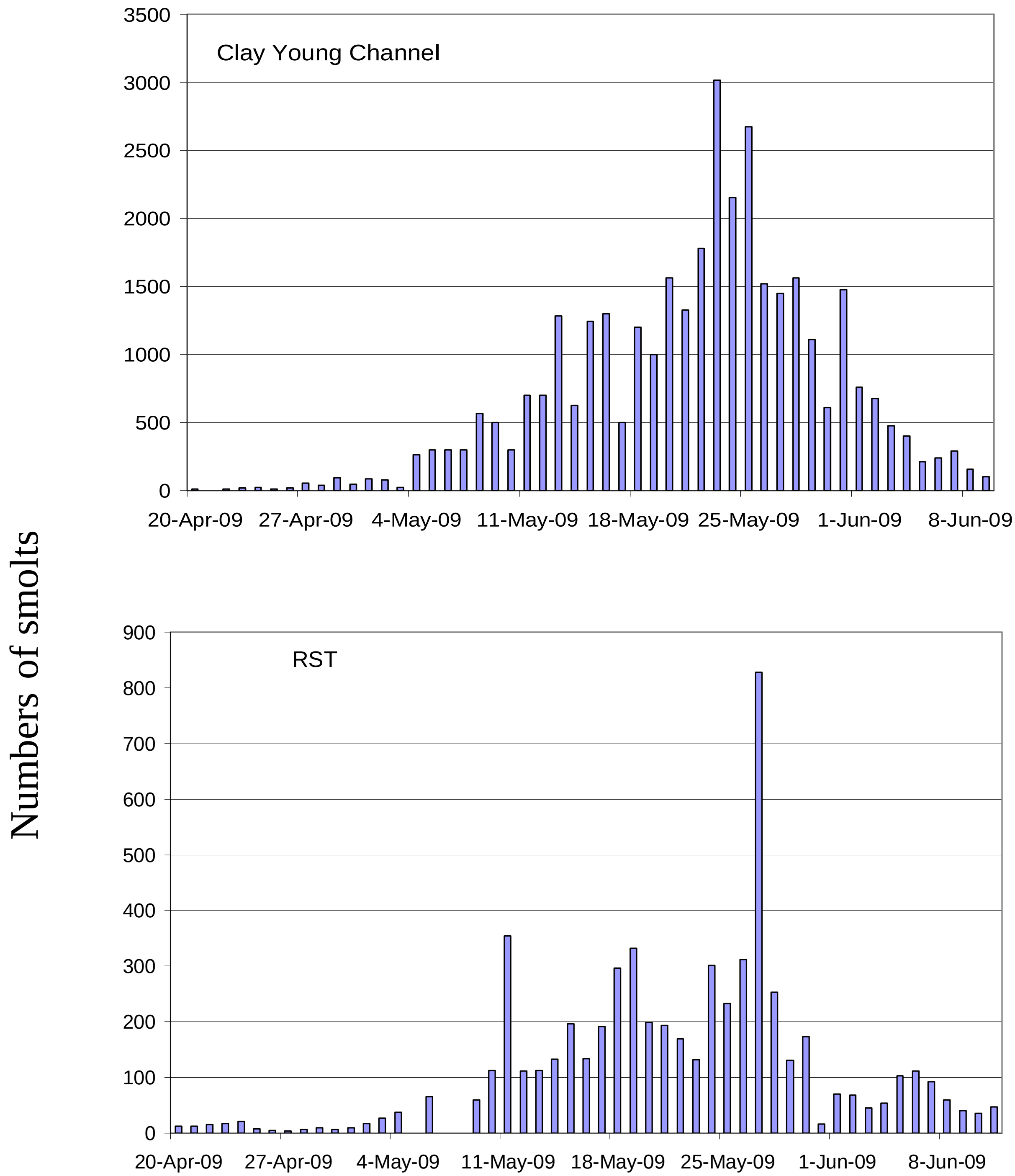


Figure 2. Daily catches from Clay Young Channel and in the rotary screw trap.

