Late Summer Distribution of Juvenile Coho Salmon In the Gates Creek Watershed

Project # 11.SON.01

Prepared for Lillooet Tribal Council
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Executive Summary

Approximately 4,600 juvenile coho salmon were caught in the Gates Creek watershed, between Gates Lake and Anderson Lake. Field work continued in 3 sections, during late May, mid-July and late September-October. This information was used to assess how juvenile coho use the Gates Creek watershed, especially with respect to habitats available in late summer and early autumn. This project was undertaken by the Lillooet Tribal Council, with the active partnership of the N'quatqua First Nation, and Fisheries and Oceans Canada.

Quantitative estimates of numbers of coho in the system were not attempted due to the minnow trapping technique and its inherent bias. The capture data was used to indicate presence and absence, size and condition of fish, and associated physical factors such as depth and temperature. Fish presence/absence was confirmed up by electrofishing, beach seining and pole seining where these techniques could be applied.

Most of the fish were caught by unbaited minnow traps. Of the 5,149 fish caught, 4,595 were juvenile coho. Other species were Dolly Varden, mountain whitefish, rainbow trout, redside shiner, prickly sculpin and an unknown species of sucker. In order to improve field safety and logistics, most of the minnow traps were not baited and tests were done to assess this effect. While minnow trapping improved catches for juvenile coho, the magnitude of this was not profound and was often overwhelmed by site-specific differences. It was evident that varying degrees of minnow trap success depended on bait, cover/space, inter- or intra-specific factors, etc. The results are qualified by the limitations of the technique.

Fish re-distributed downstream between July and October. Preferred habitats were sidechannel habitats at site 5P, most notably into agricultural drainage channels where these were available. Groundwater-fed ponds adjacent to the Anderson Lake foreshore were also important rearing habitats.

Mainstem temperatures were universally cold, indicating substantial groundwater inflows throughout the mainstem. Somewhat warmer temperatures may have attracted juvenile coho to flood plain areas near the Buffalo Farm conservation property. Depth may have been limiting later in the year, as minnow trap catches dropped off below 25 cm depth.

No coho were found in Gates Lake or its inflow tributaries, and there is no defined stream channel connection with the Poole Creek system to the west (Birkenhead drainage). The upstream limit of spawning coho appears to be downstream of the Gates Lake outlet. There may be a depth limitation associated with a reduced number of fish in September and October.

The Haylmore Creek watershed is accessible to anadromous fish for approximately 3 km, and juvenile coho were found in a sidechannel about 1.5 km upstream. However, the lower reaches have somewhat higher gradient, unstable channels and fish habitat is disrupted. Since there were no coho found near the Gates Creek confluence, it is assumed that there is a spawning area upstream below the falls, and the juveniles had

relocated down to the nearest refugia. Watershed assessment and landscape-level planning is required in this watershed.

Anderson Lake had substantial numbers of juvenile coho salmon present in certain areas, particularly in the groundwater-fed ponds south of the Gates Creek mouth. It is suspected that downstream-migrating coho reach Anderson Lake and disperse into different habitats, with an unknown survival factor. There is no local spawning area that could otherwise account for these juveniles.

The lower D'Arcy Creek watershed contains about 1.5 km of low-gradient stream habitat, of which 60% is not currently accessible to anadromous fish; 30% is partly accessible (re: partial barriers) and only 10% is freely accessible to spawning salmon. While there were 7 obstructions identified, most of these can be removed by re-routing the lower creek through a nearby wooded area, and by conducting some remedial work on the highways culverts.

Blackwater Creek is almost completely inaccessible to anadromous fish, although it has had some obstruction removal and fishway construction in previous years. Confounding factors are the possibility that this watershed has never been inhabited by anadromous fish. There has also been extensive river training and other modifications in the upstream reaches. It is proposed for stewardship activity while other initiatives develop.

Recommendations include:

- Further research on DNA profiling and survival of coho juveniles entering Anderson Lake, and quantification of coho juvenile output from the watershed;
- Developing partnerships with agricultural properties, conducting lakeshore mapping and active stewardship of the Blackwater Creek watershed;
- Emphasizing habitat management on unstable tributaries such as the Haylmore watershed;
- Biotechnical opportunities to restore fish habitats exist in several areas and could be further developed. Examples include in-stream structures in selected locations, fishway adjustments, fish passage improvements, groundwater pond complexing, lower D’Arcy Creek reconstruction, revegetation of the Buffalo Farm conservation property, and stabilization of lower Flood Creek.

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Background:

Historically, the Seton-Anderson-Gates watershed, in the central interior Fraser, supported sockeye, pink, coho and Chinook salmon populations. The construction of hydro dams in the 1950's created a number of effects that depressed these populations, and in the 1960's spawning channels were constructed at Seton Creek and Gates Creek. These facilities were designed to help rebuild sockeye and pink runs, which were the commercially important salmon species at the time. However, these spawning channels largely excluded chinook and coho salmon, and it is now recognized that further attention is needed to restore these populations (Anon. 2009).

B.C. Hydro's Bridge Coastal Restoration Program was initiated in 1999 and is intended to help restore fish and wildlife habitats that have been negatively affected by its power generation facilities. DFO has indicated that is places a high priority on the continued, successful operation of the Gates Creek spawning channel for sockeye salmon[1] (Northern St'at'imc Fisheries, 2008 and 2009). It has also recommended that a high priority be placed on improving fish passage for migrating salmon.

A high priority was also placed on protecting coho salmon and their habitat in the Gates watershed in the headwaters of the Seton-Anderson watershed, including:

- Focus on off-channel development to increase rearing and spawning capacity; and
- Feasibility studies to identify restoration opportunities in Gates Creek.

To this end, BCRP purchased two parcels of land which total approximately 233 acres. Both properties span the Gates Creek valley and provide a multitude of different habitats that include streamside, riparian, wetland and upland habitats. In 2003, other work was initiated to determine the feasibility of fish habitat restoration projects (Thevarge, 2004), in which the importance of off-channel habitats was identified and some riparian habitat protection was completed. It was also concluded that there was a need for a better knowledge of the late summer distribution of juvenile coho and more understanding of their habitat utilisation.

Objectives:

In 2011, the B.C. Hydro Fish and Wildlife Compensation Program awarded the Lillooet Tribal Council, in partnership with the N'Quatqua Indian Band and Fisheries and Oceans Canada, a grant to conduct several projects in the Gates Creek watershed. Among the deliverables is a report on the following:

> *Assess the distribution and abundance of late summer rearing coho fry in the Gates Creek watershed as part of a program to better understand this species' use of the watershed and identify restoration options.*

[1] http://www.bchydro.com/bcrp/about/docs/Bridge%20and%20Seton%20Agency%20Priorities.pdf

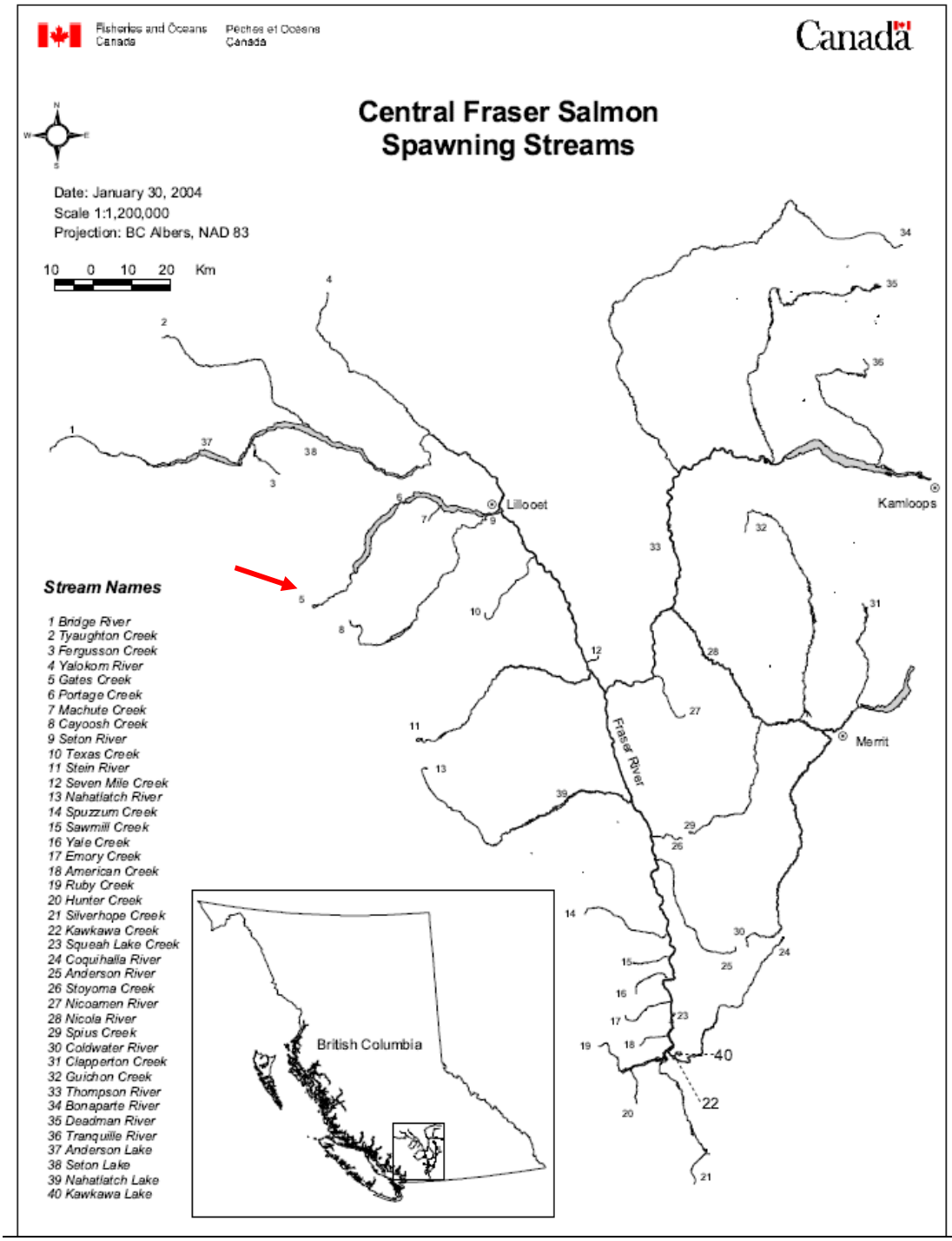


Figure 1. Location of Gates Creek within the central Fraser River.

