LOWER MAINLAND BCH
HABITAT RESTORATION
2000-2001

CHEAKAMUS RIVER
Coho Salmon Production From Constructed Off-Channel Habitat, 2001

M. Foy, Biologist; H. Beardmore, Engineer; S. Gidora, Bio-technician
Resource Restoration Group, Habitat and Enhancement Branch
Lower Fraser Area, Pacific Region, Fisheries and Oceans Canada
August, 2002

TABLE OF CONTENTS

EXECUTIVE SUMMARY…….……...3

1. INTRODUCTION……..3

2. STUDYAREA…….……3

3. METHODS…….4
3.1. Coho population estimate, off-channel habitat……4
3.1.1. Downstream weir counts…….4
3.1.2. Minnow trap mark-recapture estimate……..5
3.1.3. Total coho production from constructed habitat……..5
3.2. Coho population estimate, Cheakamus watershed…….…….5
3.2.1. Marked population……..5
3.2.2. Recovery of marked fish…….6
3.2.3. Coho production estimate, Cheakamus watershed……..6

4. RESULTS…….……..6
4.1. Coho population estimate, off-channel habitat……6
4.1.1. Downstream weir counts…….6
4.1.2. Minnow trapping mark-recapture estimate……..7
4.1.3. Total coho production from constructed habitat……..7
4.2. Coho population estimate, Cheakamus watershed…….…….7
4.2.1. Marked population……..7
4.2.2 Recovery of marked fish……..7
4.2.3. Coho production, Cheakamus watershed…….7

5. DISCUSSION…….8

6. CONCLUSIONS……9

7. ACKNOWLEDGEMENTS……..9

8. REFERENCES…….10

9. TABLES……11

Table 1. Summary of coho smolt production from off-channel habitat…….11
Table 2. Summary of coho smolt length sampling data……11

10. Figure 1. Daily catches of coho smolts…….12

APPENDIX A. FINANCIAL STATEMENT……13

Executive Summary

Over the past two decades approximately 80,000 m^2 of side-channel and off-channel pond habitat have been constructed in the Cheakamus River watershed. In 2001, coho smolts out-migrating from these sites were enumerated and a majority marked in order to assess the contribution of constructed habitat to overall smolt production in the Cheakamus River system. In 2001, spring out-migrants from these constructed off-channel sites contributed substantially to overall smolt production in the system. Smolt out-migrants from these sites represented 41% of the estimated total smolt production (41,592 of 101,262 smolts ±3%). The use of mark-recapture methodology and rotary screw traps was an effective means of estimating coho smolt numbers for the Cheakamus River watershed. This study will form the basis for an in-depth review of off-channel habitat restoration and mark-recapture assessment techniques (Decker and Foy, In preparation).

1. Introduction

Since 1981 Fisheries and Oceans Canada has been working with various partners to rehabilitate coho salmon and other salmonid populations in the Cheakamus River through hatchery enhancement and habitat restoration. A major initiative for coho has been the construction of a series of spawning side channels and ponds in the vicinity of Tenderfoot Creek Hatchery and on the grounds of the North Vancouver Outdoor School.

During the spring seaward migration of 2001, we estimated the numbers of coho smolt out-migrants from five constructed off-channel sites. One natural off-channel site was also enumerated for comparison with the constructed sites and with historic data from the early 1970's. Our study was done in conjunction with a long-term study being funded by BC Hydro to monitor the response of salmonids to the Interim Flow Agreement implemented in 1997. That program utilises two rotary screw traps to monitor juvenile salmonid migration in the Cheakamus mainstem. By marking a majority of the off-channel coho smolts produced upstream of the screw trap site, we were able to use mark-recapture methodology to assess the contribution of constructed off-channel habitat to overall smolt production in the watershed.

2. Study Area

The Cheakamus River is a major tributary of the Squamish watershed. It drains an area of approximately 1010 km^2 in the Coast Mountain Range of

southwestern B.C. In 1957 the river was dammed 26 kilometres upstream from its confluence with the Squamish impounding the Daisy Lake Reservoir. A portion of the Cheakamus flow is diverted from this reservoir through an 11-kilometre tunnel to a hydroelectric generating plant on the upper Squamish River. Anadromous salmonids are limited to the lower 17 kilometres of the river by a series of natural obstructions.

