Assessment of 2002 Steelhead Smolt Yield from the Englishman River, Vancouver Island

Prepared for

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Executive Summary

As part of the Pacific Salmon Endowment Fund Society's Englishman River recovery plan, a mark-recapture study was conducted in the spring of 2002 to assess coho and steelhead smolt production. The Community Fisheries Development Centre (Nanaimo) contracted the BC Conservation Foundation to complete the study's steelhead smolt component. Estimates of the number of steelhead smolts emigrating from the Englishman River between April 16 and June 8 ranged from 2,403 (ML Darroch estimate, 95% confidence limits: 1,365-3,442) to 2,703 (pooled Peterson estimate, 95% confidence interval: 1,784-3,624). A Schaefer estimate of 2,597 was also calculated. The smolt group was composed of 77.6% two year olds, and 22.4% three year olds, and had mean lengths and weights of 167 mm (SD 17) and 43.2 g (SD 14.8), respectively. Recommendations include continued monitoring for at least one generation, preferred trap sites, and budget allocations to deal with high trap maintenance periods and late migrants.

Acknowledgments

Bob Brown, Mike Edwards, Matt McKay, Clay Young, and Jeff Young maintained the traps and fences, performed occasional steelhead smolt sampling, and enumerated trout captures on Centre Creek and at the side-channel fences. Scott Ferguson supplied preliminary discharge data for the study period. Rick Axford, Cory Hryhorczuk, Brad Smith, and Harlan Wright assisted with smolt marking and sampling. Thanks are extended to Craig Wightman for editing the report.

Table of Contents

List of Figures

List of Tables

1.0 Introduction

In March 2001, the Englishman River was chosen by the Pacific Salmon Endowment Fund (PSEF) as one of two BC watersheds to be the focus of strategic recovery plans. The Pacific Salmon Foundation administers the fund, and the PSEF's technical committee approves projects that meet the objectives of the individual recovery plans.

The Englishman River Watershed Recovery Plan (Bocking and Gaboury 2001) identified steelhead and coho smolt enumeration as a required activity to develop baseline information and follow stock trends in response to recovery efforts. Local stream stewards working for the Community Fisheries Development Centre (CFDC) in Nanaimo were contracted in the spring of 2002 to conduct this year's mark-recapture study. With the support of the Fisheries Section of the Ministry of Water, Land and Air Protection (MWLAP) in Nanaimo, CFDC subcontracted the BC Conservation Foundation (BCCF) to design and conduct the steelhead smolt component of the enumeration using trapping equipment proposed to estimate coho production.

Captures and estimates of coho, chinook, chum, and pink salmon, as well as non-salmonids are not included in this report.

2.0 Methods

2.1 Rotary Trap Installation/Operation

On April 16, 2002, CFDC staff installed two 6-foot rotary screw traps (RST) in the Englishman River at Top Bridge Park (T1) and adjacent to Big Tent RV Park (T2), 5.0 and 1.5 km upstream of the mouth, respectively (Figure 1). CFDC staff maintained the traps daily, regularly re-aligning them relative to the thalweg and verifying optimal drum rotation (4-5 rpm) to maximize catch efficiency.

2.2 Biophysical Monitoring

Water temperature was recorded each morning using hand held mercury thermometers, and approximate water levels were noted daily. The Water Survey of Canada (WSC) maintains a permanent station (#08HB002) on the lower river at he Highway 19a bridge crossing. WSC staff in Nanaimo supplied preliminary discharge data for the study period.

2.3 Catch Monitoring, Sampling and Marking

At the RSTs, a BCCF technician performed trout counts and steelhead smolt marking 5-6 days per week, while CFDC crew members completed salmon species counts each morning. CFDC staff collected trout data and marked steelhead smolts on the remaining days.

Trap T1 was used as a marking trap, while T2 was used to sample and enumerate fish. All trout trapped in T1 were categorized by species/life stage and counted. The following definitions were used:

Figure 1. NTS map of lower Englishman River showing trap (red circle) and fence (blue square) locations. The top of the figure is North, and the blue grids indicate 1 km^2.

- **Smolt** (steelhead and cutthroat): silver bright colouration, and fork length > 140 mm.
- **Parr** (steelhead and cutthroat): parr marks evident, and fork length < 140 mm. This would include 2001 brood juveniles that were slightly less than one year old, as well as 1999 and 2000 brood parr.
- **Adult** (cutthroat): > 200 mm fork length.

