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Increasing Coho Productivity in the Chilliwack River Watershed

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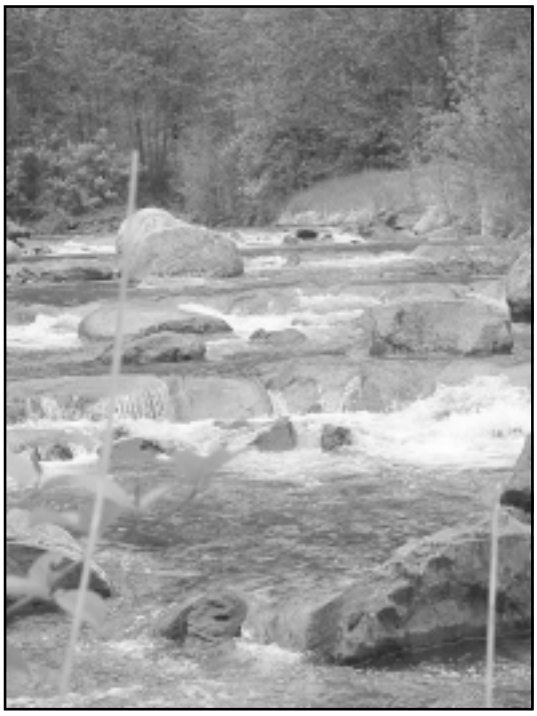
Introduction

During the past decade extensive logging, dyking, agricultural and urban development have contributed to the current status of historically low fish populations in the Chilliwack River watershed. This 26,819 ha watershed is located in the Fraser Valley approximately 150 km southeast of Vancouver (Figure 1). The river originates from the northern Cascade Mountains in Washington State and flows north to Chilliwack Lake where, at the crossing of the Vedder Bridge, the lower reach is renamed the Vedder River. From there it flows into the Sumas River and eventually drains into the Fraser River (Blackwell et al. 1999). Prior to dyking in the watershed the river flowed into Sumas Lake which has since been drained for agricultural use (Bruce Usher, pers. comm.).



In Centennial Channel boulders add complexity to spawning and overwintering habitat.

The watershed supports wild populations of steelhead/ rainbow trout (*Oncorhynchus mykiss*), Dolly Varden char (*Salvelinus malma*), chum (*O. keta*), chinook (*O. tshawytscha*), sockeye (*O. nerka*), pink (*O. gorbuscha*) and coho salmon (*O. kisutch*). All of the fish populations have suffered population declines; the most significant decline occurring in the coho salmon populations, which are currently depressed throughout the south coast (Pat Slaney, pers. comm.). Consequently, the Chilliwack River watershed has been a target for aquatic restoration for the last 6 years. A hatchery has been in place for the last 15 years (Blackwell et al. 1999). Restoration efforts in this watershed have focused primarily on the development of off-channel habitat, which targets the restoration of coho salmon populations, and to a lesser extent steelhead populations. The following review outlines the off-channel restoration works carried out to date in the Chilliwack River watershed and summarizes the latest coho productivity estimates from the Centennial/Bulbeard downstream trapping study.

Aquatic rehabilitation in the Chilliwack River watershed is on-going and has been carried out largely by the Watershed Restoration Program (WRP- funded by Forest Renewal BC) via the Ministry of Environment, Lands and Parks (MELP), Fisheries and Oceans Canada (FOC), the Steelhead Society Habitat Restoration Corporation (SSHRC) and Fisheries Renewal