The constructed side-channels and ponds have been divided in to five distinct habitat units or sites. All are located between river kilometres 4 and 8 on the lower Cheakamus. They include Upper and Lower Paradise, Kisutch, BC Rail and Mile 49. The natural off-channel area included in the study, Tenderfoot Lake and Creek, is within the same general area of the watershed.

The two oldest projects, Lower and Upper Paradise Channels were built in 1979 and 1981 respectively. They were originally designed and built as simple groundwater-fed spawning channels, primarily for chum salmon. Since that time the importance of these off-channel areas for coho rearing has been recognised. The excavation of off-channel ponds has expanded the rearing areas of both projects and habitat complexity has been increased with the placement of large woody debris. The additions to these projects are called Moody's and Farpoint respectively. Flows have also been augmented by the construction of river intakes. Construction and expansion of additional off-channel projects has occurred to the present day. These include BC Rail/Dave's Pond, Kisutch and Mile 49. Newer projects have all been designed and built as a combination of groundwater-fed spawning channels with complex off-channel ponds for rearing. The outlets of all the constructed projects except for Lower Paradise are above the screw trap site at river kilometre 5.5.

3. Methods

3.1. Coho population estimate, off-channel habitat

3.1.1. Downstream weir counts

At five of the off-channel sites, BC Rail (includes Dave's Pond), Upper Paradise (includes Farpoint), Lower Paradise (includes Moody's), Kisutch, and Tenderfoot, out-migrants were enumerated at converging downstream weir fish traps (Conlin and Tutty 1979). Each downstream weir consisted of several 1 m × 2.5 m wooden panels screened with 0.5 cm square galvanised wire mesh, a 15 cm diameter plastic entrance pipe, and a welded aluminum trap box with screened sides.

The weirs were operated daily from March 17 to June 14. Each day, the weirs were thoroughly cleaned, inspected for damage and repaired if necessary. All captured fish were identified to species, counted, and a sub-sample was measured for fork length (to nearest mm). For each weir on each day, the target sample size for length measurements was the lesser of 25 fish or the total catch. Coho longer than 70 mm were considered to be smolts and marked, while smaller fish were assumed to be yearling parr that would not smolt until the following spring, and were not marked. This criterion was based on the observation that fish smaller than 70 mm generally did not exhibit physical characteristics typical of smolts. Accordingly, the term "smolt" used in this report refers to those coho greater than 70 mm.

3.1.2. Minnow trap mark-recapture estimate

One of the off-channel sites, Mile 49 Channel has no vehicle access. This made downstream weir trap installation impractical. Minnow traps were therefore used to obtain a Petersen mark-recapture estimate of coho smolt abundance for this site. Coho were initially captured on April 10-11. Coho smolts were anaesthetised, counted and marked by clipping a small portion of the left ventral fin. Following marking, fish were then released uniformly throughout the section of each channel downstream of the weir. On April 18-19, coho were again captured, counted and examined for marks. During each trapping period, 50 "Gee" brand wire mesh minnow traps were baited with 2 g of preserved roe and set for 24 hours. Population size and 95% confidence intervals were estimated using the single mark release Petersen formula (Seber 1982).

3.1.3 Total coho production from constructed habitat

This value was derived by summing the weir counts and the minnow trap mark-recapture estimate for the five constructed off-channel sites.

3.2. Coho population estimate, Cheakamus watershed

3.2.1. Marked population

To generate an estimate of coho smolt abundance for the Cheakamus watershed, the majority of out-migrant smolts from the four downstream weir traps upstream of the rotary screw traps (BC Rail, Kisutch, Upper Paradise and Tenderfoot) were marked. Smolts were differentially batch-

marked over time so that the data could be temporally stratified into seven release groups. Marking occurred everyday.