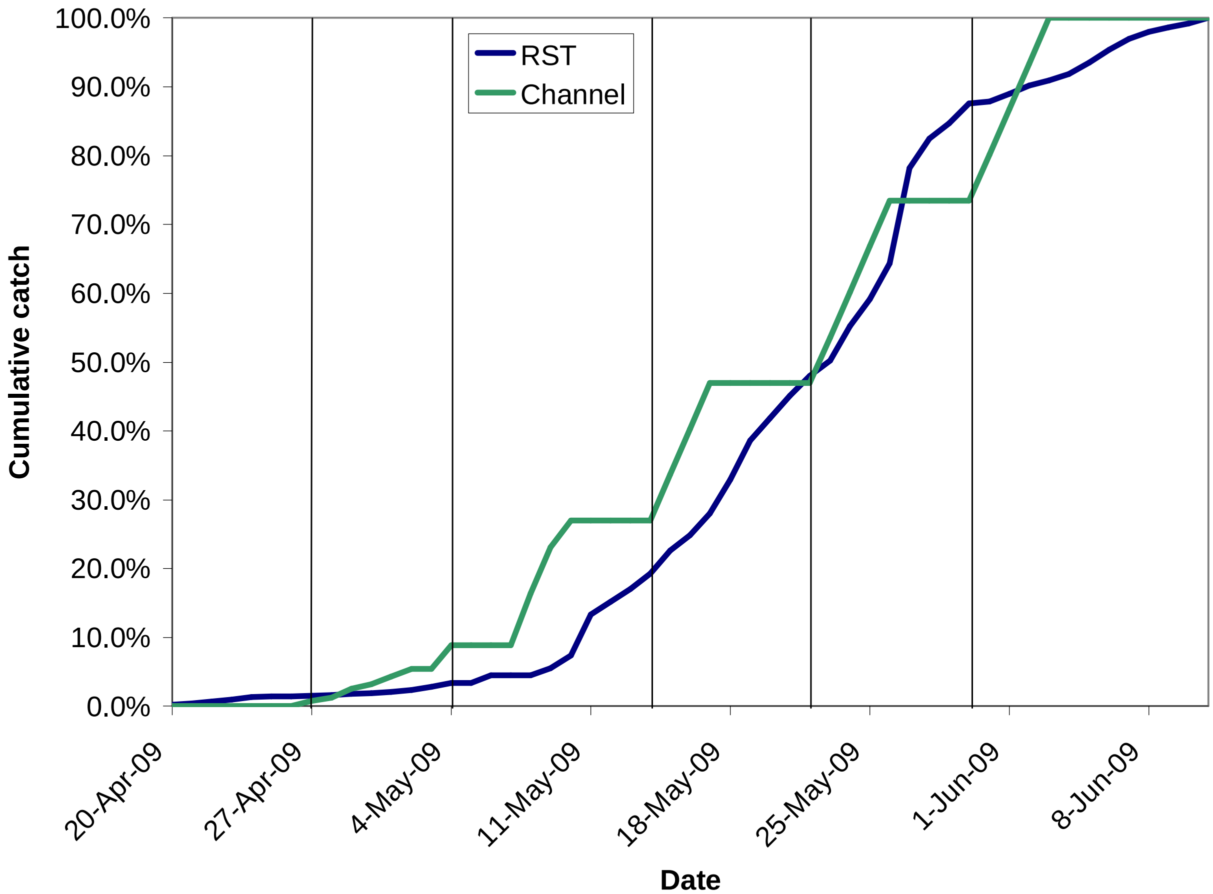


Figure 3. Comparison of cumulative frequency distribution plots of Clay Young Channel marked releases and unmarked smolts captured in the RST. Vertical lines delineate the marking strata.