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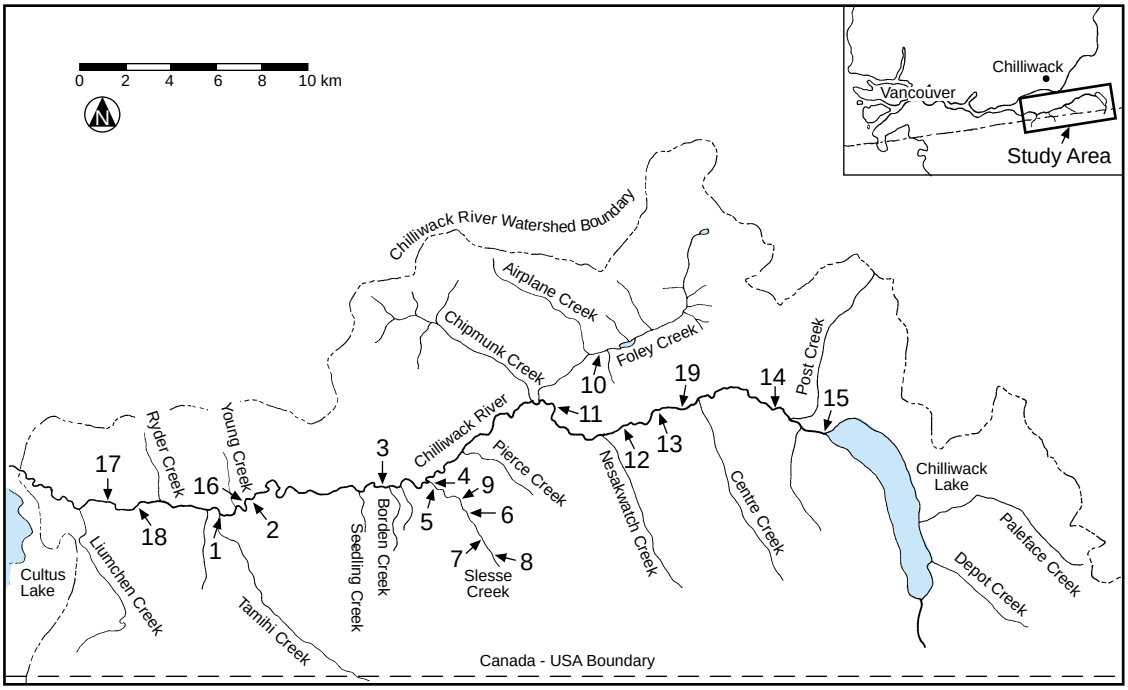

Figure 1. Location of the Chilliwack River watershed restoration projects.
1-Little Tamihi Creek 2-Anderson Creek 3-Borden Creek 4-Slesse Creek R-1 road deactivation 5-Slesse Creek R-1 pond 6-Slesse Creek R-4 road deactivation/ponds 7-Slesse Creek bar stabilization 8-Slesse R-5 9-Slesse Creek R-1 mainstem 10-Foley Creek 11-Angelwing pond 12-Millenium pond 13-Centennial/Bulbeard complex 14-Yukalaup Creek 15-Chilliwack Lake outlet 16-Young Creek 17-Deer Creek phase 1 18-Deer Creek phase 2 19-Camp Channel

BC. These combined efforts have resulted in the restoration of approximately 51,500 m^2 (12 km) of off-channel stream habitat and approximately 202,000 m^2 (20 ha) of off-channel pond habitat (Figure 2). Additionally, in the past the federal Salmonid Enhancement Program developed off-channel projects aimed at restoring and providing spawning and rearing channels for chum and coho. One of the most successful restoration projects in the Chilliwack River watershed is the Centennial/Bulbeard Channel complex (Figure 3). In 1996 the Centennial spawning/rearing channel and pond complex was constructed. At the upstream end of the project an intake was established off the Chilliwack River mainstem in order to divert a controlled flow of 1.1 m^3 sec^{-1} into Centennial Channel. Habitat restoration was carried out at Bulbeard Creek over two years. In 1996 a series of three existing seasonal ponds were bermed and flooded (Figure 4). Water is now supplied to these ponds via flows from the upper Centennial Channel (Phase 1). In 1998 Phase 2 of Bulbeard Creek was constructed, involving the development of two additional berms, enabling the re-establishment of flows to a series of old beaver ponds (Figure 5).

Maintaining the flows to this area was achieved in two ways:

(a) by connecting the ponds to Phase 1, and
(b) through an intake from lower Centennial Channel.

The Chilliwack River mainstem is a coastal stream that braids in the lower reaches and typically undergoes rearrangement after large winter floods. Thus the mainstem provides limited overwintering habitat for salmon, trout and char. Unfortunately the combination of pre-Forest Practices Code timber harvesting, urban and agricultural development, and the construction of riverside dykes and roads has resulted in the loss or isolation of many off-channel habitats along the Chilliwack River.