To effectively use this information to direct restoration effort, this work must go beyond simply cataloguing fish distribution, and also begin to forecast mechanisms that affect distribution. Accordingly, more specific questions were asked:

1. What is the maximum distribution of juvenile coho, as measured during spring and summer high water events?
2. What is limiting their distribution in the spring and summer?
3. Can minnow trapping be used effectively to determine distribution of juvenile coho?
4. Where are coho found in the fall?
5. What might be the factors distributing coho in fall habitats?
6. Where and how should habitat restoration efforts be focussed?

Methods and Results

Program Structure

Approach

The field program began with the premise that coho distribution is patchy and that only a few reaches support a majority of the fish. To be efficient, field studies must quickly focus down to these locations and identify their attributes. Population monitoring should then occur at multiple sites that represent the range of conditions in those productive areas. Finally, it should be possible to identify sites with the potential for greater abundance based on their known habitat suitability (Pess et al, 2002).

Given the above, the work was restricted to subjective information on fish distribution rather than on quantitative estimates of coho abundance. Accordingly, due to their usefulness in a wide variety of habitats, we used simple minnow trapping as the main fish capture technique. In this way, we could identify consistently productive areas, and infer from the condition of the fish and relative catches how productive these sites are, why, and how that might change.

This project was not structured in a quantitative way (e.g. before/after control/impact "BACI" study) and over-analysis would be misleading. In this case, data analysis consists of "staring hard at good graphs" and using "process knowledge" to interpret these results (Johnson et al, 2005). A reach-by-reach discussion of fish distribution follows.

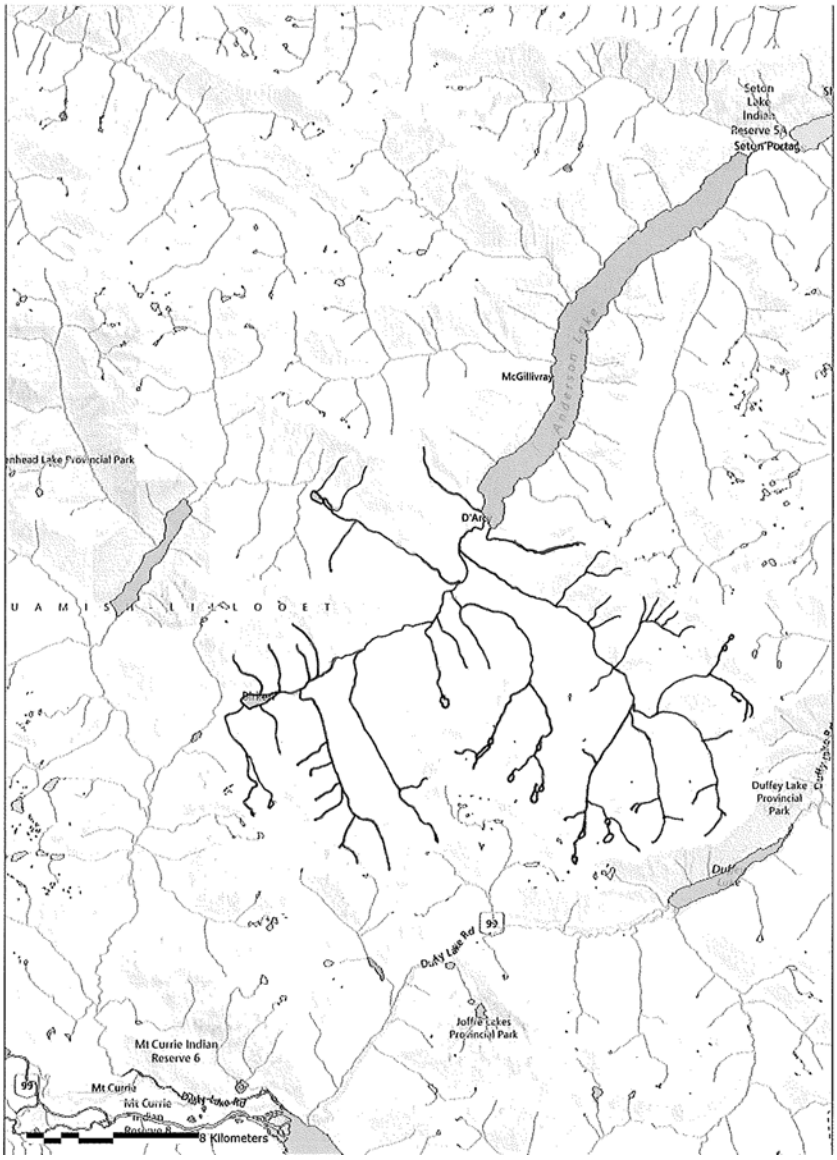


Figure 2. Gates Creek watershed study area.

Field Strategy

Field activities were focussed on three periods in 2011 when fish capture was undertaken throughout the watershed. The field activities changed throughout the season, depending on fish capture success and information gained. Figures 1 and 2 show location of the watershed, and Table 1 summarizes what was done, when, where and why.

Spring: Spring sampling continued from May 24th to June 10th, and focussed on minnow trapping and beach seining to establish the outside limits of juvenile coho migration within the Gates Creek watershed.

The field crew concentrated on locating and cataloguing effective trap sites, verifying fish distribution above and below barriers, identifying fish species, and weighing and measuring fish under field conditions. All together, 68 different minnow trap sites were identified, leading to some general conclusions about the extent of coho juvenile distribution during high water.

Summer: Summer sampling continued from July 4th to July 22nd and established a subset of 7 trap sites between Anderson Lake and Gates Lake that could be repetitively sampled for both fish populations and physical parameters. These sites are all successful trapping areas, are consistently accessible, scattered throughout the study area, and reflect a variety of different habitat types.

Mid-summer sampling had a larger field crew, so repetitive samples at these sites allowed us to establish good length-weight data that better describe fish populations. Furthermore, some ancillary testing was done that qualified minnow trap success (bait vs no bait), as well as physical data cataloguing water quality, depth, temperature, cover, and substrate.

Fall: Fall sampling continued from September 26th to October 14th and was again focussed on the 7 repetitive trap sites using established minnow trapping techniques, repeating length-weight measurements. The purpose of this was to establish whether or not there was a population shift to a new distribution, and whether or not this could be associated with measurable habitat parameters or fish condition.

Beach seining, pole seining, and electrofishing were also conducted in locations where these techniques were appropriate, in order to re-verify the likelihood of fish presence or absence in peripheral areas.

Table 1. Outline of field activities and objectives, how this relates to FWRP program objectives, and summary of the field information obtained.

Field Dates	Work Objective	**Program Objective**	Information Outcome
May 23 – 27	o Set minnow traps in local areas, recover and sample fish; o Beach seined Anderson Lake. Foreshore. o Review field techniques, set quality control standards; o Establish geographic scope of field work – review map, watershed delineation; o Establish support and management structure for field program.	o **Q: What is the maximum distribution of juvenile coho in the Gates Creek watershed?** o **Q: Is minnow trapping a suitable technique for this objective?**	o 45 minnow trap sites accessed. o 591 juvenile coho captured by minnow trapping o Other species of fish captured include Dolly Varden, mountain whitefish, sockeye, rainbow trout, prickly sculpin and sucker species; o 719 fish length sampled. o 20 juvenile coho captured by beach seining – lake foreshore is coho habitat.
May 30 – June 10	o Set minnow traps throughout watershed, recover and sample fish. o Communication established re: location identifiers, quality control of data. o Beach seining in Anderson Lake foreshore.		
July 4 - 8	o Set minnow traps throughout watershed, recover and sample fish; o Determined GPS coordinates for all watershed sample sites, depth and temperature measurements; o Establish strategy for comparative sampling, document site characteristics; o Inspected Haylmore Creek watershed;	o **Q: Where are coho found in the summer?**	o Expanded minnow trapping to 23 additional sites, mapped all 68 sites, captured 433 fish (50% coho). o Focussed on 7 repetitive sites, from Gates Lk outlet to Anderson Lake. Mix of Gates mainstem, sidechannels, lake foreshore.groundwater ponds.

July 11 - 15	o Concentrated minnow trapping on 7 repetitive sites, recover and sample fish; o Conduct bait/no bait evaluation on minnow trap effectiveness; o Inspected Blackwater Creek watershed; o Conducted preliminary information on culvert sites that are potentially blocking fish passage; o Gathered temperature, depth, bio-physical information on each permanent site.	o **Q: What is limiting their distribution in the spring and summer?**	o Minnow trap captures in July total 2,692 fish (90% coho). o Sampled 8 seine sites, notably Anderson Lake foreshore, and BFC property at R3. Captured 1,486 fish (25% coho), 3 salmonid species, 4 non-salmonid species. o Inspected 12 stream crossing sites re: potential for limiting fish distribution.
July 18 - 22	o Concentrated minnow trapping on 7 permanent sites, recover and sample fish; o Inspected Gates Lake foreshore: beach seining, minnow trapping, culvert inspections; o Conducted pole seining in 2 permanent sites, and beach seining at Anderson Lake.	o **Q: What biases might minnow trapping introduce to the data?** o **Q: Do coho salmon inhabit Gates Lake?**	o Bait affects minnow trap success, but not substantially. Traps are more effective for coho than other species. o Depth, temperature data recorded, also habitat parameters for individual traps. o Coho not found in Gates Lake, no channel connection to western watershed. No further work in this reach.
September 26 - 30	o Concentrated minnow trapping on 7 repetitive sites, recover and sample fish.	o **Q: Has the coho population re-distributed since summer?**	o 1,614 fish caught in 7 sites, 98% coho. o Coho have redistributed downstream - fall populations are more concentrated in downstream sites.

	o Gathered water quality data in selected locations.	o **Q: Are there physical factors that correlate with fish re-distribution?**	o Some sites have very different water chemistry, indicating a different water source. o Distribution is not associated with temperature, but it is with depth.
September 30 – October 13	o Conducted stream surveys on D'Arcy Creek, Haylmore Creek and 7-mile Creek. o Electrofished in 8 locations where other capture techniques were inappropriate, and no spawning was evident.	o **Q: Do fish inhabit Gates Creek tributaries?** o **Q: Is fish distribution confirmed by using a different capture method?**	o Coho fry distributed to man-made barriers on D'Arcy Creek, 7-Mile Creek, Spruce Creek and to a natural falls on Haylmore Creek (~ 3km). o Fish absence confirmed in upper D'Arcy Creek and lower Haylmore.

Overview of Field Methods:

- *Minnow Trapping:* An effort was made to identify for each fish date captured, soak time, location, water depth and temperature, species identification, fork length, wet weight and if necessary life stage (Figure 3). For logistical reasons, especially early in the season, length-weight measurements were not always taken. Where there were large numbers of coho, only fork lengths were measured (35% of the coho) and corresponding weights were generated by using a polynomial trend line equation.

Figure 3. Fish handling and sampling gear used in the field.