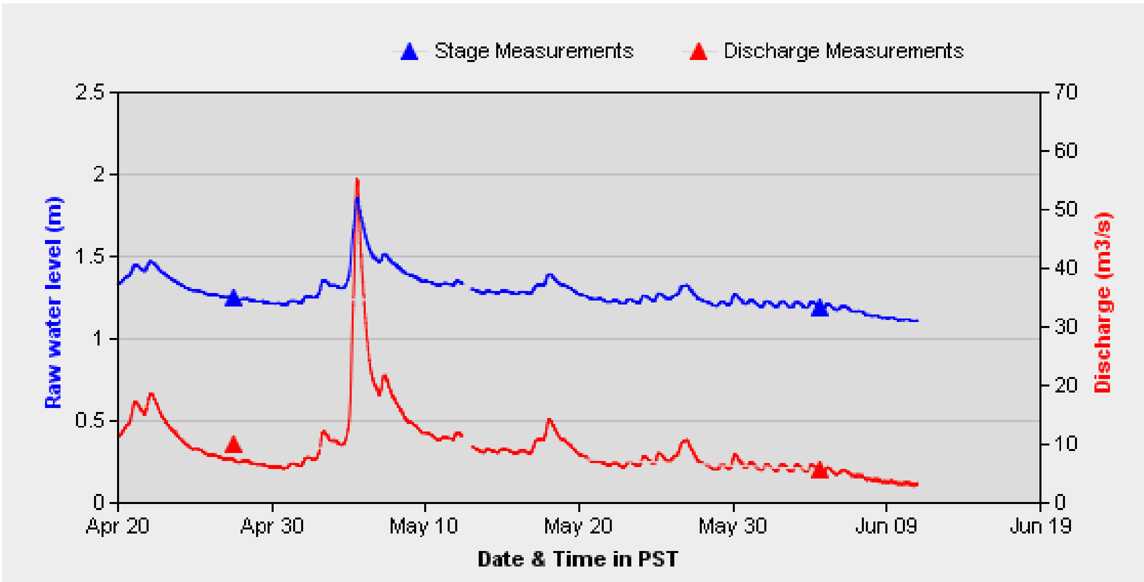


Figure 4. Preliminary water level and discharge for the Englishman River at Water Survey of Canada station #08HB002, during the study. (Data from Environment Canada http://scitech.pyr.ec.gc.ca/waterweb/fullgraph.asp).

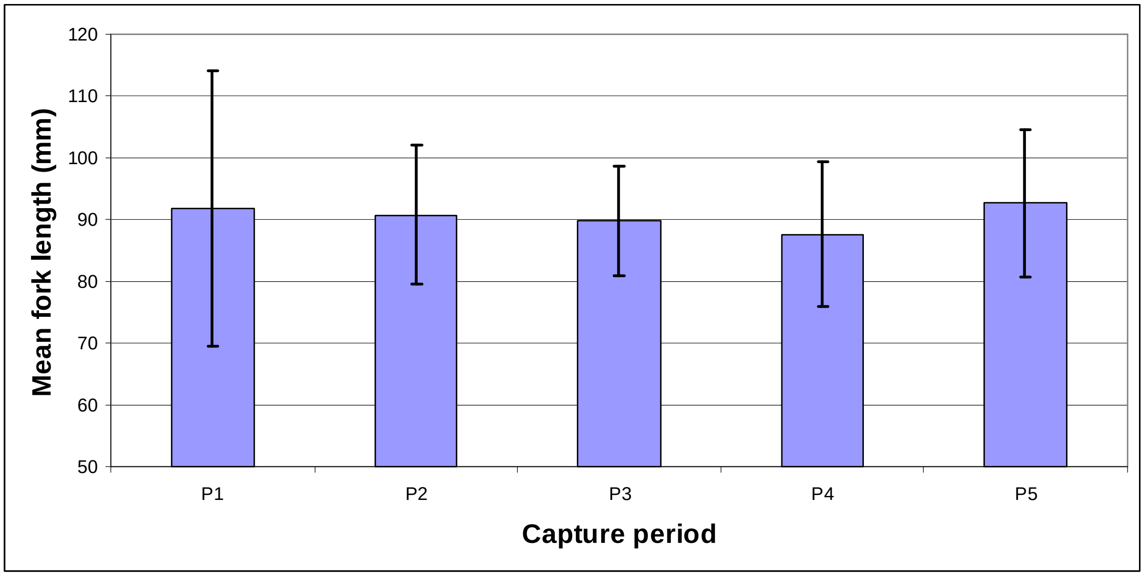
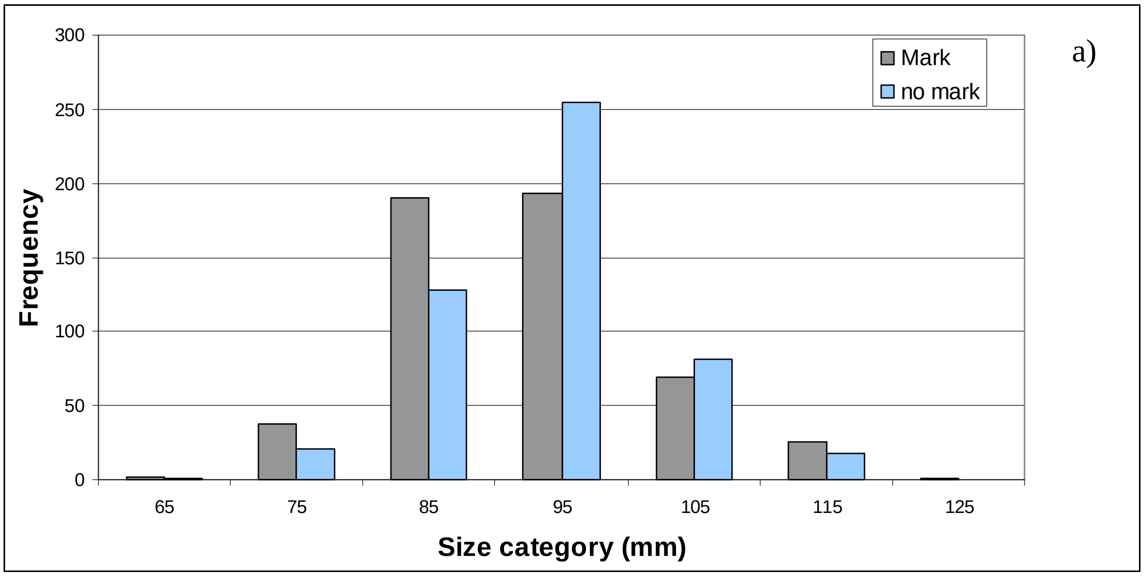


