

Integrated Watershed Restoration Projects

- evidence of water flow, suggesting that placement of drains is sensitive (1 year data).
- Cross-ditches should be closely spaced to return the cutslope seepage water to groundwater: spacing depends on site characteristics, and is particular to the conditions encountered in the Willow Watershed.
 - Cross-ditches constructed in fine soils to ATV template had no breaches after the fall rains and hunting traffic; several constructed to 4WD template had been breached in the same conditions.

- The effective channel length was reduced to 44% of its pre-deactivation state in one watershed. This should reduce the peak flow in the streams and reduce destabilizing forces on landslides below.
- Riffles constructed by hand using compressed air withstood the large flood of spring 1999 (estimated to be greater than the average flood). ▲

S. Sterling, 2000. Upper Willow Watershed Effectiveness Evaluation Strategy, Northwest Hydraulics Consultants, North Vancouver, B.C. Progress Report.

The Keogh and Waukwaas Rivers Paired Watershed Study for British Columbia's Watershed Restoration Program: Juvenile Salmonid Abundance and Growth

D.J.F. McCubbing and B.R. Ward.

Project Description

The study assesses the effectiveness of WRP stream habitat rehabilitation techniques through in-stream sampling (electrofishing and seine netting) in representative treated and untreated reaches, and through comparison of results with population dynamics data gathered from 25 years of salmonid juvenile abundance in-stream, smolt enumeration, and adult steelhead run size estimates. In-river treatments include stream habitat structures and slow-release nutrient applications, in the Keogh watershed. These have been incrementally increased over the five-year period (Figure 1), along with earlier road deactivation and on-going construction of off-channel ponds and channels. Juvenile salmonid density, growth, smolt yield, and adult escapement data will be collated and analyzed for change, in a staircase-type experimental design. To strengthen the analysis, a neighbouring watershed (Waukwaas River) is being monitored, but without WRP stream rehabilitation treatments. Data on the escapement enumeration of pink and coho salmon in the Keogh River will be added to the adult steelhead data. This will assist in evaluating the effectiveness of WRP techniques, and in calibrating coho and steelhead smolt yield to adult escapement (i.e., smolts per spawner as a function of spawners pre- and post-treatment).

The Keogh and Waukwaas Rivers, two fourth-order streams, are situated at the northern end of Vancouver Island, B.C., in the coastal western hemlock biogeoclimatic zone. The logging histories of both watersheds are similar. A summary of Keogh watershed logging history indicates that approx. 53% of the basin had been logged since 1940, including 55% of the floodplain and up to 70% of the sub-basins. Past

Unit	1994 - 96	1997	1998	1999	2000	Reach
1		S	S	Fs	Fs	Zt
2		S	Fs	Fs	Fs	Yt
3		F	F	Fs	Fs	X
4		F	F	F	Fs	W
5			F	NS	NS	Yu
6				NS	NS	Zu
7						Waukwaas

Figure 1. Treatment plan and reaches used for fish density, growth, survival, and smolt yield assessment in the Keogh and Waukwaas Rivers for evaluation of WRP stream habitat rehabilitation techniques. See Figure 1 for definition of reaches; t= treated, u=untreated, blank = no treatment, F = fertilizer, S = structures, and Fs = fertilizer and structures, NS = not sampled.

Integrated Watershed Restoration Projects

forest practices harvested 23 km of the river's mainstem riparian zone, and 26 km along the riparian zones of its tributaries. Habitat rehabilitation has been focused on these mainstem sections that lacked complex habitat structure.

In 1997, 121 WRP structures, such as LWD complexes and boulder clusters (Figure 2), were placed in the Keogh River over 5.4 km, and nutrient addition included the lowermost 19 km of the Keogh River mainstem and approximately 10 km of tributary stream length to compensate for depressed salmon escapements. In 1998, an additional 67 WRP structures were placed, for a total treated length of 6.8 km with fertilizer added to over 27.5 km of mainstem river and 11 km of tributaries. A further 121 WRP structures were placed over a length of 1.0 km in 1999. Inorganic nutrients, as an annual application of slow-release briquettes (total application rates on file = 1110 kg) were added over a total length of 36.5 km of the Keogh River mainstem, from the river mouth to 4 km upstream of Keogh Lake, as well as fertilizer addition to 11 km of key tributaries entering the mainstem from Muir Lake to the river mouth.