- *Field location:* All locations where field work was conducted were verified on three levels: by GPS unit location coordinates, by map annotation (1:20,000 scale) and by field site visits. For report purposes, fish distribution is annotated on satellite imagery.
- *Physical habitat measurements:* Water quality measurements were recorded using a Hanna multiparameter meter, flow measurements with a Swoffer 3000 current meter, depth with a meter stick, and temperature with a hand-held thermometer.
- *Secondary Fish Capture:* To verify fish presence or absence in areas that were not conducive to minnow trapping, seining was conducted (beach and pole seines) in some areas, and electrofishing in others.

Minnow Trap Results

Trap Site Locations

Figure 4 shows the locations of 68 minnow trap sites that were accessed by the field crew during May and July 2011. This distribution represents the limit of accessible stream area where coho juveniles can access, and where minnow trapping could be used to capture them. All the sites were confined to a narrow corridor in and adjacent to the mainstem, with some trapping in the lower reaches of two tributaries (Haylmore and Blackwater Creeks). The 7 permanent sites were selected for their abundant, consistent coho catches, field accessibility, and representation of different habitat types.

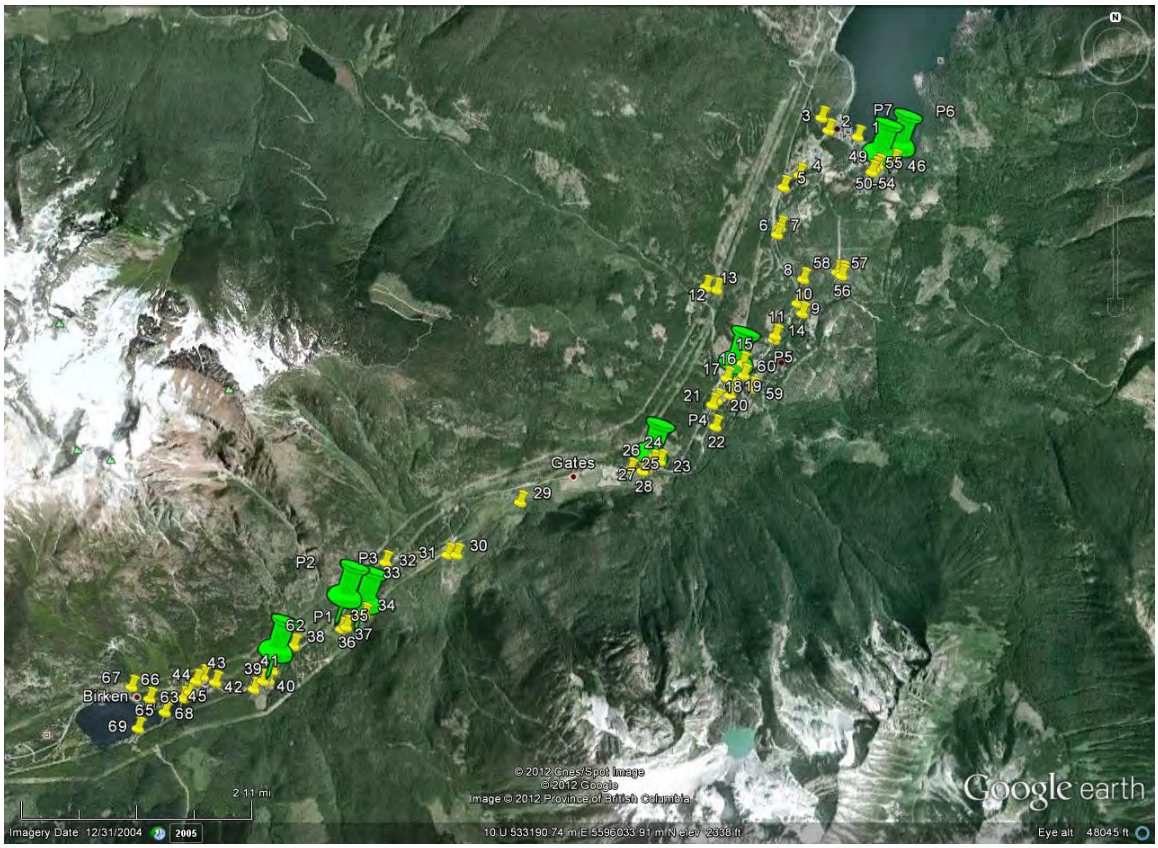


Figure 4. Overview of preliminary trap sites (yellow) and permanent, repetitive trap sites (green) in the Gates Creek watershed.

Total Numbers Caught

Table 2 summarizes the entire minnow trap catch in the program. The data indicate that there were at least 7 fish species recovered. Fish capture success increased in summer and fall trapping, as a consequence of field efforts becoming focussed on areas that were productive for juvenile coho. In this study, nearly 4,600 juvenile coho were captured by minnow trapping alone. Of this total, over half had length measurements recorded, and one third had both their lengths and weights recorded.

Table 2. Summary of all fish caught and sampled by minnow trapping in the 2011 program.

Pick Up Date	Total Number of Fish Caught	Coho	Dolly Varden	Mtn Whitefish	Rainbow	Redside Shiner	Sculpin species	Sucker species
24-May-11	24	20	0	0	2	0	2	0
26-May-11	24	15	2	0	7	0	0	0
31-May-11	14	4	2	0	8	0	0	0
02-Jun-11	105	76	14	0	15	0	0	0
07-Jun-11	67	51	15	0	1	0	0	0
09-Jun-11	96	40	3	22	22	0	7	2
05-Jul-11	219	214	0	0	0	0	5	0
07-Jul-11	184	0	4	0	11	169	32	0
12-Jul-11	275	240	9	0	21	1	4	0
13-Jul-11	267	217	5	0	9	0	2	0
14-Jul-11	594	545	22	0	16	0	11	0
15-Jul-11	400	385	7	0	6	0	2	0
19-Jul-11	1,161	1,117	21	0	15	0	4	0
27-Sep-11	799	783	7	0	2	0	6	1
28-Sep-11	516	503	6	0	3	0	3	1
12-Oct-11	401	385	7	0	8	0	1	0
Total Catch	**5,149**	**4,595**	**118**	**22**	**147**	**170**	**79**	**4**
Number length only sampled	2,822	2,576	76	22	89	0	56	3
Number length-weight sampled	1,491	1,389	37	0	46	0	19	0

Minnow Trap Efficiency

Bait effectiveness: Minnow trapping was conducted without using bait, contrary to established techniques. The decision to eliminate bait was made in order to reduce the bear hazard, improve the logistics required given the large numbers of fish being handled, and to improve overall standardization of the technique. To verify the effect of this strategy, special tests were conducted in July, comparing catch from baited (Gates sockeye roe) and non-baited traps:

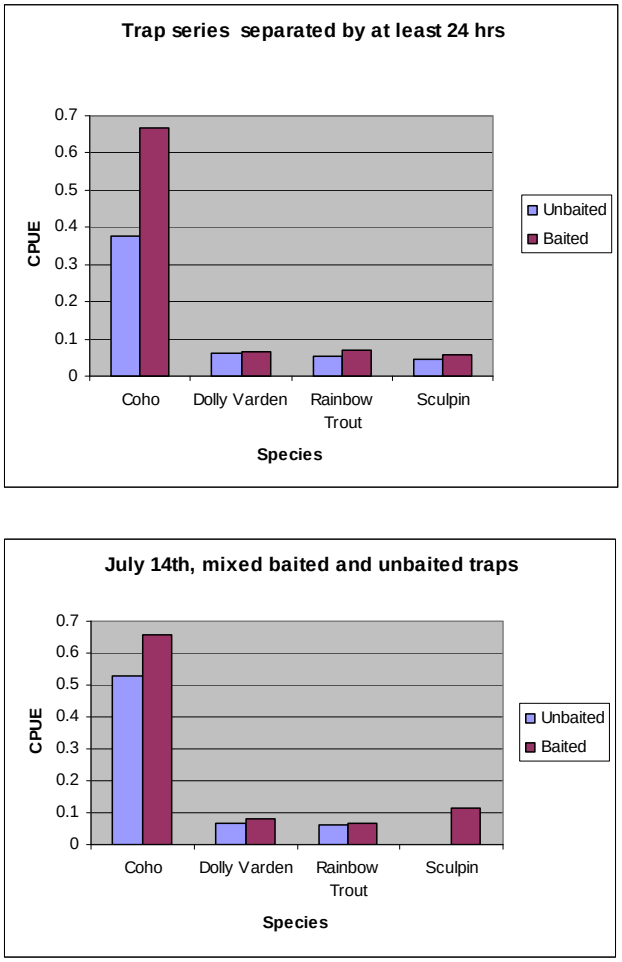


Figure 5. Catch efficiency expressed in catch per unit effort (CPUE), showing relative efficiency of baited and unbaited minnow traps.

The data indicate that while juvenile coho are attracted into minnow traps in sufficient numbers to attempt a sampling program, adding bait to the trap generally improves capture success. This is more pronounced for juvenile coho than for the other species.

Site-to-site Variation: During the field program it was also noted that there are differences between sites in terms of trap efficiency. To explore this, the data below are standardized to reflect only the trap sites during July when bait trials were being conducted. Since the sites were originally elected for their diversity, it is not surprising that some other factor sometimes overwhelms the bait effect. Where coho are concerned, adding bait to site 1P created 3 times the trap efficiency, while site 6P became actually less efficient. Minnow trapping success is not productive enough for the other species to make statements about their site-specific behaviours.