Figure 5. Mean fork length (mm) of smolts collected in the RST by capture period. Approximate 95% confidence intervals are shown.

b)



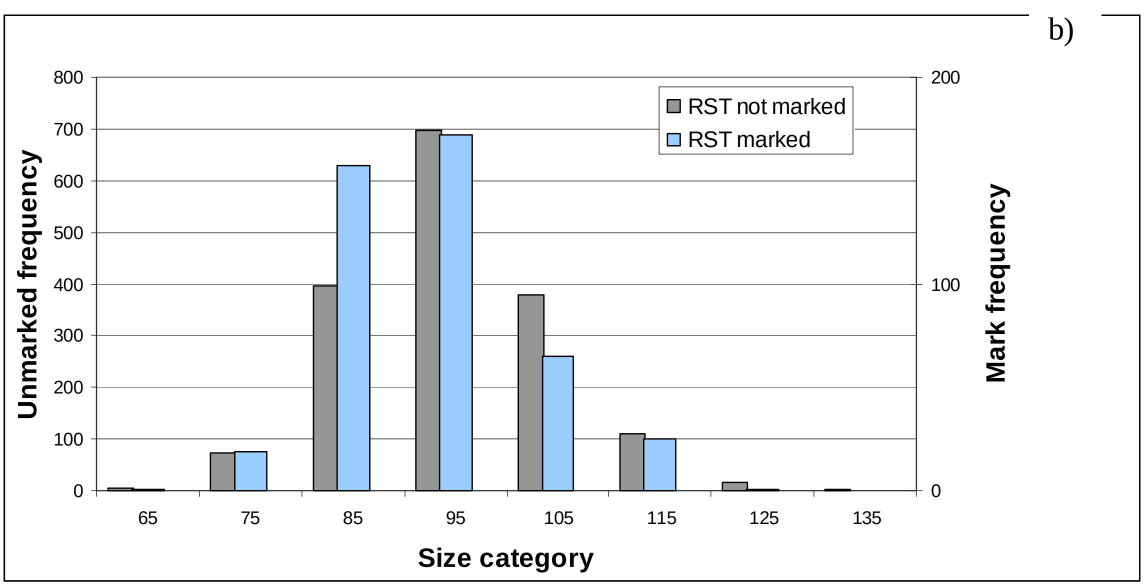


Figure 6. Frequency distributions a) of catches in the RST by 10 mm size category compared with mark recaptures and b) mark recaptures with marks released from the Clay Young Channel.