Figure 2. This boulder cluster in the Keogh River is one of the 121 structures constructed as habitat restoration in 1997.

Criteria for Restoration and Evaluation

Evaluation of success of watershed rehabilitation techniques can be measured by a positive response across several criteria: juvenile salmonid abundance, distribution, growth, survival, smolt yield, and adult escapement. Analyses here compared juvenile salmonid abundance within and among reaches, and within and between watersheds, along with assessment of the utilization of individual structure type and the benefits of nutrient addition to offset depressed salmon runs.

Restoration Responses 1997-1999: Juvenile Fish Abundance, Standing Crop and Smolt Yield.

A wide variance in salmonid abundance was found, both within watersheds and between watersheds in the three study years. These differences, where apparent, may have been the result of a combination of factors, including: habitat availability, adult escapement, juvenile mortality, and reach location within the watershed, along with environmental conditions in the year of sampling (e.g., drought low flows, winter floods, etc.).

Steelhead fry abundance in the Keogh River has been limited by low adult escapement (<100 adults) in recent years, due to poor rates of survival from smolt to adult (<4%). Despite low adult returns, a statistically significant ten-fold increase (to a mean of ~140 fry per 100m²) in overall steelhead fry abundance was apparent between 1997 and 1999.

Densities of steelhead parr were significantly higher in 1999 on the Keogh River (mean of 55 parr per 100m²), compared to 1998 and 1997 data (mean of 22.5 and 17 parr per 100m² respectively). In 1999, steelhead parr were in greatest abundance on the Keogh River in the reaches treated with structures and fertilizer (45 to 126 parr per 100m²) compared to fertilizer-only reaches in the same river locations (40 parr per 100m²). These densities from treated reaches in the Keogh River were greater than steelhead parr densities throughout the untreated Waukwaas River (4 to 38 parr per 100m²).

Coho fry abundance was, on average (all reaches), higher in the Keogh River in 1999 than in either of the previous sample years, increasing by an average of 53% over 1998 results to 500 fry per 100m². Coho fry abundance on the Waukwaas River also increased over 1998 data by an average 42% to 173 fry per 100m², but was lower than that recorded in 1997.

Smolt yield from the two watersheds has been assessed for five years, including two years pre-treatment and three years partial post-treatment of the Keogh River (Figure 3). Coho smolt numbers rose steadily for both watersheds through the first three years of investigation, but fell sharply in the Keogh River in 1998. A marked recovery of coho smolt yield was observed in 1999, to 53,000 fish (72% of 25-year average). In the Waukwaas River, the dramatic increase in coho smolt yield measured in 1998 was not sustained; yield dropped to levels that were similar to those of Keogh River in 1999. Steelhead smolt numbers had remained low and were increasingly reduced over the four-year study period to 1998 at the Keogh River. However, in 1999 smolt yield increased two-fold over 1998 to the highest on record since 1993. Substantial increases in estimated