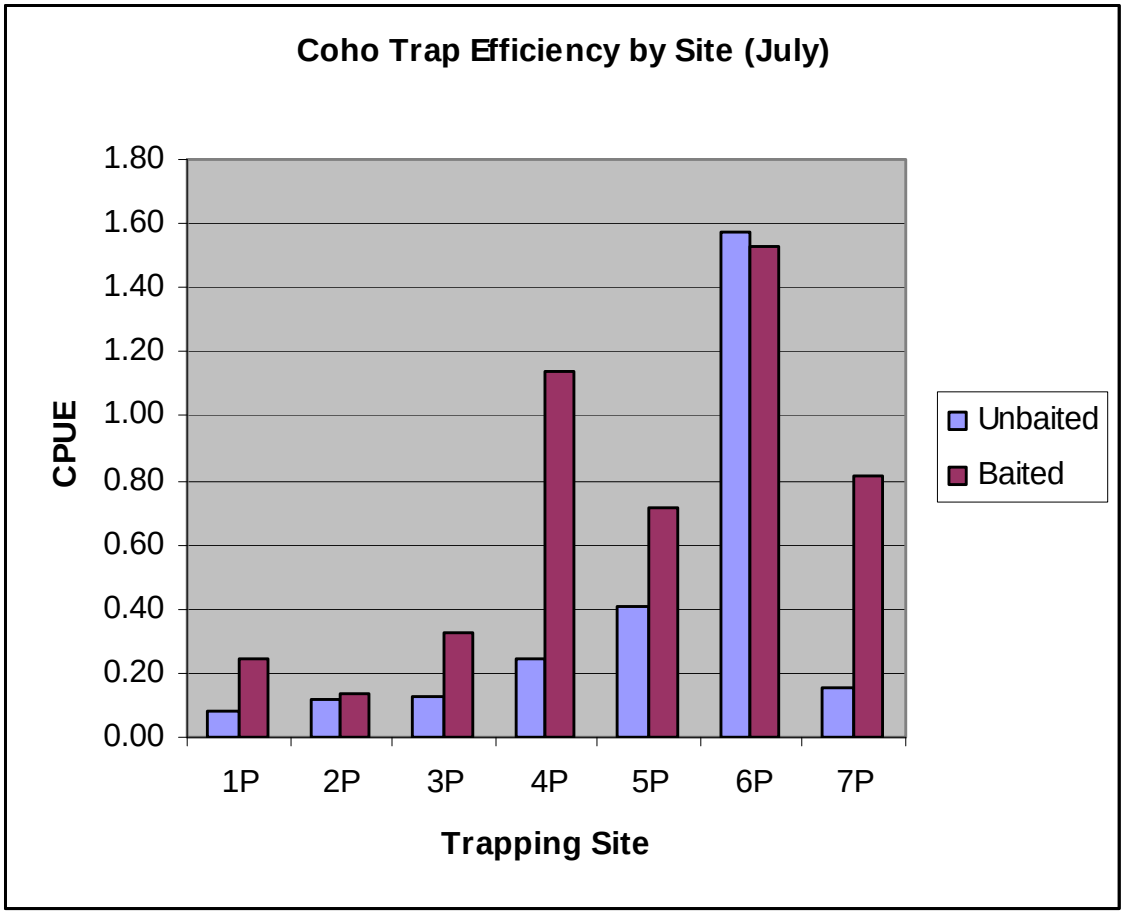


Figure 6. Catch efficiency expressed in catch per unit effort (CPUE), showing site-specific differences between baited and unbaited minnow traps.

Size Selection: The same time and area filters were used to compare the weights of fish caught in minnow traps to determine if there was size selection occurring when bait was present. The following data show that there are average size differences of +/- 30% between baited and unbaited traps at the same site. This warrants a more extensive data treatment as it indicates that there is probably some behavioural selection going on that is not directly related to bait (Table 3).

Table 3. Summary of weight differences between coho catches in baited and unbaited traps.

	Coho Wet Weight (g)		Weight Difference	
Site	Unbaited	Baited	Weight (g)	%
P1	1.70	1.93	0.22	13%
P2	2.74	3.67	0.93	34%
P3	4.42	3.05	-1.37	-31%
P4	2.09	2.17	0.09	4%
P5	1.81	1.70	-0.10	-6%
P6	2.19	2.71	0.52	24%
P7	2.53	2.50	-0.03	-1%

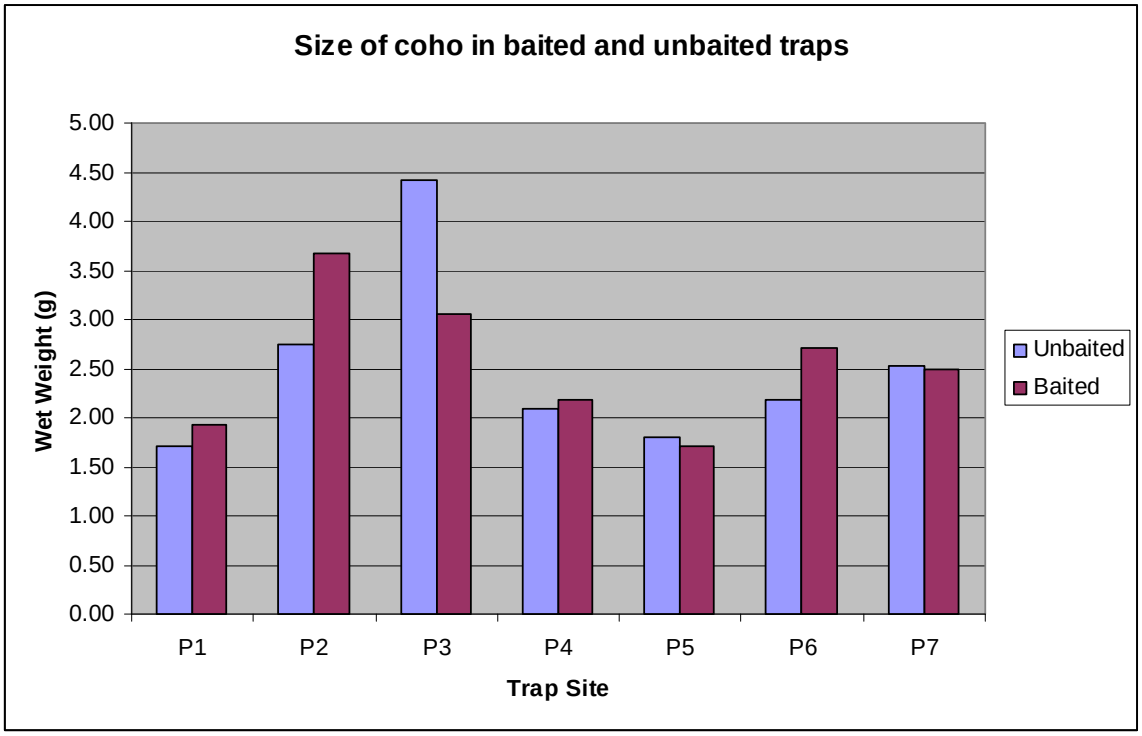


Figure 7. Average wet weights of juvenile coho, showing site-specific differences between baited and unbaited minnow traps.

Summary: This data set raises further questions that are not addressed within the scope of the current project. The current minnow trap data should be qualified:

- Unbaited minnow traps are productive enough to indicate presence and absence of coho, but possibly not for some other species;
- Variation in site-to-site trap efficiency and erratic size selectivity are indicators that the influence of bait in the traps can be overwhelmed by other factors (e.g. cover/space, inter or intra-specific factors, etc.);

- Minnow trapping is primarily a qualitative technique: total population size should be derived using a different method.

Beach and Pole Seining

Figure 8. Overview of beach and pole seine sites in Gates Creek, May and July, 2011.

Anderson Lake Foreshore:

Beach seining was focussed on the Anderson Lake foreshore to determine if there was a significant presence of juvenile coho in the vicinity of the mouth of Gates Creek. While seining success was erratic, it was evident that the dominant species was sculpin, followed by much smaller numbers of juvenile coho and some sockeye. What we were observing were newly-hatched sculpin fry, consistent with their spawning habitat requirements in lower Gates Creek (larger, rocky substrate, flowing water) and time of spawning (spring-summer). It is also important to note that there must have been some downstream movement of juveniles from Gates Creek or D'Arcy Creek that contributed to the juvenile coho population, as there are no other known spawning areas that could account for these fish.

Table 4. Summary of beach seine catches along Anderson Lake foreshore in 2011.

	May	July
Sockeye	10 fry	4 fry
Coho	14 fry, 6 smolts	314 fry
Sculpin	490 fry and juveniles, 1 adult	577 fry and juveniles, 5 adults

There are too many variables to use the data from the seine catches for anything other than a general indicator of presence/absence, and CPUE referencing was not attempted. Further information on the fate of juvenile coho that enter Anderson Lake, the impact of the large sculpin population, and seasonal hydrologic changes are beyond this scope of this study.

Gates Lake Foreshore and Tributaries:

Minnow trapping recovered large numbers of redside shiners in Gates Lake and its tributaries; however, there was no evidence of juvenile coho. Beach seining in July was limited by poor and unproductive sites, and no fish were recovered. Since there are no known spawning areas upstream of the Gates Lake outlet, no further investigation was done.

Buffalo Farm Conservation Property:

Due to the site characteristics, a 5m x 2m pole seine was used to provide an alternative view of the aquatic biota that may be present. While the dominant species was juvenile coho, it was evident that minnow trapping alone may be underestimating the biodiversity at this site, as evidenced by the whitefish and amphibians that were recovered.

	July
Coho	23 fry
Whitefish	1 fry
Amphibians	2 salamander (unknown species)

Electrofishing

Electrofishing presented limited opportunities for fish capture due to high flows in most of the mainstem locations, as well as the presence of fall spawning species which required avoidance. Essentially, electrofishing confirmed the fish distribution established by minnow trapping and did not yield new information.