T1 smolts were anaesthetized in a bath of dilute clove oil to enable confirmation of minimum length and allow the appropriate mark to be applied with the least amount of stress. Handling was kept to a minimum and simple marks (no dye) were scheduled for application during the estimated peak of the outmigration (May 20), based on CFDC smolt counts from 2001. The caudal fin was cut dorso-ventrally at a point less than one-fourth the distance from the tip of the lobe to the caudal peduncle. Alcian blue coloured dye was applied with a jet inoculator to produce a mark 3-6 mm long on the fin. Marked smolts were allowed to fully recover and released 100 m downstream, in the next riffle below the RST pool.

To assess the catch efficiency of T2, all steelhead smolts from T1 were marked in unique release groups according to Table 1:

Table 1. Mark schedule for steelhead smolts trapped at T1.

Date	Mark	Code
April 16-20:	Lower caudal clip, plus dye left pectoral	(LCLP)
April 21-30:	Upper caudal clip, plus dye anal	(UCA)
May 1-10:	Lower caudal clip, plus dye anal	(LCA)
May 11-20:	Upper caudal clip	(UCO)
May 21-30:	Lower caudal clip	(LCO)
May 31-June 7:	Upper caudal clip, plus dye upper caudal lobe	(UCUC)

All steelhead smolts trapped at T2 were anaesthetized with clove oil and sampled for length, weight, marks and scales to determine age. All rainbow parr were sampled for length and weight, and about 10%, mostly larger parr, were sampled for scales to allow better separation of age cohorts. Length and life stage were recorded for all cutthroat.

Rainbow and cutthroat smolts and parr were also counted daily by CFDC staff at each of three fence operations (Figure 1). Fish tight fences were operated near the mouth of Centre Creek, and near the bottoms of the TimberWest (north side of mainstem) and Weyerhaeuser (south side of mainstem) side-channels primarily to evaluate coho production.

Population Estimates

In a mark-recapture study, a population estimate is generally derived by dividing the total catch by the proportion of the total marked smolts recaptured (also known as the total estimated catch efficiency, or ECE). Assumptions for this mark-recapture study as outlined by Seder (1982) include:

1. the population is closed such that the population is constant;
2. all untagged steelhead smolts have the same probability of being captured at the traps;
3. marking/clipping the smolts does not affect their catchability in the trap;
4. sampling at the trap for marks is a simple random sample where each of the possible combinations of marked and unmarked smolts have an equal probability of occurring;
5. smolts do not lose their marks between the release site and the recapture site;
6. all marks are reported on recovery in the second sample.

As well, we also assume that:

7. marked and unmarked smolts have similar movement patterns from the T1 release site to T2;
8. smolts can pass the rotary trap only once and all marked smolts pass T2 by the end of the study (i.e., no smolts remain above T2).

9. there is no mortality and no smolts leave the system without passing T2.

Given these assumptions are met the Peterson estimate gives a population estimate in most cases from the equation (Ricker 1975):

Equation 1

$$N = \frac{(M+1)*(C+1)}{(R+1)} + \text{(mortalities)}$$

Where N = population estimate,
C = total catch,
R = number of marked fish recaptured, and
M =number of marks released.

If random mixing of marked and unmarked individuals is assumed, then the variance of recovered marks has a binomial distribution. In these cases it is best to obtain approximate confidence intervals from a table or equations that approximate the binomial distribution using recovered marks as the key parameter. Ricker (1975) derives the confidence intervals for N in large sampling regimes (>25) as in *Equation 1* as approximately equal to:

Equation 2

$$R(V) = R + 1.92 \pm 1.96 \sqrt{(R+1)}$$

Where V = the variance of R, and
R = number of recaptures.

By substituting the upper and lower calculated values of R (*Equation 2*) the confidence limits for Peterson population estimates can be derived. However actual daily out-migrations have been observed to violate a number of the above assumptions (Decker 1998, Schubert et al. 1994). For example, differential mortality of marked and unmarked fish may occur. Additionally, daily or marked group recapture efficiencies may be significantly different both between species and age classes of fish and across marked groups and release dates.