Integrated Watershed Restoration Projects

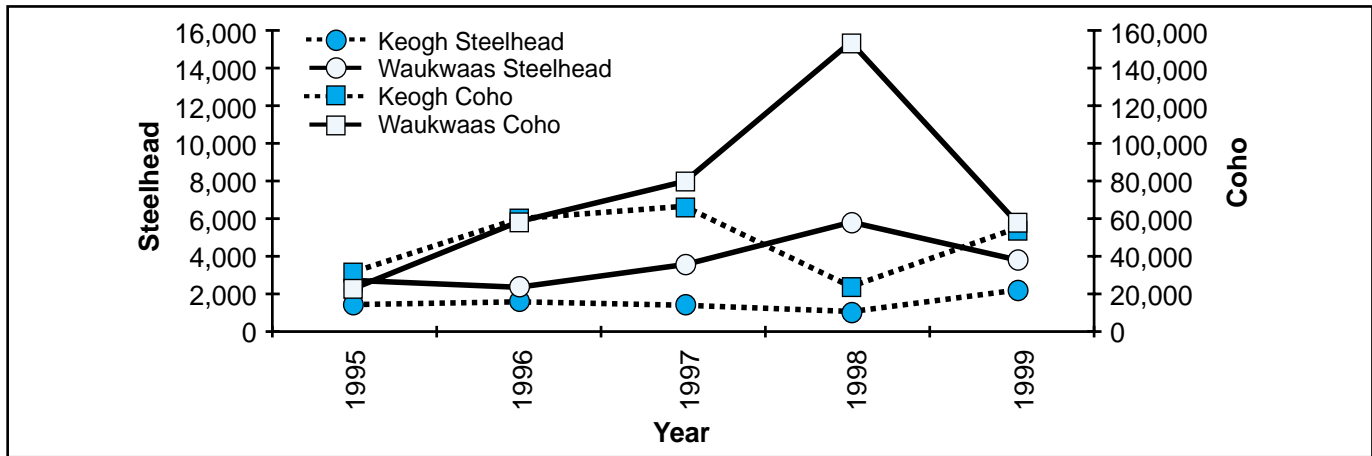


Figure 2. Smolt yield from the Keogh and Waukwaas Rivers 1995 to 1999. Keogh River, dashed lines and dark blue points; Waukwaas, solid lines and light blue points; steelhead, circles; coho, squares. The full response is not expected until 2001.

steelhead smolt yield on the Waukwaas River in 1998 were not sustained; levels fell to 1997 levels. Increases in Dolly Varden and cutthroat trout smolts were also recorded at the Keogh in the spring of 1999, for the first time in several years.

Habitat Structure Utilization

The average density of fish (no. per 100m²) from 1997 to 1999 for all structure sites and for each structure type were compared, including results for steelhead fry, steelhead parr, and coho fry. The range in mean density was broad among common structure types in 1999 (coho fry, 41 to 95 fry per 100m²; steelhead parr, 0 to 11 parr per 100m², e.g. Figure 4). This was in agreement with the overall range in values observed in 1998, which were an improvement over 1997 although fish response within each structure type was markedly different. For example, the greatest steelhead parr densities in 1999 were recorded in lateral debris jams (LDJ), versus root wads complexes (RW) in 1998 and A-Log structures (AL) in 1997. In 1999, steelhead fry, coho fry and steelhead parr densities in lateral debris

jams (LDJ, n=9), boulder clusters (BC, n=7), single log deflectors (SDL, n=6), double deflector logs (DDL, n=2), root wads (RW, n=4), and A-logs (n=3) were not significantly different (anova) in these five structure types. Possibly this was due to high variance among sites and low sample size. Examining results from all structures across all sample years, trends emerged. Steelhead fry were most abundant in double deflector logs, and boulder clusters, whilst steelhead parr favoured double deflector logs and lateral debris jams. Coho fry were most abundant in double deflector logs and lateral debris jams, although there was much variance within this data. In all cases, yearly and within reach (same year) variations in juvenile salmonid abundance suggested that no common structure type significantly outperformed any other.

Growth and Fertilization

Summer steelhead fry weights and lengths were significantly greater in the nutrient-enriched Keogh River than in the Waukwaas River (untreated) in 1999 (p<0.001, t-test for both weight and length). Similar results were observed in fertilizer-treated sections of the Keogh River in 1997 and 1998. Average weight of steelhead fry by autumn in the Keogh also exceeded that in the Waukwaas River, by over 50% (Figure 5).

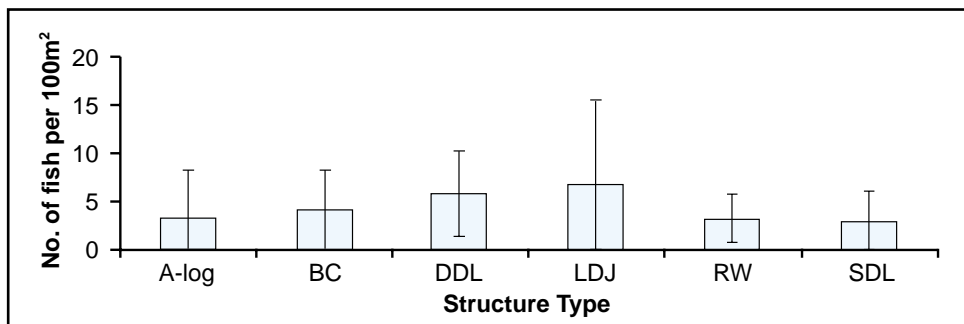


Figure 4. Average densities (+/- IS.D.) of steelhead parr in the Keogh River (1997 to 1999) in common habitat structure types: A-logs, boulder clusters (BC), double deflector logs (DDL), lateral debris jams (LDJ), root wads (RW) and single deflector logs (SDL).