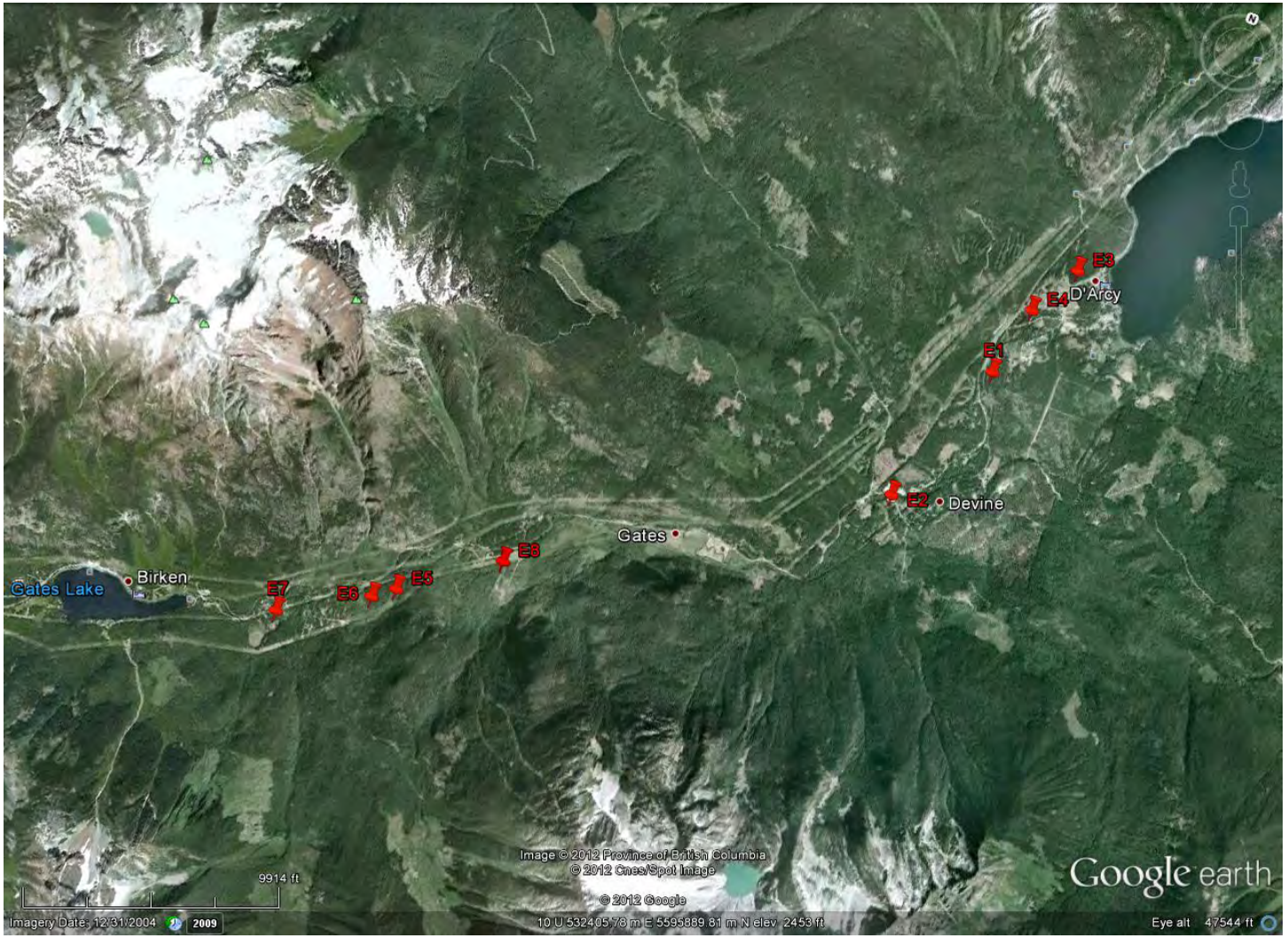


Figure 9. Overview of electrofishing sites in Gates Creek, October, 2011.

Table 5. Summary of electrofishing results in Gates Creek Watershed.

Site	E1	E2	E3	E4	E5	E6	E7	E8
Date	October 5, 2011	October 5, 2011	October 6, 2011	October 6, 2011	October 6, 2011	October 6, 2011	October 6, 2011	October 13, 2011
Description	Lower Haylmore Creek, stable sidechannel on right bank	Lower Spruce Creek, stable sidechannel near residence	Above culvert DC1	Above and below concrete sill on river left, Gates Creek	Side channel of Gates Creek, at permanent site 3P.	Bottom of Flood Creek, corresponds to site 2P, side channel to Gates Creek.	Downstream of Gimse's farm, permanent site 1P. Mainstem of Gates Creek.	Confluence of 7 Mile Creek and Gates Creek.
Reach	Haylmore R1	Gates R2	D'Arcy R4	Gates R1	Gates R4	Gates R4	Gates R5	Gates R3
Voltage	300	300	300	200	200	200	200	200
Settings	I-4	I-4	I-4	I-4	I-4	I-4	I-4	I-4
Seconds	202	203	200	201 (below) 203 (above)	200	203	204	212
Northing Easting	0536096 5598626	0535529 5596604	0536603 5600221	0536301 5599551	0529960 5593069	0529780 5592939	0528725 5592301	0531135 5593948
Catch	2 Dolly Varden 4 escapees	3 Dolly Varden 1 Rainbow 1 Dolly Varden adult 3 escapees	4 Rainbow 3 escapees	5 Rainbow below 2 Coho above 2 Rainbow above	4 Coho 1 Dolly Varden	10 Coho	2 Coho 3 Rainbow	2 Coho 1 Rainbow 1 large escapee
Comments		Man made structure with shale boulders.			Low water, low flows. Sidechannel inflow through cut bank with visible fry.	Lots of cut banks and woody debris. Lots of places for fry to hide.	Low water condition.	Access through Thompson residence. Small creek, pool habitats.

Culvert Inspections:

In this study, DFO's preliminary information protocol was used to determine whether or not removal, re-design or alteration of the structure might improve fish passage enough to warrant the retrofitting cost. To this end, 17 different sites were examined to determine whether or not stream crossing structures were likely to restrict fish distribution. Table 6 indicates that, with one exception, fish migration was likely not affected by high drops at the outlets of the culverts. Appendix 1 outlines the culvert inspection results in more detail.

However, when migration barriers are considered more holistically, there are other areas of concern. In particular, 5 obstructions in the lower 600m of D'Arcy Creek (Culverts D-1a to D4) collectively prohibit upstream fish access to at least 2 species of anadromous salmon (coho and pink) and likely also fragment populations of rainbow trout and Dolly Varden char. Restoring fish access by re-routing the stream channel to the south would allow anadromous fish access to about 1.5 km of limited and stable stream habitat.

Figure 10. Locations of culverts surveyed in 2011.

Some streams have significant bedload movement and present problems for stream crossing structures. For instance, Falls Creek, flowing beneath both Portage Road (bridge) and the CN Rail line (twin culverts GCT-1) has had disruption to fish and

aquatic habitats downstream of the transportation corridor. The issue is not fish passage but the negative impacts of the unstable hydraulic conditions associated with the culverts.

Fish stranding behind the C Rail line adjacent to the Buffalo Farm Conservation property (GCT – 3,4,5) is a concern, when fish migrate into habitats across the flood plain during high water, and then have the potential to become stranded as water levels drop in late summer and early fall. This effect is not unique to culverts, and is a feature of flood plain fragmentation.

Water Quality

In late September three locations were checked to determine whether or not water quality may be limiting fish distribution (Table 7). The measured values indicate that lethal limits were not approached, and that fish would not even have been avoiding these areas. However, it does indicate that there is considerable variation in water chemistry, particularly across the Gates Creek flood plain: this has other effects on freshwater ecology.

Figure 11. Locations of measured water quality sites in Gates Creek habitats, September, 2011.

Table 6. Summary of preliminary information for further fish passage review: Gates Creek watershed culverts, 2011.

Culvert	Location	Type of pipe	Diameter	Length	O/L drop	Freeboard	Fish[2]	Partners
D-1a	Eastkan Rd	Concrete box	1-2.5m	10-25m	None	.85m	CO, RBT, DV/BT, PK sculpin	Private property
D-1	Eastkan Rd	Twin Round CMPs	< 1m	< 10m	None	.85m	CO, RBT, DV/BT, PK sculpin	Private property
D-2	Kootcha-Eastkan Rds	Round CMP	< 1m	10-25m	None	.4m	CO, RBT, DV/BT, PK sculpin	Ownership not clear
D-3	Eastkan Rd	Round CMP	< 1m	10-25m	None	.41m	CO, RBT, DV/BT, PK sculpin	N'Quatqua Band
D-4	Portage Road and CN Rail	Twin Round CMPs	< 1m	> 25m	None	.615m	CO, RBT, DV/BT, PK sculpin	Ownership not clear
D-5	Off Seton Portage Rd.	Round CMP	1-2.5m	< 10m	None	.85m	RBT, DV/BT	N'Quatqua Band
D-6	Off Seton Portage Rd.	Twin Round CMPs	< 1m 1-2.5m	10-25m	None	.68m .78m	RBT, DV/BT	N'Quatqua Band
D-7	Off Seton Portage Rd.	Round CMP	< 1m	< 10m	None	.175m	No fish present	N'Quatqua Band
BW-1	Portage Rd.							
BW-2	Off Blackwater Rd	Round CMP	1-2.5m	< 10m	None	.6-.8m	RBT, DV/BT	
BW-3	Off Blackwater Rd							
GCT-3	CN Rail at NCC	Round CMP	< 1m	< 10m	None	.5-1m (crushed)	CO	CN Rail
GCT-4	CN Rail at NCC	Round CMP	< 1m	< 10m	None	< .5m (crushed)	CO	CN Rail
GCT-5	CN Rail at NCC	Round CMP	< 1m	< 10m	None	.2m pool	CO	CN Rail
GCT-1	Falls Creek	Twin Round CMPs	1-2.5m	10-25m	None	1.45m	CO, RBT	CN Rail
GCT-2	King Creek	Round CMP	< 1m	10-25m	None	.37m	Unknown	MOTH
GC-1	Gates Lake Lk.	Open Bottom CMP	> 2.5m	10-25m	None	> 1m	CO, RBT, DV/BT, others	MOTH
GL-1	Gates Lake Rd.	Twin Round CMPs	< 1m	< 10m	None	.39m	Other	Private property
GL-2	West side Gates Lk.	Round CMP	< 1m	< 10m	None	Almost dewatered	RBT, others	Private property
GL-3	Whispering Falls Cr.	Twin Round CMPs	1-2.5m	10-25m	2m	.8m	RBT, needs survey	MOTH
GL-4	Gates Lake Rd.	Round CMP	< 1m	10-25m	.75m	.3m	RBT, needs survey	MOTH

[2] CO = coho salmon, RBT = rainbow trout, DV/BT = Dolly Varden char or bull trout, PK = pink salmon, sculpin = unidentified species of sculpin.

Table 7. Summary of measured water quality parameters in selected Gates Creek habitats in September, 2011.

Site	Ward #1a	Ward #1b	Ward #1c	Menzel 2a	Menzel 2b	Menzel 2c	Menzel 2d	Ralph 3a	Ralph 3b
Date	September 29, 2011	September 29, 2011	September 29, 2011	September 29, 2011	September 29, 2011	September 29, 2011	September 29, 2011	September 29, 2011	September 29, 2011
DO (% saturation)	41.2	41.2	97.9	47.8	66.6	40.1	4.67	86.2	91.3
DO (mg/l)	4.60	4.54	10.90	4.99	7.12	4.43	5.00	9.82	10.36
pH	7.66	7.86	8.63	7.08	6.89	6.33	6.75	8.05	7.73
Temperature (oC)	7.82	8.78	8.39	11.29	10.16	8.37	9.87	7.93	8.18
Conductivity[3] (ms/cm)	430	554	369	59	69	54	49	305	313
Total Dissolved Solids (ppm)	214	277	184	30	34	27	25	153	157
Salinity (ppt)	0.21	0.27	0.18	0.03	0.03	0.02	0.02	0.15	0.15
Area (m)	20 x 10	5 x 10	45 x 5	2 x 6	3 x 2	6 x 4	25 x 12	80 x 30	10 x 10
Depth (m)	.955	.45	1.49	.495	.278	1.15	.94	1.16	.62
Vegetation	Emergent veg, algae, surrounded by *typha latifolia* and alder	Emergent veg, algae, surrounded by *typha latifolia*, sedge and alders	Grass	Grass	Grass	Grass	Grass	Grass/alder	Grass
Easting/ Northing	5594928 0531882	5594932 0531861	5594954 0532126	5595151 0533877	5595205 0534092	5595205 0534092	5595175 0534004	5599733 0537694	5599733 0537694

[3] Microsiemens per centimetre.