Logging in the Chilliwack River watershed commenced at the end of the 19th century and continues today. Currently 20-35% of the Chilliwack River watershed has been logged, including approximately 75% of the operable forest land and 90% of the floodplain (Hay 1992; MOF 1996). Combined with the creation of 600 km of logging roads (MOF 1995), the extensive past logging of streambanks and floodplains has resulted in the loss of off-channel and mainstem habitats, a reduced

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amount of large woody debris (LWD) in streams, bank destabilization, river widening, and increased sediment loads (Hay 1992). Dyking along the lower portion of the Chilliwack River, which began in 1892 (MOF 1995), also contributes to the destruction of important off-channel habitat and unfortunately this factor may continue to destroy productive habitat, as additional dyking may be proposed for other portions of the watershed (Hay 1992).

Juvenile coho generally reside in freshwater for one year, although this can be extended up to four years in colder waters (Sandercock 1998). In the Chilliwack River watershed, off-channel habitats are dominated by coho juveniles, but steelhead, chum, and pink salmon also use these habitats to a much lesser degree (usually during/after flooding events). Off-channel habitats are used by coho for summer and overwinter rearing, as they prefer characteristic features such as overhanging banks, LWD, riparian vegetation, deep pools and the calmer water velocity typical of groundwater-fed habitats (Blackwell et al. 1999). In off-channel habitats, coho depend on LWD for cover and protection (Slaney and Martin 1997), and as a result, the historical decline in coho returns to the Chilliwack River watershed (Figure 6) can be partially attributed to the lack of adequate cover and overwintering habitat (Slaney et al. 1996). Consequently the importance of creating and rehabilitating off-channel stream and pond habitat in this aquatic system is fundamental for sustaining and increasing the populations, as this helps to ensure the existence of adequate rearing and overwintering habitat for juveniles.

Coho smolt yields

Downstream trapping studies have been carried out at various restored and natural (existing) off-channel habitats in the Chilliwack River watershed. Trapping migrating coho smolts enables us to determine the productivity of the restored off-channel habitat as well

No.	Sites	Type of Restoration	Pond Area (m^2)	Pond Area (ha)	Stream/ Channel Restored (m^2)	Stream/ Channel Restored (km)
1	Little Tamihi Creek[1]	Riffle-pool sequencing (1998/99)	0	0	2,090	0.55
2	Anderson Creek	Side channel & pond (1995)	15,000	1.50	250	0.25
3	Borden Creek	Side channel & ponds (1997/98)	32,184	3.22	5,038	1.98
4	Sleese Creek	R-1 Road deactivation & pond (1999/00)	400	0.04	30	0.10
5	Sleese Creek	R-1 Pond (1998/99)	1,500	0.15	20	0.02
6	Sleese Creek	R-4 Road deactivation, groundwater channels & ponds (1996-2000)	5,098	0.51	1,693	0.81
7	Sleese Creek[2]	R-4 Bar stabilization (1998/99)	0	0.00	100	0.10
8	Sleese Creek	R-5 Off-channel pond complex (1997/98)	200	0.02	20	0.10
9	Sleese Creek	R-1 Mainstem LWD placement (1999/00)	0	0.00	1,520	0.50
10	Foley Creek	Side channel & LWD placement (1998/99)	800	0.08	3,200	0.40
11	Anglewing Pond Complex	Side channel & ponds (1997-1999)	9,120	0.91	2,050	0.82
12	Millennium Pond - 15 Mile Creek	Side channel & ponds (1998-2000)	40,000	4.00	2,000	1.00
13	Centennial/Bulbeard Complex	Side channel & ponds (1997/98)	80,000	8.00	15,000	1.50
14	Yukalaup (Post) Creek	Side channel & ponds (1997/98)	2,400	0.24	2,000	0.67
15	Chilliwack Lake Outlet	Gravel placement (1995)	0	0.00	2,500	0.10
16	Young Creek[3]	Riffle-pool sequencing & ponds (1998/99)	(2,000)	(0.20)	(200)	(0.13)
17	Chilliwack River[4]	LWD placement (39 structures) (1998/99)	0	0.00	11,425	2.00
18	Chilliwack River	LWD placement (near Centre Creek) (1999/00)	0	0.00	240	0.50
19	Deer Creek (phase 1)	Pond (1998/99)	1,100	0.11	10	0.01
20	Deer Creek (phase 2)[3]	Side channel & ponds (1999/00)	7,921 (74)	0.79 (0.0074)	1,205 (709)	0.49 (0.32)
21	Camp Channel	Side channel & ponds (1999/00)	4,300	0.43	1,100	0.28
Totals			200,023 (2,074)	20.00 (0.21)	50,582 (909)	11.72 (0.45)