Marking consisted of applying either a sub-dermal tattoo with a Pan-Jet dental inoculator (Herbinger et al. 1990) or a small clip at one of several fin locations. Efforts were made to minimize the stress on smolts during the marking process. Prior to marking, smolts were anaesthetised in a bath of dilute clove oil dissolved in ethanol. The holding and recovery buckets were also aerated using a battery-operated pump. Only those smolts that appeared healthy were marked. Coho sampled for length were not generally used for marking as the added stress could affect their ability to migrate. As soon as the smolts had recovered from the marking process, they were immediately released.

3.2.2. Recovery of marked fish

Marked and unmarked coho smolts were recovered using two 2.0-m diameter rotary screw traps (RST's) operated in the mainstem of the Cheakamus River, 5.5 km upstream of its confluence with the Squamish River. Trapping methods are described in Melville and McCubbing (2001). The two RST's were operated from March 2nd until June 15th, 2001.

3.2.3. Coho production estimate, Cheakamus watershed

For the purposes of this report, the calculation of smolt abundance for the watershed is based on the estimate derived by Melville and McCubbing (2002) using the off-channel marked smolts as a single mark release group or "pooled Petersen estimator" (PPE) (Seber 1982). This PPE was calculated for the watershed above the screw trap site including constructed habitat. In order to determine an estimate for coho production for the watershed, exclusive of constructed habitat, first the population estimate for constructed habitat above the RST's was deducted from the PPE. Next a production rate was calculated for the 11.5 km of anadromous mainstem (smolts·km^{-1}) above the RST's. Finally this production rate was extrapolated to the entire 17 km of anadromous mainstem to determine an overall coho production estimate for the watershed (excluding constructed habitat).

4. Results

4.1. Coho population estimate, off-channel habitat

4.1.1. Downstream weir counts

In 2001, the number of yearling coho captured at the five downstream weir traps ranged from 3,400 fish at Kisutch Channel to 18,718 fish at Upper

Paradise Channel. Of the total number of coho caught in the weir traps, 97% (48,850 fish) were considered to be 'smolts' (fork length > 70 mm). Out-migration of coho smolts from the side-channels began in mid-April, peaked in late May, and was largely complete by the first week of June. No incidence of weir failure was reported at any of the sites. For all sites, the observed mortality for coho smolts was less than 1%.

4.1.2 Minnow trapping mark-recapture estimate

The number of coho smolts marked and released after the first capture (April 11) was 345. The number of smolts recovered during the second capture (April 19) was 346 of which 63 were marked (18% capture efficiency). The mark-recapture estimate (minnow trapping) of smolt abundance for the Mile 49 Channel was calculated to be 1,876 smolts (± 679).

4.1.3. Total coho smolt production from constructed habitat

In total, an estimated 41,592 smolts (± 679) over-wintered in constructed off-channel habitat (Table 1). Coho smolt densities were relatively similar among most side-channel sites (0.68-0.95 smolts·m^{-2}, or 4,640-6,920 smolts·km^{-1}), the exception being Lower Paradise channel (0.45 smolts·m^{-2}, or 3,965 smolts·km^{-1}). Mean density for all five constructed channels was 0.67 smolts·m^{-2} or 5,041 smolts·km^{-1}.

4.2. Coho population estimate-Cheakamus watershed

4.2.1. Marked population

In 2001, a total of 30,616 coho smolts were batch-marked by sampling period and released at the four downstream weir traps (BC Rail, Kisutch, Tenderfoot, Upper Paradise) which were located upstream of the RST's in the Cheakamus River mainstem. This represented 85% of the estimated 35,962 smolt out-migrants from these four sites.

4.2.2. Recovery of marked fish

At the RST's, a total of 2,851 marked off-channel produced smolts were recovered. An additional 3,678 unmarked coho were captured, of which, 3,524 (96%) were smolts (>70 mm).