To overcome bias created by using an average ECE through the whole study period, data may be pooled into different marked groups. This pooled data utilizes the different marked groups and their recapture efficiencies as sampled over time to create an estimate. Analysis was carried out utilizing the SPAS computer program (Arnason et al. 1996) which reports the pooled Peterson estimate (PPE) and its standard error, using the Chapman hypergeometric model as described in Seber (1982). It is not yet clear what criteria are best for pooling data although in this case temporal groups (of seven days) were used. Recapture rates may vary between these groups as a result of differential tagging stress, temporal variances in recapture rate through release date and river discharge and/or due to residulization and mortality.

A Schaefer estimate of population emigration was also undertaken. Schaefer (1951) developed an estimate of total population size, N, using ratio and expectation arguments. This estimate is biased unless capture probabilities are equal in all initial strata or recovery probabilities are the same in all final strata. No standard error (SE) is available with this estimator and it is simply used to compare with the pooled Peterson estimate for possible sampling bias.

One final estimate method was used on the data. The maximum likelihood Darroch estimator developed by Plante (1990) is iterative and uses initial values calculated by least squares methods. These calculated stratum values are compared to the predicted values from the fitted model and a goodness of fit test is used to assess the deviation of the observed from the predicted. Such a method can be applied to remove bias that can occur in complete pooling (Seber 1982).

3.0 Results

3.1 Biophysical Monitoring

Morning water temperatures ranged from a low of 4.0 °C on April 23 to a high of 10.5°C on June 4 (Figure 2). Daily discharge generally decreased through the study period from a high of 22 m^3/s (160% of MAD) on April 16 to low of 5 m^3/s (37% of MAD) on June 8 (Water Survey of Canada, preliminary unadjusted data; Figure 2).

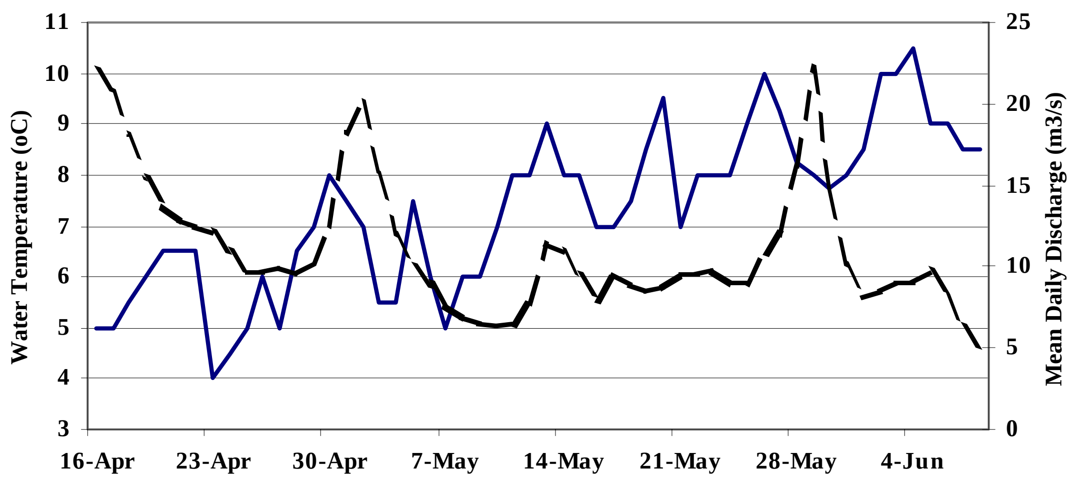

Figure 2. Englishman River mainstem water temperature (solid line) and mean daily discharge (dashed line; WSC preliminary unadjusted data) during the study period.

3.2 Catch Monitoring

Traps operated 24 hours per day from April 16 to June 8, 2002. During this period, the upper trap (T1) was found jammed with debris and not turning on two occasions (May 15 and 17) and vandalized once (May 20) resulting in low and/or no captures. Over the same period, T2 was found jammed and/or not turning on May 3, 22, 28, and 29. It had also slipped out of correct fishing position on May 27. Of eight steelhead smolt mortalities during the project, all were related to T2 debris jams, and only one of these could not be assessed for the presence of a mark.

On May 12, the lower trap (T2) was moved to a more efficient location immediately upstream of Parrys RV Park, about 1.8 km upstream of the mouth.

At the upper trap (T1), a total of 286 smolts were captured and marked (Figure 3). Other trout captures included 244 rainbow "parr" and 22 cutthroat (13 smolts, 8 parr, 1 adult).