[1] Restores fish access to 0.4 km of stream.
[2] Augments natural processes.
[3] Brackets denote dry non-functional habitat.
[4] Centre Creek, Alison Creek, Anderson Creek (at confluence), Ford Camp, Middle Creek and Chilliwack River sites combined.

Figure 2. Summary of restoration projects in the Chilliwack River watershed, funded by FRBC.

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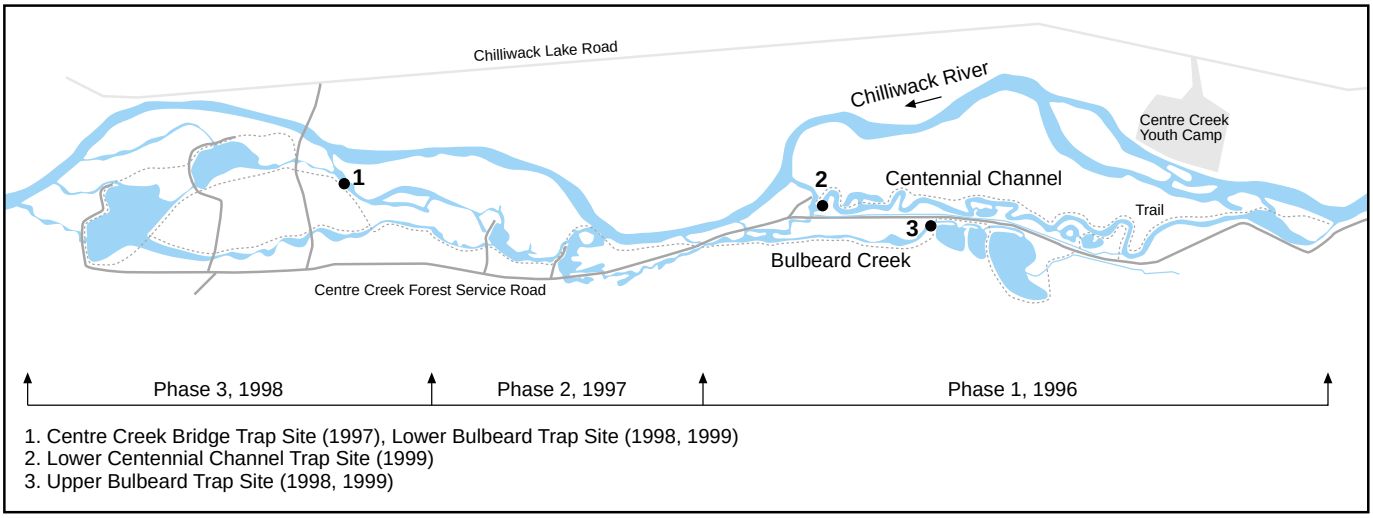

Figure 3. Centennial/Bulbeard off-channel study location in the Chilliwack River watershed.

as to examine how the creation of additional off-channel habitat is affecting the overall coho production in the Chilliwack River. (Note that in this review the terms smolt and juvenile are interchangeable as only migrating coho were counted, thus parr and fry were excluded).

Trapping at the Centre Creek Bridge site was carried out in 1997. As this site was a previously existing off-channel habitat, the trapping data serves as a baseline comparison for pre-restoration coho productivity in the area. Annual downstream trapping commenced at Bulbeard Creek (Phase 1 and 2) in 1998 and at Centennial Channel in 1999. Although a variety of juvenile salmonid species were collected during the sampling period (including coho, steelhead, chum, char and cutthroat) it is the coho salmon outputs that are of particular significance in these off-channel habitats. Figure 7 outlines the coho trapping results.