Discussion

Lengthy high flows at a time when rearing juvenile coho are present may create an inhospitable mainstem environment where fish re-located into off-channel habitats and any areas where velocities are reduced. Assembling spatial information to refine our knowledge of this movement into fall habitats is the subject of this field work. To this end, it is appropriate to focus on two behaviours that juvenile coho salmon commonly exhibit (Sandercock, 1991):

1. Juvenile coho prefer pools. Young fry hold in mainstem and marginal pools, slack backwater areas, and migrate into quiet off-channel habitats such as groundwater ponds and tributary mouths. This species is also associated with beaver dams.
2. They set up territories and have competitive interactions that cause the downstream emigration of some individuals, with high mortality. Coho production is linked to the territories available during critical rearing periods, such as summer droughts.

Both of these behaviours occur in the Gates Creek coho population, although summer drought conditions are not apparent. To look at this further, the discussion has been split first into mainstem and off-channel fish distribution, and second as a reach-by-reach outline of accessible habitats.

Mainstem Fish Distribution

Seasonal Re-distribution: Juvenile coho are redistributing downstream as the season progresses. The data has been standardized so that 50 minnow traps all have no bait, identical trap sites, and the same effort. Figure 4 shows that there are generally more coho in the downstream sites, and this becomes exaggerated as the season progresses, reflecting some concentration of individuals within shrinking habitats. Note that site 1P is at the upstream end of the mainstem near the Gates Lake outlet, and site 5P is further downstream near the creek mouth at Anderson Lake. Site 6P and 7P have been omitted as they are outside the Gates Creek mainstem.

As noted above, coho salmon have a distinct territorial behaviour: they distribute themselves throughout a stream, perhaps orienting to a rock or log to obtain a small space of slack water. Once territories are established they remain in the same area for relatively long periods and aggressively defend their positions. As the season progresses, fish grow and conditions change, some fish are forced downstream and experience disproportionate mortality. In the graph below, the concentrations of fish in the downstream habitats reflect changing stream conditions that are apparently forcing some fish out.

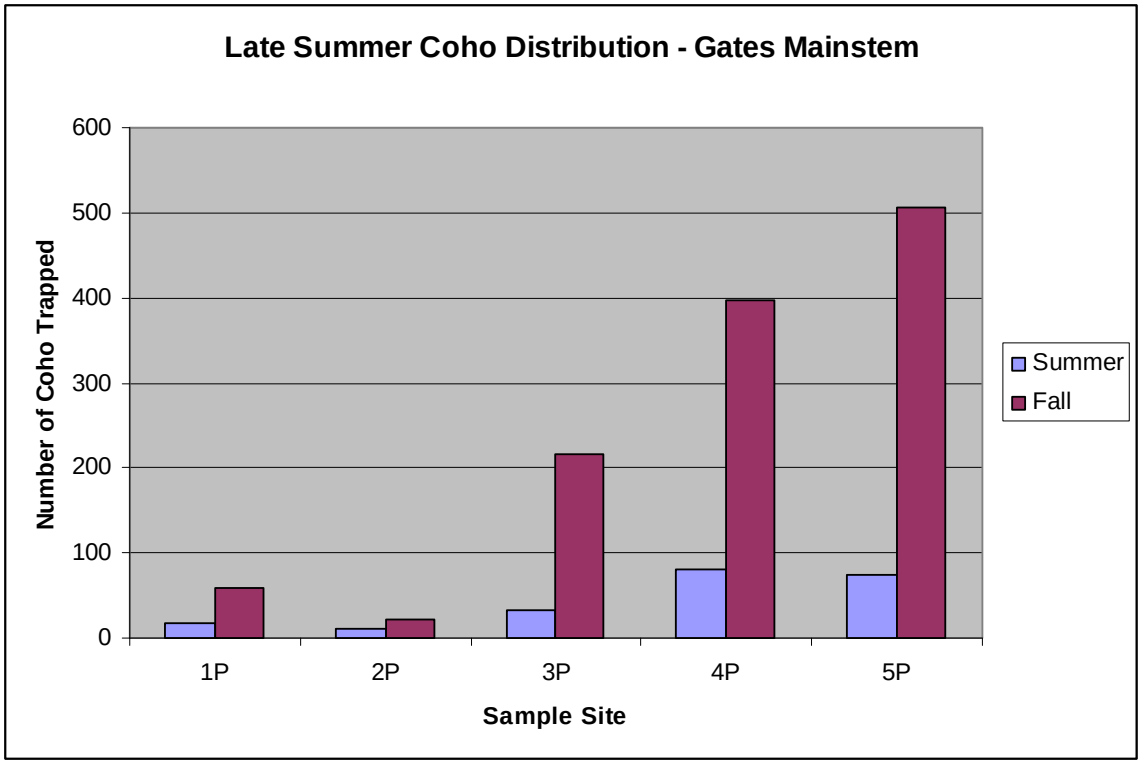


Figure 12. Seasonal distribution of juvenile coho between 5 mainstem sample sites.

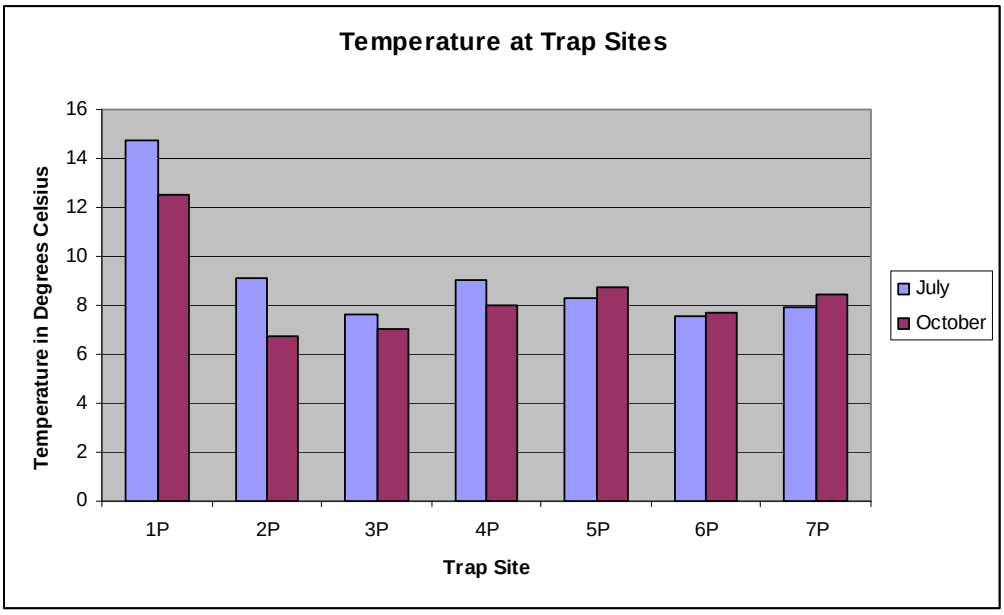
Depth and Temperature Effects: Mainstem water temperature did not exhibit much seasonal change, and none of the temperatures recorded would be likely to induce juvenile coho to avoid some areas. Constant temperatures at sites 6P and 7P indicated groundwater sources in ponds adjacent to Anderson Lake. As expected, warmer water was evident at site 1P (Gates Lake outlet), although less than 1 km downstream the water is 5^{o}C cooler. This cool, stable temperature profile can indicate groundwater influence and in this case it seems prevalent during the growing season (Figure 13).

Generally, rearing coho salmon prefer water temperatures in the 12 – 14^{o}C range. They are beginning to avoid certain areas at about 18^{o}C, and encounter lethal limits at 25^{o}C. Conversely, they usually survive very low temperatures providing the tissues do not actually freeze. At these mainstem temperatures in summer and fall, we expect that fish would be actively seeking warmer areas (Sandercock, 1991).

While mainstem temperature did not vary, water depth did. The data shows that where water depth at the trapping site was less than 25 cm, coho catch efficiency dropped off sharply. This threshold may have had an effect near the Gates Lake outlet, where depths became quite shallow in October. Since trap sites were chosen at least in part for their accessibility, there is insufficient data to make the same statement at the upper end of the depth scale.

Rearing coho prefer shallow water pool areas, including back eddies, log jams, undercut banks, sidechannels, etc. They are not selecting for a preferred water depth per se, they

are searching for suitable territories. In this case, water depth is reflected as an index of available habitat.



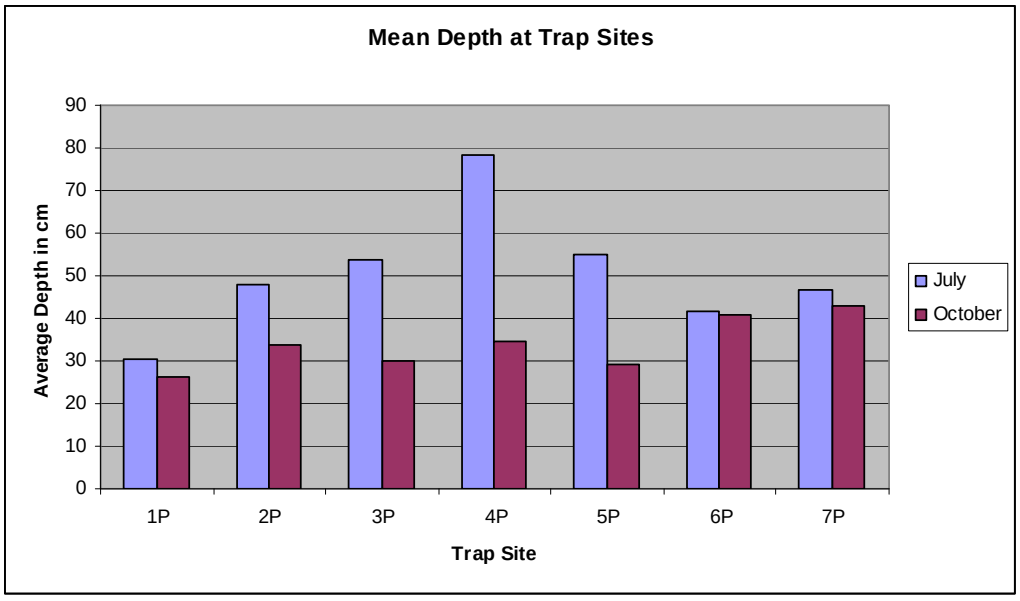
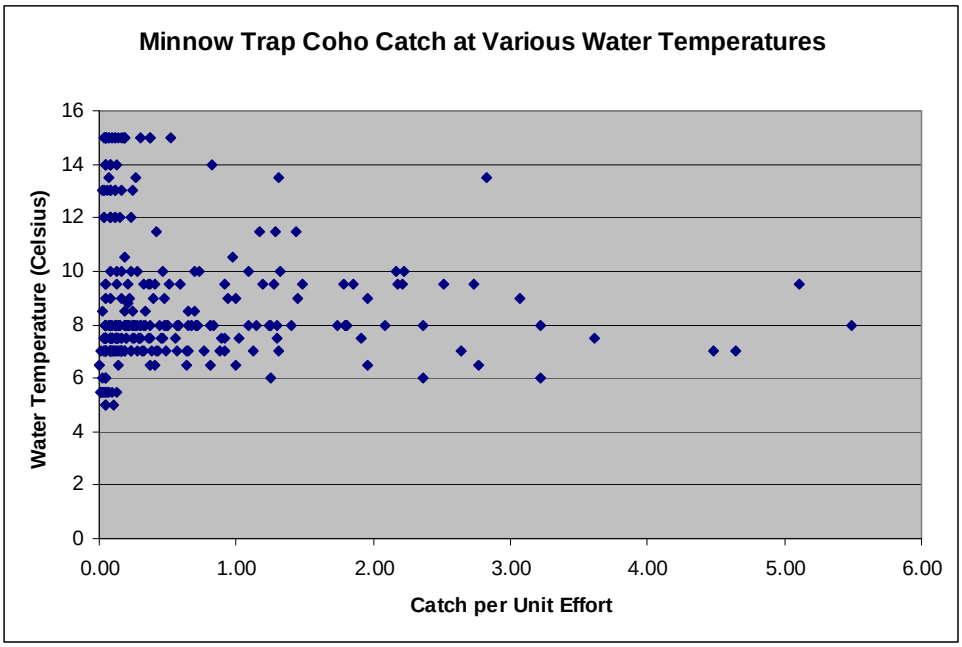