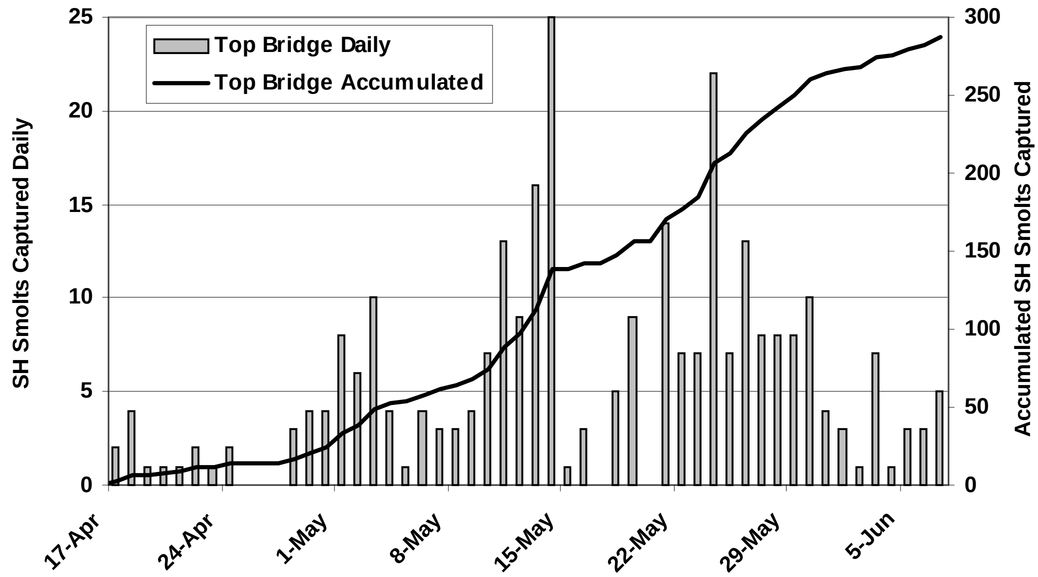

Figure 3. Steelhead smolt captures at T1 (Top Bridge) April 17-June 8, 2002.

A total of 260 steelhead smolts were captured at the lower trap (T2; Figure 4), including four specimens between 133 and 139 mm in length that were obviously smolting. The peak day of capture occurred on May 14 when 31 smolts were caught. Steelhead smolt emigration peaked between May 13 and 26, when 178 smolts (69% of the total catch) were captured.

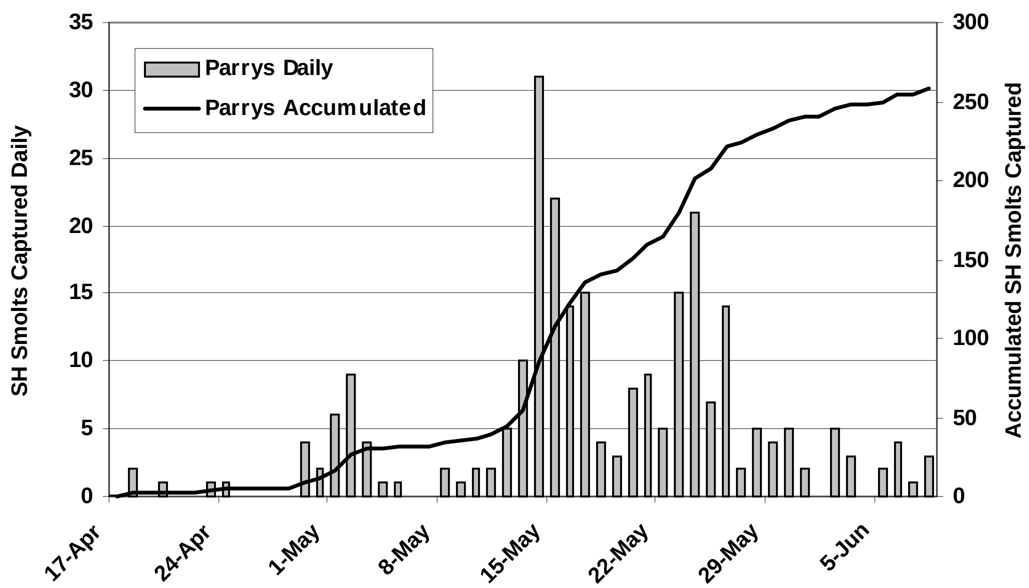

Figure 4. Steelhead smolt captures at T2 (Big Tent/Parrys) April 17-June 8, 2002.