4.2.3. Coho production-Cheakamus watershed

The PPE estimate (pooled release and recovery data) for the number of coho smolts produced upstream of the RST's as reported by Melville and McCubbing (2002) is 67,298 (±1,736). Subtracting the number produced in constructed off-

channel habitat (26,936±3%) leaves an estimate of 40,362(±3%) smolts from the upper 11.5 km of anadromous habitat. The production rate for the upper watershed exclusive of constructed habitat is therefore estimated to be 3,510 smolts·km^{-1}. Extrapolation of this production rate to the entire 17.0 km of anadromous salmonid habitat results in a smolt production estimate for the watershed of 59,670 smolts (±3%).

5. Discussion

In 2001, coho smolt production in four off-channel habitat restoration sites in the Cheakamus River met or exceeded provincial bio-standards for constructed side-channels and ponds (0.67 and 0.69 smolts·m^{-2}, respectively; Koning and Keeley 1997) (range 0.68 to 0.95 smolts·m^{-2}, Table 1). One project (Lower Paradise) was considerably lower (0.45 smolts·m^{-2}). This site was known to have limited salmon access due to beaver activity. Production from the constructed off-channel habitat compared favourably with the one natural site included in the study (Tenderfoot Creek and Lake, 0.75 smolts·m^{-2}). The production from Tenderfoot exceeded historic levels determined in the early 1970's (0.64 smolts·m^{-2}, Marshall and Britton, 1990).

The estimate for coho smolts produced in constructed off-channel habitat is 41,592 smolts ±2% (Table 1) and the mark-recapture estimate for the rest of the watershed is 59,670 smolts ±3%. Summing these results in an overall estimate for the watershed of 101,262 smolts ±3%. The constructed off-channel sites accounted for 41% of the estimated total smolt production for the system.

The high proportion of total smolt numbers contributed by the constructed off-channel sites could not be explained by unusually low smolt production throughout the rest of the Cheakamus River watershed in 2001. Not including the estimated number of smolts from the constructed channels and ponds, smolt density in the Cheakamus River in 2001 was 3,510 smolts·km^{-1}. This is considerably greater than the mean value of 1,476 coho smolts·km^{-1} reported for Pacific coastal streams of similar latitude which were also thought to be fully-seeded (Bradford et al. 1996). Moreover, in 2001, estimated smolt density in the Cheakamus River was greater than a mark-recapture estimate of 2,561 smolts·km^{-1} for the Cheakamus River in 1966 (Marshall and Britton 1990). When production from both natural and constructed habitat is included, total coho smolt production for the Cheakamus watershed in 2001 was calculated to be 5,957 smolts·km^{-1}

The relatively high use of constructed off-channel habitat by over-wintering juvenile coho in the Cheakamus River is comparable to the relative use of natural and/or constructed off-channel areas by coho in other streams. In a similar study conducted for three years in the Coquitlam River an average of 46% of the total smolt population for the system over-wintered in six constructed off-channel habitat sites which represented about 14% of the available habitat (Decker and Lewis, 2000).

The use of full-span weirs to enumerate smolts from the off-channel sites was an efficient means of obtaining a large marked population (30,616 smolts). Considering the size of the Cheakamus River and the large number of migrating smolts, overall capture efficiency of the RST's for marked off-channel fish was reasonably good (9%).

6. Conclusions

Large numbers of wild coho salmon over-wintered in constructed off-channel habitat in the Cheakamus River and in 2001, spring out-migrants from off-channel habitat contributed substantially (41%) to overall smolt production in the system. If it is assumed that coho smolt production in the Cheakamus River is limited by over-wintering habitat, then it is reasonable to suggest that overall coho productive capacity of the system has been increased as a result of side-channel and pond construction. The observed 133% increase in coho smolt production from 1966 to 2001, (2,561 vs. 5,957 smolts$\cdot$km^{-1}) supports this conclusion.

The mark-recapture sampling design used here appears to be a practical way to estimate the abundance of migrating smolts in streams too large to accommodate full-span downstream weirs.