Coho fry mean weights were on average 16% greater in the Keogh River in 1999 than in the untreated Waukwaas River. Despite this evidence

Integrated Watershed Restoration Projects

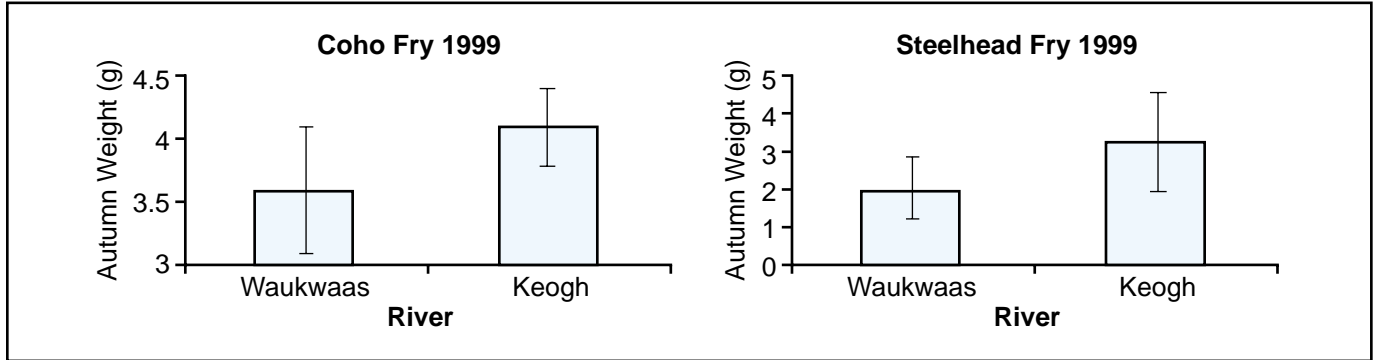


Figure 5. Weight (g) of coho salmon and steelhead trout fry (mean and standard deviation) by autumn in the Keogh and Waukwaas Rivers in 1999.

these data were not significantly different between rivers for either length or weight ($p > 0.05$, anova), due in part to large variance between the mean weights of fry in different reaches on both rivers. A pattern of decreasing size and weight was observed in autumn coho fry on the Keogh River with increasing distance up the river. This was likely a density dependent response (high density, lower mean weight).

Growth differences in steelhead parr were more difficult to interpret as several age classes comprised the population within any reach. The age class structure also varied by reach on the Keogh River in any sample year. This was a function of recruitment and the progressive treatment of nutrient addition through the watershed as well as the number of years in which resident parr may or may not have been exposed to improved nutrient conditions. Abundance, size and scale age data from Keogh River smolts in 1999 (first year of a response in age 2 smolts from nutrient addition which began in 1997 over the lower

half of the watershed) was used to examine the response to nutrient addition. These promising preliminary results indicated a numerical increase in smolt yield, an increased length-at-age (Figure 5), and decreased age at smolting. Initial results from whole-river nutrient addition on smolt yield are not expected until 2001.

Summary

Positive effects of treatments with nutrient addition, habitat structure introduction, off-channel habitat creation, and slope stabilization, all part of watershed restoration, were increasingly apparent from studies of juvenile salmonids in the Keogh River from 1997 to 1999. Results further indicated this positive response when compared to reference data collected in the untreated Waukwaas River. Results are summarized, for each key species:

steelhead response

- increased abundance and geographically wider distribution of steelhead fry within the watershed despite a continued low escapement of adults