Figure 13. Change in average water temperature and water depth at the trap sites



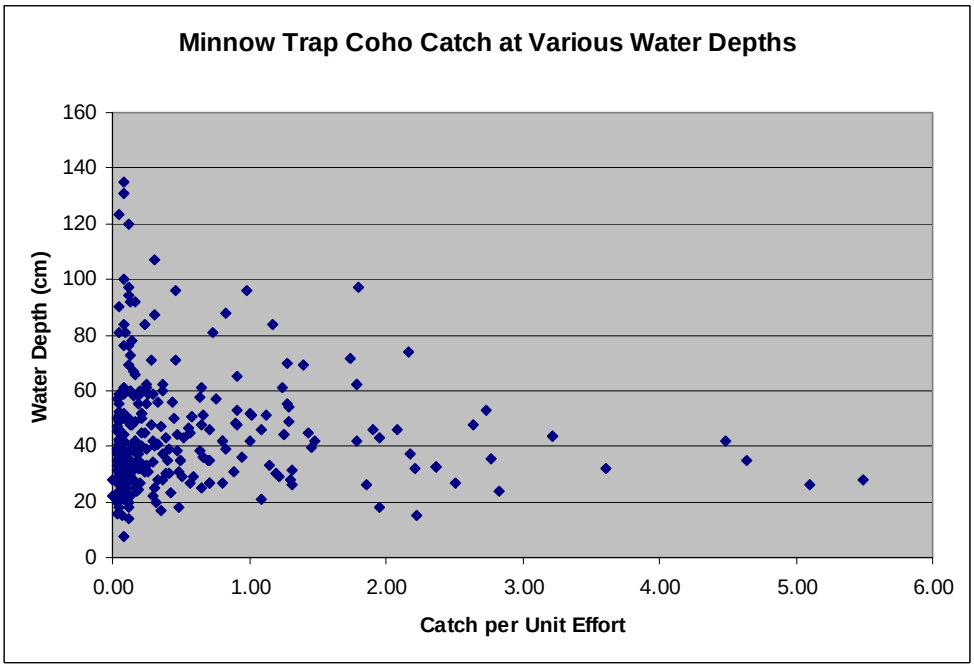


Figure 14. Scatterplots of coho CPUE, depth and temperature at individual minnow traps (n=100).

Off-channel Habitat Utilisation

In partitioning fish capture data into "habitat type", the graph below illustrates seasonal differences that reflect a combination of factors, such as migratory behaviour, watershed hydrograph, and habitat availability. Without teasing apart these layers, it is still evident that:

- There is a difference in habitat preference between summer and fall conditions;
- The Gates Creek mainstem is not the preferred habitat;
- The groundwater-fed ponds adjacent to the Anderson Lake foreshore become less populated later in the season;
- Those sidechannel habitats that can be clearly identified as such (5P) become more populated in the fall.

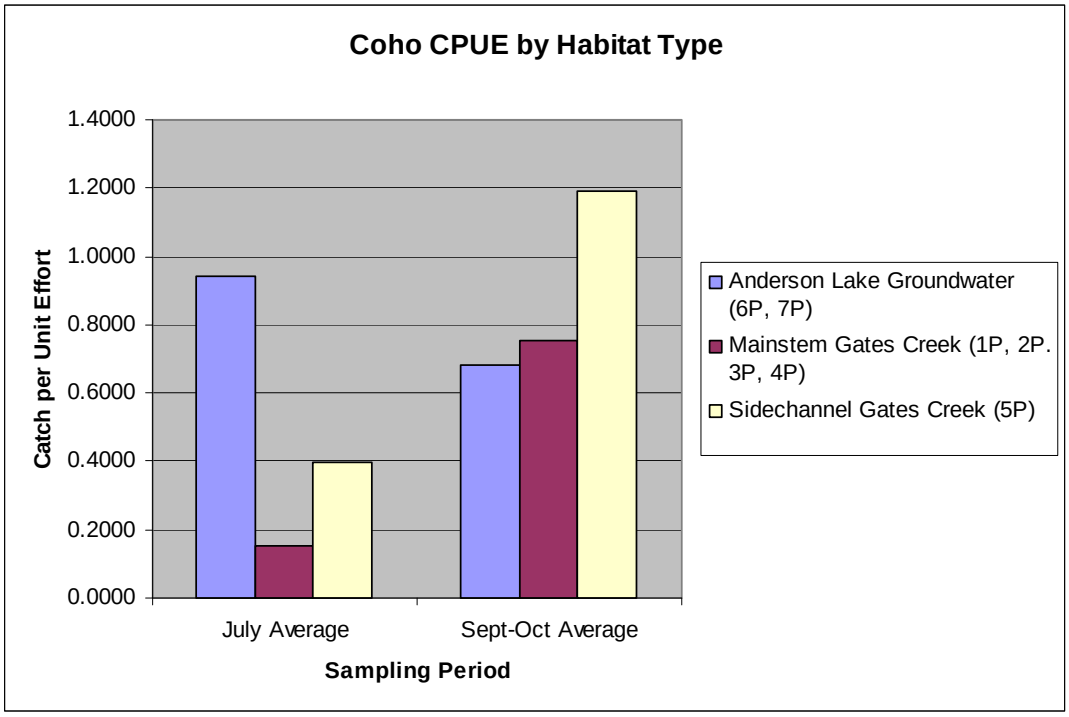


Figure 15. Comparison of coho densities in different habitat types, expressed in catch per unit effort.

If we used size and condition of fish as an indicator of habitat quality, it is evident that there are ecological differences in the different habitat types that stratify in the fall, and that mainstem habitats are not the most productive ones. Note that the data used to derive the graphs included baited and unbaited traps, in order to use the largest possible data set. However, when baited trap catches were excluded, results were very similar and there was no visible difference in the graphical data. Further analyses are inappropriate in this report.

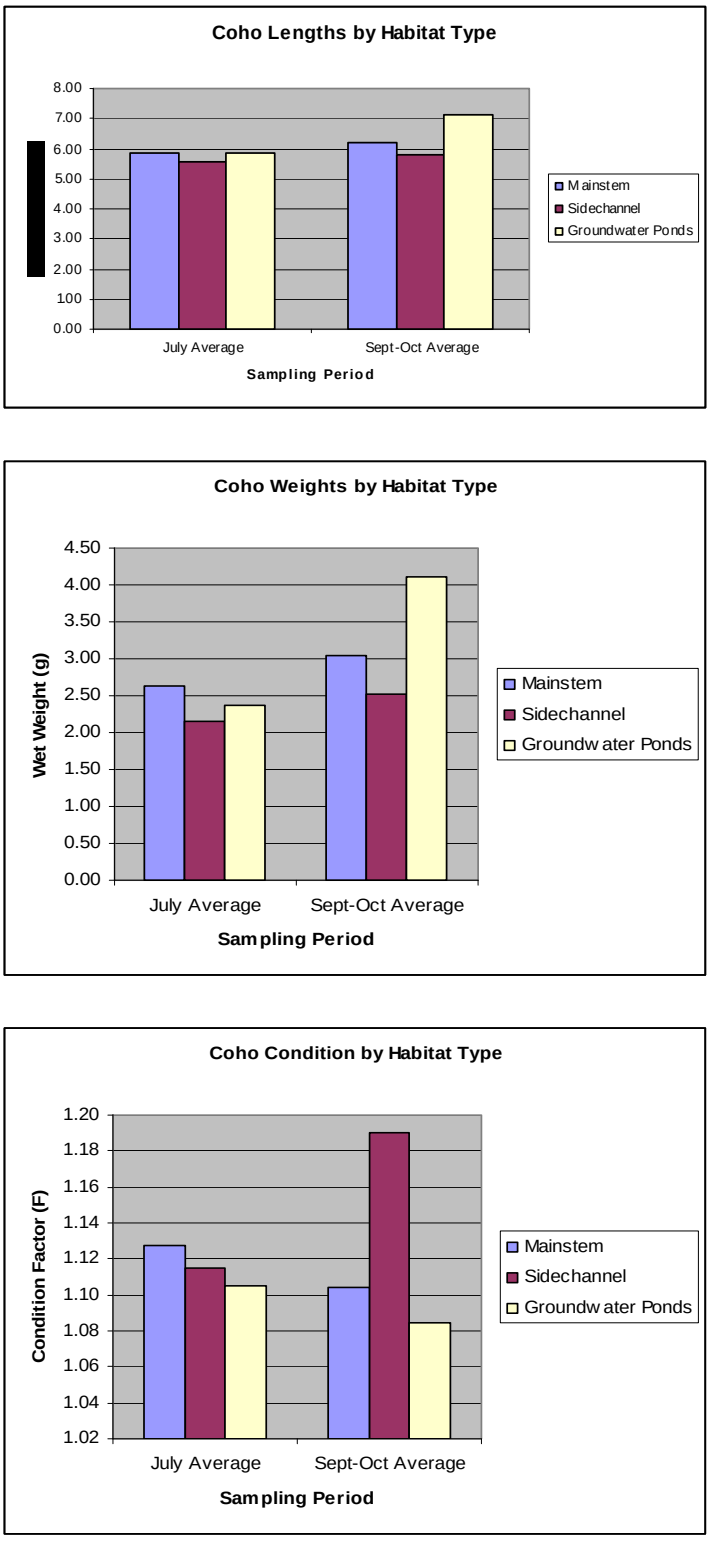


Figure 16. Seasonal comparison of fish weight, length and condition factors amongthree habitat types.