Biostandard analysis

Biostandards provide a means to predict the productivity of constructed habitats based on empirical relationships. These standards can be compared with actual trapping numbers from the Chilliwack River. Two separate off-channel habitat biostandards generated by Keeley et al. (1996) and Koning and Keeley (1997) were used in this analysis:

$$\log_{10} \text{fish number} = 0.51 \log_{10} \textit{pond} \text{ area (ha)} + 3.47 \quad (1)$$

$$\text{smolt number} = 0.69 \text{ smolts/m}^2 \cdot \textit{side-channel} \text{ habitats} \quad (2)$$

Equation (1) is a logarithmic relationship that relates the *pond* area to the number of fish in the off-channel pond (deep, calm water) and equation (2) represents the average smolt production in *side-channel* habitats (flowing water). Because these are stable off-channel habitats dominated by coho juveniles, we assume that the number of migrating fish is directly proportional to the number of coho juveniles (or smolts).

It is clear from the Centre Creek Bridge data in column 1 (Figure 8) that there exists no difference between the observed and predicted coho outputs. Consequently in 1997 the Centre Creek habitat was producing a sustainable number of coho juveniles (1,351) relative to the habitat area.

The results obtained in 1998 at Bulbeard Creek are inconclusive because it was the first year salmon occupied this habitat. In 1999, a substantial rise in juvenile output from 13,055 to 20,909 was observed.

Figure 4. At Bulbeard Creek the development of berms enabled the re-establishment of flows to a series of old beaver ponds.

Figure 5. This beaver baffle helps deter movement of beavers back into the Bulbeard Creek ponds.

This 60% increase demonstrates how rapidly that enhanced off-channel habitat can become productive in terms of coho outputs. A comparison using equation (1) (appropriate because the majority of this site is pond habitat) demonstrates that in both years the Bulbeard Creek site had surpassed the estimated productivity.

Downstream trapping of coho juveniles at Centennial Channel was carried out for the first time in 1999. This habitat, which is similar in size to the Bulbeard Creek site (30,000 m^2 vs. 35,000 m^2), produced 5,085 coho juveniles. Analysis using equation (2), which determines the smolt numbers in a side-channel site, suggests that this habitat has only reached 1/3rd of it's carrying capacity for coho juveniles. A possible explanation for the low coho smolt production in this site, with respect to (2), is that this particular off-channel site is also heavily used by steelhead smolts and there may be competition for the site. In 1999, 819 steelhead smolts were trapped in Centennial Creek. This compares to 77 at Bulbeard Creek (1999) and 2 at Centre Creek Bridge (1997). Consequently interspecies competition for limiting resources may be responsible for the somewhat depressed coho smolt productivity at Centennial Channel.

The biostandards, as described, did not accurately predict the coho productivity in the restored off-channel habitats. It may be that the complexity of factors controlling the productivity of restored off-channel habitats limit the predictive capabilities of the described mathematical relationships. Measurement of changes in coho smolt productivity may require an intensive multi-year study of many different restored and natural ponds and channels in order to define non-linear relationships for each habitat type.

While the measured productivity of restored habitats have varied between projects and between years an argument can be made that good quality restored off-channel habitat appears to be comparable (or superior) in productivity to good quality natural off-channel habitat in the Chilliwack River. The true benefits of restoration to coho salmon populations derive from an overall increase in the amount of productive off-channel habitat in this part of the Chilliwack River watershed.

Overall production

Instead of relating the coho output data to various derived productivity biostandards, it should be more informative to look at how these restored habitats are increasing the overall production of the Chilliwack River. Marshall and Britton (1990) carried out a review examining 22 streams to determine the carrying