Length and weight data of 252 steelhead smolts sub-sampled at T2 are summarized in Table 2. Mean condition factor for smolts was 0.89 x 10^{-5}. The smolt group was composed of 77.6% two year olds, and 22.4% three year olds, based on 246 readable scale samples.

Of 174 rainbow parr captured at T2, 163 were sampled for length and 158 for weight (Table 2). Fish just less than one year old (2001 brood) comprised 74.2% of the total parr sampled, and had average lengths, weights and condition factors of 81 mm, 5.7 g, and 1.01 x 10^{-5}, respectively. This breakdown assumes 2001 brood were up to 100 mm in length, based on scale analysis of 10% of the larger parr captured (Figure 5).

Table 2. Summary of juvenile steelhead sampling results from T2, Englishman River 2002.

		Length (mm)	Weight (g)
Steelhead Smolts	N=	252	252
	Max	228	118.5
	Mean	167	43.2
	Min	133	21.2
	S.D.	17	14.8
Steelhead Parr[1]	N=	163	158
	Max	139	28.3
	Mean	91	8.6
	Min	59	2.0
	S.D.	19	5.7

1. Steelhead parr defined as juveniles <140 mm fork length

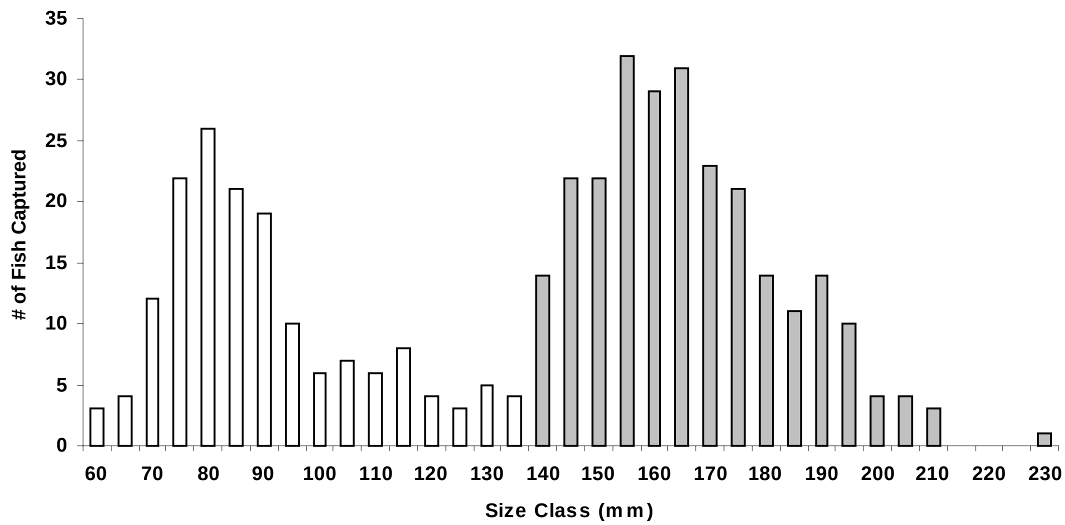

Figure 5. Length frequencies of steelhead smolts (solid bars) and parr (open bars) captured at T2, Englishman River 2002.

3.4 Steelhead Smolt Yield Estimates

In total 287 steelhead smolts were captured at the upstream trap (Top Bridge), with no mortalities. Of this total 286 were marked and released downstream of the trap location. Twenty-five of the marked fish were recaptured at the lower trap site (Big Tent-Parrys) giving an average ECE of 8.7%. Six mark groups of steelhead smolts were released over the migration period. Recapture rates ranged from 0% to 13.6% (Table 3). Based on the combined mark and recapture data (i.e., pooled Peterson estimator) the total steelhead smolt emigration past the trap site was estimated to be 2,703 fish, with 95% confidence intervals from 1,784 to 3,624. However, the assumption of complete mixing was not met, indicating the percentage of marks recovered differed between release periods (chi-square, df = 5, X^2=5.43, p = 0.37). The assumption of equal proportions of marked versus unmarked fish among recovery strata was also not met (chi-square, df = 7, X^2 = 5.42, p = 0.61) as can be seen by the variance in Table 3.

Table 3. Summary of steelhead smolt mark and recapture data, Englishman River 2002.