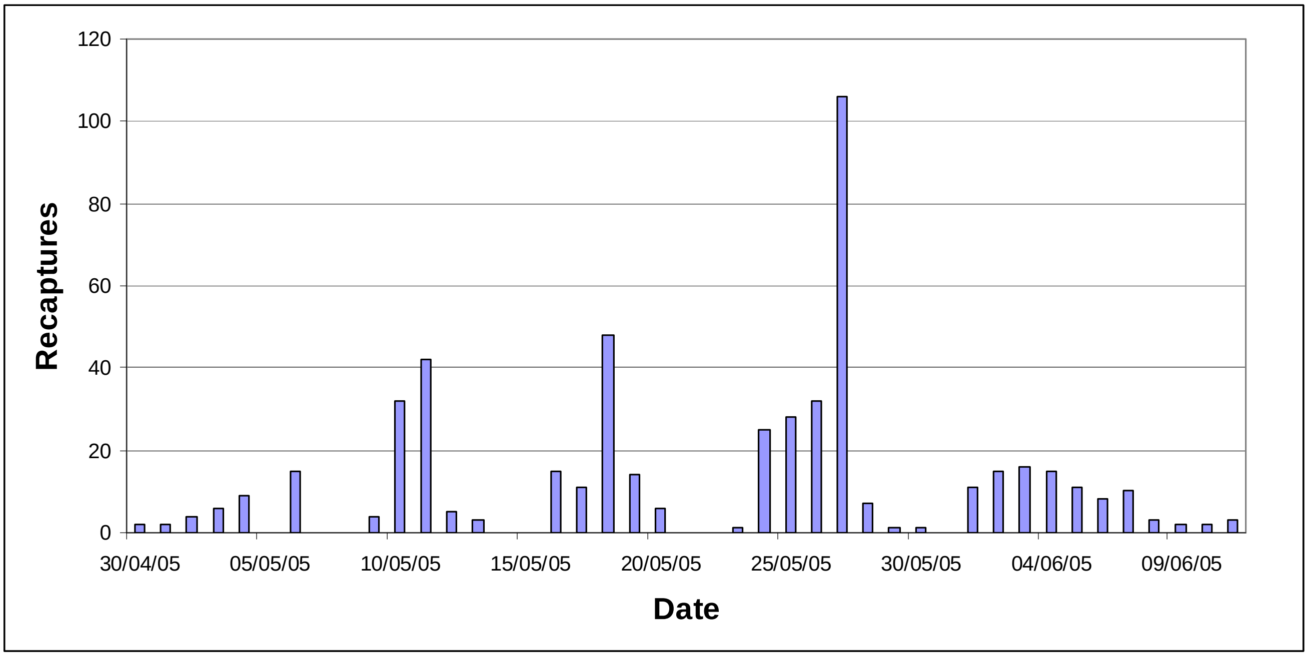


Figure 7. Daily recaptures of marked smolts in the RST.

Appendix 1. Total daily catch of coho smolts at the fence and in the RST, and releases by date and mark type, from Clay Young Channel.

Date	Channel Catch	Marks released	RST Catch
20-Apr	11	0	12
21-Apr	0	0	12
22-Apr	13	0	15
23-Apr	18	0	17
24-Apr	24	0	21
25-Apr	10	0	7
26-Apr	21	0	5
27-Apr	55	55	4
28-Apr	40	40	6
29-Apr	96	96	9
30-Apr	49	49	6
01-May	85	85	9
02-May	80	80	17
03-May	23	0	27
04-May	265	265	37
05-May	300	0	high water
06-May	300	0	65
07-May	300	0	RST repair
08-May	567	567	RST repair
09-May	501	501	59
10-May	300	300	112
11-May	700	0	354
12-May	700	0	111
13-May	1282	0	113
14-May	626	0	133
15-May	1243	501	196
16-May	1300	500	134
17-May	500	500	191
18-May	1200	0	296
19-May	1000	0	332
20-May	1564	0	199
21-May	1325	0	193