7. Acknowledgements

This study was jointly funded through a collaborative agreement between BC Hydro and Fisheries and Oceans Canada. Instream Fisheries Consultants were contracted to carry out the project and summarise the data. The North Vancouver Outdoor School, Squamish Nation, Tenderfoot Hatchery and local landowner Lynn Wilbur provided access to the field study sites. Tenderfoot Hatchery staff assisted with the construction and installation of the downstream weir traps.

8. References

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.

Conlin, K. and B.D. Tutty. 1979. Juvenile field trapping manual. Fish. and Mar. Serv. Man. Rep. #1530.

Decker, S., and M. Foy. (In preparation). The Contribution of Constructed Side-channels and Ponds to Coho Salmon Smolt Production in the Cheakamus River.

Decker, S., and G. Lewis. 2000. Fish Response to Increased Minimum Flows and Habitat Restoration in the Coquitlam River: a 5 Year Review. Unpublished report prepared for B.C. Hydro Power Facilities, Burnaby, B.C., December 2000. 40 p.

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.

Koning, C.W., and E.R. Keeley. 1997. Salmonid bio-standards for estimating production benefits of fish habitat rehabilitation techniques. *In* P.A. Slaney and D. Zaldokas. [eds.] Fish habitat rehabilitation procedures. Watershed Restoration Technical Circular No. 9.

Marshall, D.E., and E.W. Britton. 1990. Carrying capacity of coho salmon streams. Can. MS Rep. Fisheries and Aquatic Sciences No. 2058: 32p.

Melville, C., and D. McCubbing. 2001. Assessment of the 2000 juvenile salmon migration from the Cheakamus River, using rotary screw traps. Unpublished report prepared for B.C. Hydro and Power Authority, Vancouver, B.C. 40 p.

Melville, C., and D. McCubbing. 2002. Assessment of the 2001 juvenile salmon migration in the Cheakamus River, using rotary screw traps. Unpublished report prepared for B.C. Hydro and Power Authority, Vancouver, B.C. 53 p.

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

9. Tables

Table 1. Summary of coho smolt production from off-channel habitat

Constructed Sites	**Estimation Method**	**Lgth (km)**	**Area (m^2)**	**No. Smolts**	**No./ km**	**No./ m^2**
BC Rail	Count	0.83	6,460	5,744	6,920	0.89
Kisutch	Count	0.58	3,970	2,691	4,640	0.68
Up. Paradise	Count	3.23	21,310	18,393	5,703	0.86
Lo. Paradise	Count	3.25	28,700	12,888	3,965	0.45
Mile 49	PPE	0.36	1,970	1,876 ± 679	5,211	0.95
Total		8.25	62,410	41,592±679	5,041	0.67
Natural Sites						
Tenderfoot	Count	0.95	12,200	9,134	9,615	0.75

Table 2. Summary of coho smolt length sampling data.
Mean fork lengths, standard deviations (SD), and sample sizes (*n*), for coho smolts (> 70 mm in length) at five off-channel sites and mainstem area of the Cheakamus River in 2001.

Site	Mean length	SD	*n*
BC Rail Channel	90	10.5	196
Kisutch Channel	82	7.3	239
Tenderfoot Channel	98	8.9	312
Upper Paradise Channel	86	8.7	213
Lower Paradise Channel	88	11.3	1,380
Off-channel (weighted mean)	90	11.0	6,795
Mainstem (weighted mean)	91	9.0	893