Release Stratum	Period	Fish Marked	Recovery Stratum 1	2	3	4	5	6	7	8	Percent Recoveries
			20-Apr	27-Apr	4-May	11-May	18-May	25-May	1-Jun	8-Jun	
1	April 14-20:	8	0	0	0	0	0	0	0	0	**0**
2	April 21-30:	17	0	0	2	0	0	0	0	0	**11.8**
3	May 1-10:	50	0	0	1	1	0	0	0	0	**4**
4	May 11-20:	81	0	0	0	0	9	1	1	0	**13.6**
5	May 21-30:	103	0	0	0	0	0	3	4	0	**6.8**
6	May 31-Jun 10:	27	0	0	0	0	0	0	0	3	**11.1**
Untagged Fish			**3**	**2**	**25**	**8**	**90**	**65**	**28**	**15**	
Total Recovered			**3**	**2**	**28**	**9**	**99**	**69**	**33**	**18**	
Marked proportion			**0**	**0**	**10.7**	**11.1**	**9.1**	**5.8**	**15.2**	**16.7**	

These tests indicate that pooling may create bias in the population estimate. In an attempt to examine the bias, we pooled recovery strata 1 and 2 with 3, and 5 with 6 (low numbers or no recaptures). We also pooled marking strata 1 with 2 and 3 (low numbers of marked fish in some strata). A ML Darroch estimate of 2,403 steelhead smolts, with 95% confidence limits from 1,365 to 3,442, was calculated. The low G^2 value associated with this estimate (G^2 = 0.10, df =1, p=0.75) indicates a good fit to the data (Arnason et al. 1996). The Schaefer estimate was 2,597.

Fences were operated from April 3 to June 7 on Centre Creek and the two mainstem side-channels. Trout captures (CFDC data) are summarized in Table 4.

Table 4. Summary of trout captures in Centre Creek and in the TimberWest and Weyerhaeuser side-channels, April 3 to June 7, 2002 (CFDC data).

Location	Rainbow/Steelhead		Cutthroat		
	smolt	parr	smolt	parr	adult
Centre Creek	153	74	96	54	15
TimberWest S/C	17	21	2	3	5
Weyerhaeuser S/C	6	15	0	1	2

4.0 Discussion/Recommendations

The results include three smolt population estimates that are similar. The ML Darroch estimate supports the pooled Peterson value, and with the Schaefer estimate, suggests a population of about 2,550 steelhead smolts in 2002. Existing models would suggest that 2002 smolt production was 32 to 55% of the river's estimated capacity (Table 5).

Table 5. Englishman River steelhead smolt production in 2002 compared to existing habitat capacity models.

Model	Estimated wild smolt capacity	2002 estimate as a % of capacity[1]
Ptolemy (1998)	4,604	55%
Tredger (1986)	5,738 - 5,925	43-44%
Lirette, Hooton & Lewynsky (1987)	6,591 - 6,859	37-39%
Bocking & Gaboury (2001)	8,000	32%

[1] uses median figure of 2,550 smolts for 2002.

This year's smolt population would have been generated from what were believed to be poor adult returns in 1999 and 2000 based on peak snorkel survey counts of 8.5 and 1.8 fish/km, respectively, in those years (MWLAP Files, Nanaimo). Assuming 4% marine survival and historical Englishman River age-at-spawning data (Hooton et al. 1987), this smolt group should contribute approximately 46, 50 and 6 steelhead adults to escapements to the Englishman River in 2004, 2005, and 2006, respectively. **To better appreciate steelhead smolt production and to track abundance trends, this smolt program should be repeated annually for at least one generation (four more years), or until adult escapement consistently reaches target levels.**

Flows in the Englishman River during the spring of 2002 appeared to be ideal for smolt migration. No extreme events occurred, with flows ranging from 160% to 37% of mean annual discharge. However, estimated catch efficiency varied considerably, with recoveries of between

0% and 13.4% at the downstream trap. Both traps experienced heavy debris accumulations that caused increased trap-related stress and/or mortalities and may have decreased efficiency. The lower trap slipped out of preferred fishing position on May 27 and was discovered not turning due to debris loading on May 28. The latter event, occurring just past the peak migration period, would certainly affect our population estimate. **A budget component specific to *trap maintenance during high water and/or heavy wind periods (i.e. midnight shift)* is recommended for future downstream smolt trapping projects on the Englishman.**