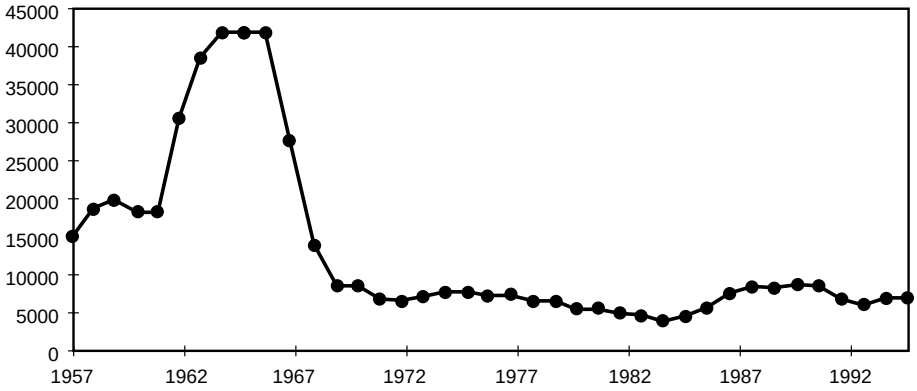

Figure 6. Estimated wild coho salmon escapements in the Chilliwack River from 1957 to 1995 (source: DFO Salmon Escapement Data System).

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Site	Total surface area (m^2)	Restored or natural	Coho juveniles 1997	Coho productivity[1] 1997	Coho juveniles 1998	Coho productivity[1] 1998	Coho juveniles 1999	Coho productivity[1] 1999
Centre Creek Bridge	2,639	natural	1,351	51	–	–	–	–
Bulbeard Creek (Phase 1)	17,500	restored	–	–	8,753	50	7,328	42
Bulbeard Creek (Phase 2)	18,000	restored	–	–	4,302	24	13,581	75
Centennial Channel	30,000	restored	–	–	–	–	5,085	17

[1] Coho productivity is calculated as # juveniles/100m^2.

Figure 7. Downstream trapping of off-channel habitats in the Chilliwack River watershed.

capacity of small (mean length=0.5 km) and large (mean length=30 km) coho salmon streams. Large streams, which tend to be more productive per unit length than small streams (but less productive per unit area), were calculated to produce a mean annual smolt yield of 1,894 smolts/km.

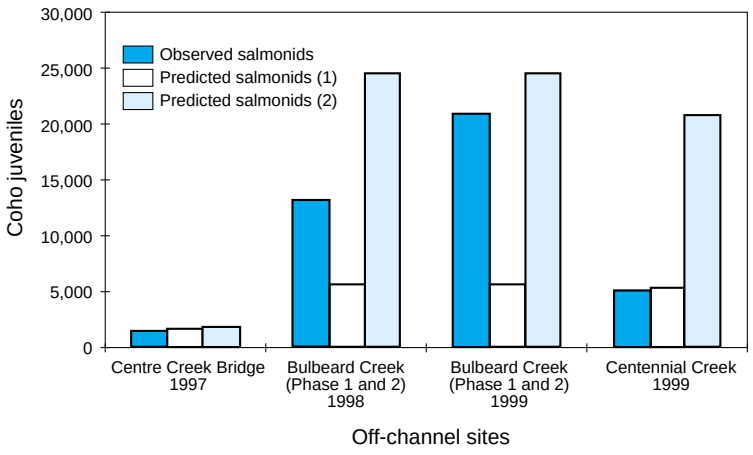

Figure 8. Coho juvenile production from off-channel habitats in the Chilliwack River watershed as compared to (1) the logarithmic biostandard (Keeley et al. 1996) and (2) the fish production biostandard (Koning and Keeley 1997).

The Centennial and Bulbeard restored off-channel habitats contribute to coho production along a 3 km reach (linear distance) of the Chilliwack River. According to Marshall and Britton (1990), this 3 km reach would be expected to produce approximately **5,682 smolts** or 1,894 smolts/km (prior to restoration works in 1997). Since the creation of additional (65,500 m^2) off-channel habitat between 1997-1999 this reach produced a total of (5,682 +25,994 - 1,351=) approximately **30,325 smolts** or 10,108 smolts/km (in 1999, Figure 9). In summary, overall production increase from this off-channel habitat, per km of Chilliwack River reach, is five times the expected value for this amount of habitat.