Appendix 1 Cont'd

Date	Channel Catch	Marks released	RST Catch
22-May	1779	0	169
23-May	3014	500	132
24-May	2154	500	301
25-May	2674	500	233
26-May	1519	500	312
27-May	1450	0	828
28-May	1562	0	253
29-May	1109	0	131
30-May	610	0	173
31-May	1478	500	16
01-Jun	758	500	70
02-Jun	677	500	68
03-Jun	478	500	45
04-Jun	399	0	54
05-Jun	214	0	103
06-Jun	239	0	111
07-Jun	292	0	92
08-Jun	155	0	59
09-Jun	101	0	40
10-Jun	0	0	35
11-Jun	0	0	47
Totals	35,160	7,539	5,964

Appendix 2. Total daily catch of steelhead salmon at the fence and in the RST.

Date	Channel Catch	RST Catch
14-Apr	4	0
15-Apr	3	0
16-Apr	0	0
17-Apr	0	7
18-Apr	2	0
19-Apr	4	7
20-Apr	0	10
21-Apr	2	15
22-Apr	22	24
23-Apr	8	37
24-Apr	9	29
25-Apr	3	9
26-Apr	10	8
27-Apr	19	0
28-Apr	15	9
29-Apr	17	5
30-Apr	9	3
01-May	13	4
02-May	11	21
03-May	6	20
04-May	10	24
05-May	0	0
06-May	0	30
07-May	0	0
08-May	0	0
09-May	10	9
10-May	9	6
11-May	0	14
12-May	0	12
13-May	6	11
14-May	9	8
15-May	8	11

Appendix 2 Cont'd

Date	Channel Catch	RST Catch
16-May	9	7
17-May	12	13
18-May	0	21
19-May	8	14
20-May	5	11
21-May	5	3
22-May	3	10
23-May	2	12
24-May	12	12
25-May	26	14
26-May	8	5
27-May	3	24
28-May	6	14
29-May	4	10
30-May	0	5
31-May	9	0
01-Jun	4	4
02-Jun	7	5
03-Jun	2	4
04-Jun	3	1
05-Jun	3	5
06-Jun	2	2
07-Jun	3	7
08-Jun	0	1
09-Jun	0	0
10-Jun	0	0
11-Jun	0	2
Totals	345	539

Appendix 3. Daily water temperatures (^{0}C) at the the RST site and Clay Young Channel.

Date	RST	Fence
20-Apr	8	8
21-Apr	7	7
22-Apr	7	7
23-Apr	7	7
24-Apr	8	6
25-Apr	7	7
26-Apr	7	7
27-Apr	8	7
28-Apr	7	7.5
29-Apr	7.5	8
30-Apr	7.5	9
01-May	8	7
02-May	8	8
03-May	8	9
04-May	7.5	8.5
05-May		
06-May	High water conditions	
07-May		
08-May	9	9
09-May	8	8
10-May	9	9
11-May	8	8
12-May	7	7
13-May	9	9
14-May	6	7
15-May	9	10
16-May	10	11
17-May	10	11
18-May	9	10
19-May	7.5	7.5
20-May	7	8.5
21-May	9	8

Appendix 3 Cont'd

Date	RST	Fence
22-May	9	9
23-May	12	11
24-May	11	12
25-May	12	12
26-May	12	13
27-May	10	12
28-May	11	12
29-May	13	12
30-May	12	14
31-May	13	14
01-Jun	13	14
02-Jun	13	14
03-Jun	14	15
04-Jun	14	16
05-Jun	14	16
06-Jun	15	16
07-Jun	14	16
08-Jun	14	16
09-Jun	14	16
10-Jun	14	
11-Jun	14	
Averages	10.0	10.3

Appendix 4. Mark releases and recovery of marks by recovery stratum, in the RST.

		Recovery stratum				
Release stratum		1	2	3	4	5
start date	coho marked	3-May	14-May	22-May	30-May	11-Jun
27-Apl	405	27				
4-May	1633		98			
15-May	1501			94		
23-May	2000				192	
31-May	2000					96
	unmarked catch	177	849	1616	2171	644