T2 catch efficiency also changed as of May 12, when the RST was moved 300 m further upstream to a confined channel immediately above Parrys RV Park. This site was likely more efficient, but was thought to be logistically more dangerous for the crew. Moving the downstream trap mid-project may have created additional error in the population estimate. **Subject to safety considerations, the Parrys RV Park location should be the preferred downstream trapping site for future enumerations.**

Most of the required assumptions for the mark-recapture were met. The lower trap was located 1.8 km upstream of the mouth, and the area's low gradient and degree of tidal influence would suggest that very few steelhead smolts are generated in the reach below the trap. Spatially speaking, virtually all steelhead smolts would have to pass T2.

In temporal terms, the early component was likely well-sampled, as seen by the capture results. However, using the last capture efficiency (11.1%) derived for the period May 31 through June 10 (Table 3), an estimated 18 smolts were outmigrating daily over the last five days of trapping (June 4-8). This suggests that the late component of the smolt population may have been under-represented in the population estimate. **Consideration could be given to extending the trapping period to better enumerate late migrants.** This would entail a small amount of additional labour (2 technicians, 3 hours each/day) and require flexibility in the RST rental agreement. Estimated cost/day is $250, including on BCCF and CFDC technician wages (incl. Mercs), vehicle/RST rental, and administration.

Though trapping-related mortality was not fully assessed, there would likely have been minimal impact in that regard. Care was taken to minimize handling and maximize recovery time prior to release, and release locations offered LWD and/or broken water cover for fish.

As expected, steelhead smolt production from side-channels was relatively low (mean of 0.45% of total estimated production). Centre Creek steelhead were 6% of the total smolt production, a significant proportion considering the size of this stream. The degree to which parr rear in mainstem areas and over-winter in Centre Creek is likely significant but has not been documented.

5.0 References

Arnason, A.N., C.W. Kirby, C.J. Schwarz, and J.R. Irvine. 1996. Computer analysis of data from stratified mark-recovery experiments for the estimation of salmon escapements and other populations. Can. Tech. Rep. Fish. Aquat. Sci. 2106 37p.

Bocking, R. and M. Gaboury. 2001. Englishman River watershed recovery plan. *Prepared for* Pacific Salmon Endowment Fund Society, Vancouver, BC. 46 pp plus appendices.

Decker, A.S. 1998. Influence of off-channel habitat restoration and other enhancement on the abundance and distribution of salmonids in the Coquitlam River. Report prepared for B.C. Hydro, Power Facilities, Burnaby, B.C. and Department of Fisheries and Oceans Resource Restoration Division, Vancouver, B.C.

Hooton, R.S., Ward, B.R., Lewynsky, V.A., Lirette, M.G., and A.R. Facchin. 1987. Age and growth of steelhead in Vancouver Island populations. Fisheries Technical Circular No. 77. Ministry of Environment and Parks. Victoria, BC 39 p.

Lirette, M.G., Hooton, R.S. and V.A. Lewynsky. 1987. Preliminary steelhead production capability estimates for Vancouver Island streams. Fisheries Technical Circular No. 74. Ministry of Environment and Parks. 23 p.

Plante. 1990 estimation de la taille d'une population animale a l'aide d'un modele de capture-recapture avec stratification. MSc Thesis, Universite Laval Quebec.

Ptolemy, R.A. 1998. Preliminary estimates of steelhead production from eight east coast Vancouver Island watersheds with emphasis on minimum spawning escapement. Unpubl. data summary. Ministry of Fisheries, Victoria. 1p.

Schaefer, M.B. 1951. Estimation of the size of animal populations by marking experiments. U.S. Fish and Wildl. Serv. Fish. Bull 69: 191-203.

Schubert, N.D., M.K. Farwell, and L.W. Kalnin. 1994. A coded wire tag assessment of Salmon River (Langley) coho salmon: 1991 tag application and 1992-1993 spawner enumeration. Can. Man. Fish. Aquat. Sci. 2208: 21p.

Seber, G.A.F. 1982. The estimation of annual abundance and related parameters. 2nd Ed. London: Griffin.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Brd. Can. 191: 382 p.

Tredger, C.D. 1986. First cut steelhead smolt yield estimates: model preparation and application to BC streams. Unpubl. MS. Ministry of Environment, Fisheries Branch. Victoria, BC. 19p.