Conclusion

The primary goal of fish habitat restoration is to restore the productive capacity of the watershed to pre-disturbance conditions. By relating coho smolt outputs from restored off-channel habitat to the productivity of the mainstem, we are able to understand how the creation of these off-channel habitats has increased the coho productivity of the upper Chilliwack River. In taking this approach, it is easy to see the benefits that have accrued due to the restoration of off-channel habitats in the watershed. Off-channel habitat restoration in the Chilliwack River watershed has been quite successful to date. In total 200,023 m^2 of pond habitat and 12 km (50,582 m^2) of channel habitat have been created. Off-channel restoration at the Centennial/Bulbeard site (65,500 m^2) produced approximately 30,325 coho smolts in 1999.

The next step in restoration studies within the Chilliwack River watershed will be to determine what percentage of the overall Chilliwack River

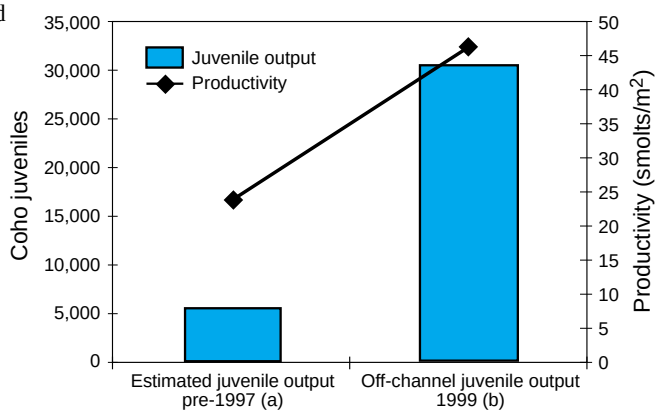

Figure 9. Coho juvenile outputs (pre- and post- restoration) as related to a 3km reach of the Chilliwack River (a) estimated juvenile output from Marshall and Britton (1990), (b) combined (Bulbeard and Centennial) off-channel juvenile output in 1999.

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coho production comes from the restored off-channel habitats. An initial mark-recapture study of the Coquitlam River indicated that 47% of the coho salmon smolts migrating from that river originated from constructed off-channel ponds and channels (Decker and Foy 1998). Next spring a similar mark-recapture study of the Chilliwack River will attempt to address this same question. This type of effectiveness evaluation study is crucial to provide us with insight into what level of restoration effort is required to bring large river systems, such as the Chilliwack River, back to a level of high coho smolt productivity. This information will also be useful when designing targets for future off-channel projects in other damaged and degraded watersheds.

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LWD structure creates habitat in Centennial Channel.

References

Blackwell, C. N., C. R. Picard, and M. Foy. 1999. Smolt productivity of off-channel habitat in the Chilliwack River watershed. Watershed Restoration Project Report No. 14.

Decker, A. S., and M. Foy. 1998. The contribution of restored off-channel habitat to smolt production in the Coquitlam River. Streamline 4(3): 22-24.

Hay and Company Consultants Limited. 1992. Chilliwack River hazard management study interim report. Fraser Cheam Regional District.

Keeley, E. R., P. A. Slaney, and D. Zaldokas. 1996. Estimates of production benefits for salmonid fishes from stream restoration initiatives. Watershed Restoration Management Report No. 14.

Koning, C. W., and E. R. Keeley. 1997. Salmonid biostandards for estimating production benefits of fish habitat rehabilitation techniques. Chpt. 3 *in* P. A. Slaney and D. Zaldokas (editors) 1997. Fish habitat rehabilitation procedures. Watershed Restoration Technical Circular No. 9.

Marshall, D.E., and E.W. Britton. 1990. Carrying capacity of coho salmon streams. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2058. Fisheries and Oceans Canada.

Sandercock, F. K. 1998. Life history of coho salmon (*Oncorhynchus kisutch*). *In* C. Groot and L. Margolis [eds.]. Pacific salmon life histories. UBC Press, Vancouver, BC. pp.397-445.

Slaney, T. L., K. D. Hyatt, T. G. Northcote, and R. J. Fielden. 1996. Status of anadromous salmon and trout in British Columbia and Yukon. Fisheries 21 (10): 20-35.

Slaney, P. A., and A. D. Martin. 1997. The Watershed Restoration Program of British Columbia: accelerating natural recovery processes. Water Quality Research Journal of Canada 32:325-346.

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