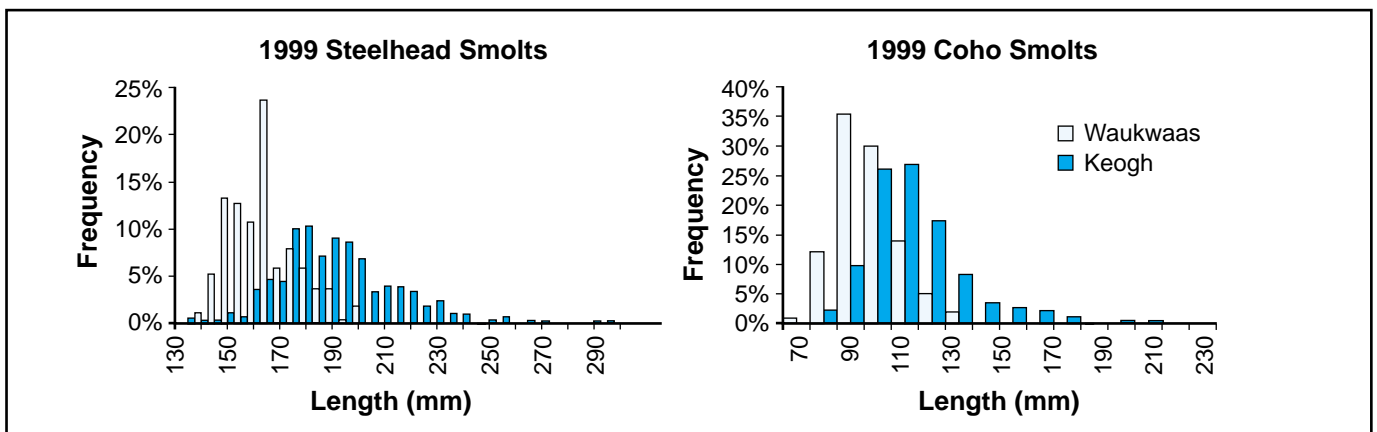


Figure 6. Steelhead trout and coho salmon smolt length frequency distribution in the Keogh (dark blue bars) and Waukwaas (light blue bars) rivers in 1999.

Integrated Watershed Restoration Projects

- enhanced fry abundance within reaches in relation to nutrient addition
- fry growth rates improved by 50% compared to the untreated neighbouring watershed
- substantially increased parr abundance (260% since treatment began)
- improved smolt yield (highest count since 1993)
- larger size-at-age of smolts, indicating improved growth rates of parr during their in-stream residence
- evidence of a positive relationship between the complexity of the habitat structure and an increased abundance of steelhead parr.

coho response

- since treatments started, highest fry abundance was in 1999
- improved smolt yield in 1999, to 70% of long-term average (despite low fry densities in 1998)
- increased growth of fry despite high densities (approx. 1 fry per m²)
- improved utilization of habitat by progeny of high adult escapement in 1998
- increased size-at-age of coho smolts
- evidence of a strong association of in-stream fry distribution with structure placement (particularly LWD)
- significant use of off-channel habitat developments, and in-stream structures during winter and summer.

other anecdotal observations

- increased size and abundance of (resident) cutthroat trout
- increased counts of cutthroat trout smolts
- increased Dolly Varden parr and smolt yield
- increased crayfish population size and distribution within the watershed.

Lessons Learned

Preliminary results to smolt yield indicate that habitat rehabilitation for juvenile salmonids in streams may partly counteract recent dramatic and persistent declines in survival observed in freshwater and marine life stages. Despite dangerously low levels of spawning escapement, fry and parr were found at high levels of abundance in treated areas, and at rates of growth and survival that surpassed that in the untreated stream.

Variations in structure performance indicated that a complex variety of habitat is required by all species of salmonids through the variety of environmental conditions they may experience in freshwater ecosystems. There may be danger of incorrect choice of habitat structure preference when the assessment of

structure effectiveness has been over too short a term of evaluation, and without investigation of the effects of flow, adult escapement, habitat change, and overwinter survival. Evaluation must take place over the longer term, and preferably be based on treatment and control results from the diversity of B.C. watersheds.

The addition of nutrients to the stream enhanced growth and survival of coho and steelhead juveniles, and resulted in increased smolt abundance, greater mean size and larger size-at-age. The results of whole-river nutrient addition are expected to be greater still.

Long-term monitoring is required to fully determine the restoration benefits. Further increases in juvenile abundance, smolt yield, and eventually, adult escapement are likely as the benefits of this WRP project unfold.

This positive recovery response is timely given the severe conditions for survival in the ocean that are now documented for steelhead and coho. A similar intensive effort at WRP in streams of the east coast of Vancouver Island and the Georgia Basin with stocks at risk should proceed immediately, while the work at Keogh continues to measure variation in response and the full benefits of treatments. ▲

The details included above are based on a compilation of three reports. The first (titled as above) was published in 1997 (BCWRP Technical Report Number 6), the second in 1998 (BCWRP Technical Report Number 12), and the third, based on 1999 results, is in preparation for publication. Thanks to Bruce Ward and Don McCubbing for updating this article with the most recent data in January 2000.

Please see the back page of Streamline for information on ordering Watershed Restoration Technical Reports from the Queen's Printers.