10. Figures

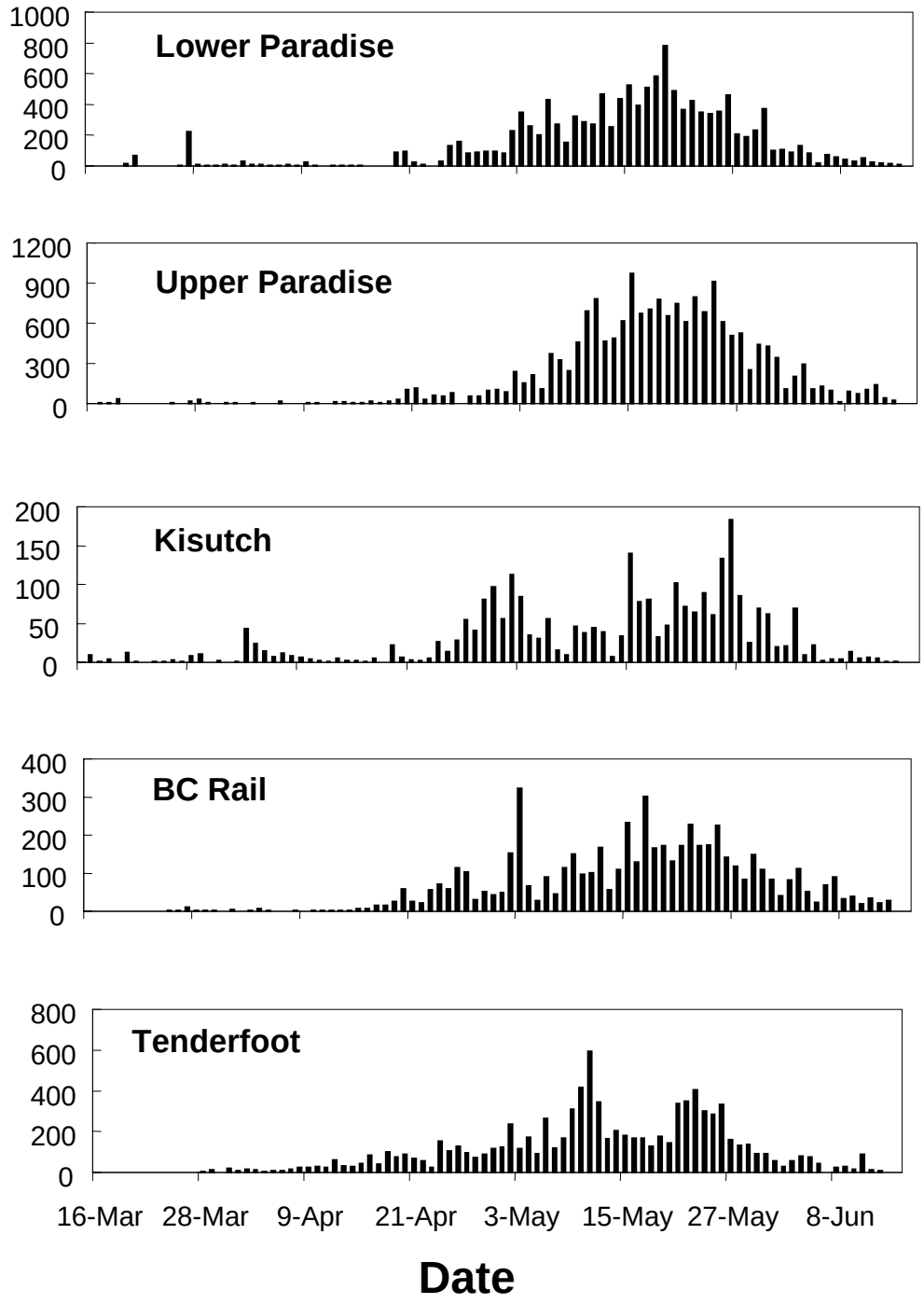

Figure 1. Daily catches of coho smolts.
Daily catch totals for coho smolts (> 70 mm in length) at five off-channel sites in the Cheakamus River, 2001

11. Appendix A. Financial Statement

Item	Description	Income	Expense	Totals
1	**Funding**			
1.1	BCHydro	49,225		
1.2	Fisheries and Oceans Canada	20,000		
	Subtotal Funding			**69,225**
2	**In-kind Support**			
2.1	Fisheries & Oceans Canada (Professional and technical Support)	30,000		
	Subtotal In-kind Support			**30,000**
3	**Expenditures**			
3.1	Equipment and Labour (trap construction/installation)		26,685	
3.2	Materials (enumeration/marking)		2,679	
3.4	Labour (enumeration/marking)		33,107	
3.5	Professional and Technical Support		36,754	
	Subtotal Expenditures			**99,225**