Summary: Minnow trap catches in standardized locations can provide some solid information on fish distribution and re-distribution:

- Juvenile coho seem to be making a one-way downstream migration. .
- Juvenile coho salmon are present throughout the mainstem, from Gates Lake to Anderson Lake. Note that the lower 2 km of Gates Creek had very little slack water habitat and was not effectively trapped.
- Mainstem stream temperature is generally constant in the 7 – 9^{o}C range. This is somewhat colder than optimal for rearing coho.
- Water depth may be limiting fish populations, with an inflection point near 25 cm when fish capture drops off. The area near the Gates Lake outlet may be particularly affected.

Reach 6 - Gates Lake and tributaries

Coho Utilization

This reach is upstream of all areas where coho are known to spawn. Gates Lake does not have any accessible tributaries (other than its outlet stream), and no spawning habitat (flowing, gravelled stream areas) was found. There were no juvenile coho captured by minnow trapping or beach seining. In Gates Lake, only non-anadromous, resident species were captured, primarily large numbers of redside shiners, mountain whitefish (near the outlet) and some rainbow trout.

Barriers to Fish Movement

Four culverts were located and surveyed in tributaries to Gates Lake. Three of the four are potentially fish barriers for resident species. However, the culverts are situated at the bottom of steep slopes and the main negative effect is as check points for bedload material shifting downstream.

Table 8. Summary of culvert inspections in Reach 6.

Number	Location	Main Effect on Fisheries
GL-1	South side Gates Lake, under Gates Lake Road.	Loss of stream productivity
GL-2	West side Gates Lake, private property.	Loss of stream productivity
GL-3	Northeast side Gates Lake, under Portage Road.	Loss of stream productivity
GL-4	Northeast side Gates Lake, under Portage Road, 500m east of GL-3.	Loss of stream productivity

Fish Habitat Notes

The western side of Gates Lake is bounded by private property and a swampy area that defines a height of land separating the Poole Creek drainage (flowing southwest to the lower Fraser River) and the Gates Creek drainage (flowing northeast to the middle Fraser River, at Lillooet). In this study, no defined channel could be found connecting the two watersheds; however it is likely that they were joined in the past and that some mixing of the freshwater populations has occurred.

Figure 17. Gates Creek Reach 6. Map shows Gates Lake and its outlet creek flowing east towards Anderson Lake. Icons show culvert assessment sites (red), minnow trap sites (yellow), beach seine sites (orange), upper limit of coho spawning (purple teardrop) and 5-6 reach break (white teardrop).

Reach 5 - Gates Creek downstream of Gates Lake

Coho Utilization

This reach encompasses the upstream limit of the main identified coho spawning area. There were some juvenile coho located ~ 300m upstream of this limit; however this was attributed to a few isolated coho spawning upstream of the identified area, rather than indicating an upstream movement of the juveniles. Fish capture consisted of minnow trapping and electrofishing, which also confirmed the presence of Dolly Varden, mountain whitefish and rainbow trout. Non-salmonids such as prickly sculpin and a species of sucker made this reach the one with the most aquatic biodiversity. A permanent site in the mainstem (P1) was identified for repetitive sampling.

Barriers to Fish Movement

Table 9. Summary of culvert inspections in Reach 5.

Number	Location	Main Effect on Fisheries
GC-1	East side of Gates Lake, outlet stream under Gates Lake Road.	Change in stream hydraulics and bedload deposition pattern at the lake outlet.

It is possible that there is a depth barrier at the outlet of Gates Lake that discourages coho fry from colonizing. Temperature and depth records indicate that while temperature did not rise about 15^{o}C during the study, depth at some trapping sites dropped to 16 cm, or less than the top of the trap. While coho salmon adults can migrate through and spawn in stream depths less than 30cm, coho fry prefer deeper water (30 - 120 cm).

Fish Habitat Notes

This reach includes a hayfield and livestock that encroach upon the riparian zone in an area where coho are spawning (~ 400m affected). Some restoration of riparian function, bank protection and in-stream complexity (e.g. adding some LWD) would result in pockets of increased cover and depth that would improve fish habitat utilization, especially for juvenile coho.

Figure 18. Gates Creek Reach 5. Map shows Gates Lake outlet creek flowing east towards Anderson Lake. Icons show culvert assessment sites (red), electrofishing site (red, E7) minnow trap sites (yellow), upstream limit of coho spawning (purple teardrop), permanent trap site P1 (green) and reach breaks (white teardrop)

Reach 4 - Gates Creek near the Falls Creek confluence

Coho Utilization

This reach encompasses the main identified coho spawning area, and some significant tributary habitat as well. Juvenile coho were abundant here, and were found throughout the well-vegetated riparian zone in the mainstem as well as lower Falls Creek.

Fish capture consisted of minnow trapping and electrofishing, which produced large numbers of juvenile coho, as well as Dolly Varden. Fish capture was almost exclusively limited to these two species. Permanent sampling sites were established at the Falls Creek confluence (P2) and further downstream in the mainstem at a private cabin (P3).

Barriers to Fish Movement

Table 10. Summary of culvert inspections in Reach 5.

Number	Location	Main Effect on Fisheries
GCT-1	Lower Falls Creek. There are twin culverts under the CN Rail crossing, visible upstream from the Portage Road bridge.	There has been significant bedload movement and flooding that has buried and re-routed the lower stream channel. This has destroyed fish habitat in the tributary and in the adjacent mainstem.

Fish Habitat Notes

The fish habitat in this reach is largely in its pristine condition. Mature trees and intact riparian vegetation has provided the complex bank and in-stream structure necessary to maintain juvenile coho in structured stream habitats. The stream temperature in the mainstem seems to be groundwater-fed and is a uniform 6 - 8^{o}C throughout the study.

However, Falls Creek has become unstable in the vicinity of the two stream crossings at Portage Road and upstream at the CN Rail crossing. While juvenile coho are found in the confluence area, it is evident that the lower 200m has been degraded by extreme flood events. Due to its proximity to the coho spawning area, this site should be treated to some remedial work to stabilize the stream channel and crossing structures.

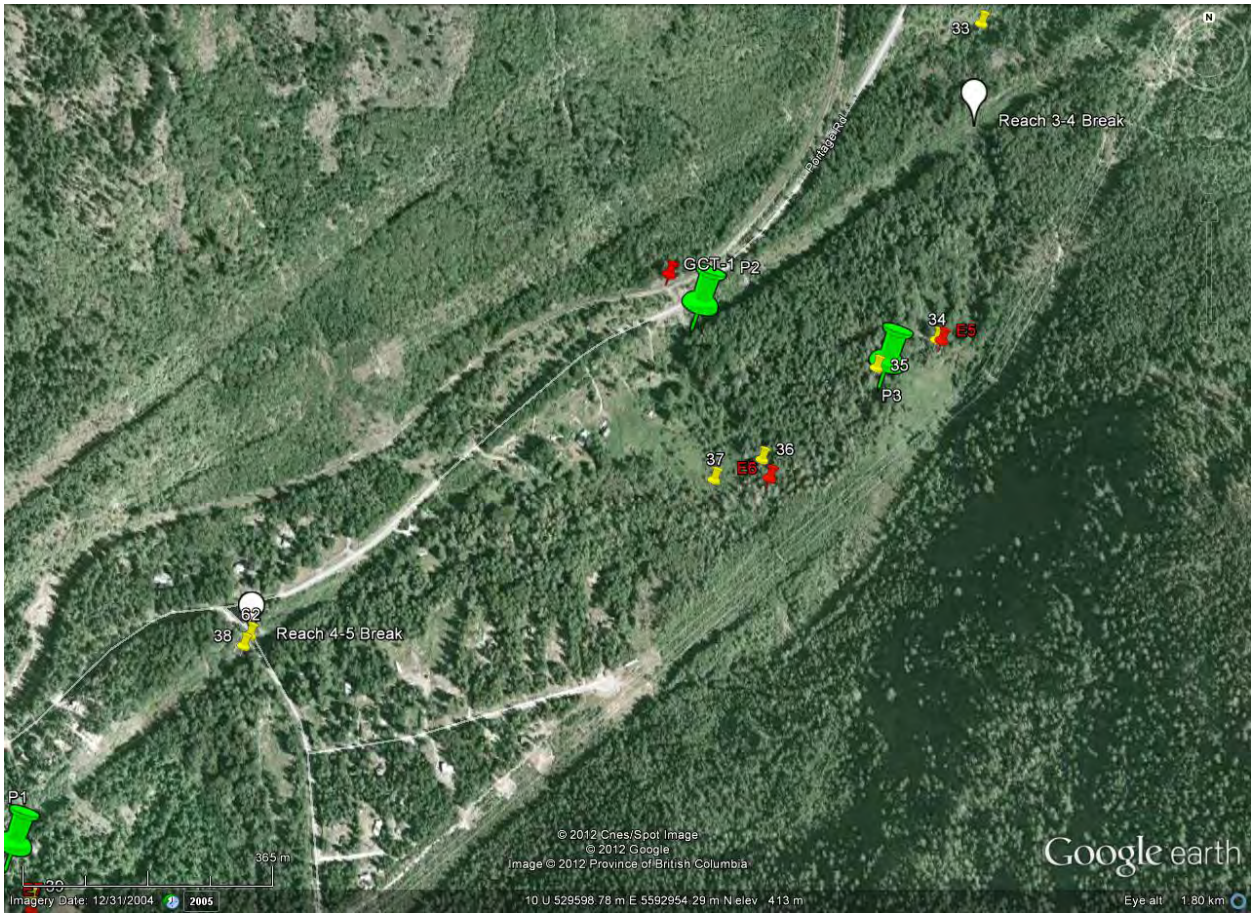


Figure 19. Gates Creek Reach 4. Map shows Gates Creek flowing northeast. Icons show culvert assessment sites (red), electrofishing sites (red, E5, E6) minnow trap sites (yellow), permanent trap sites P2, P3 (green) and reach breaks (white teardrop

Reach 3 - Gates Creek near the Buffalo Farm conservation property

Coho Utilization

This reach encompasses the lower limit of the main identified coho spawning area, and includes some significant off-channel habitats over a wide groundwater-fed flood plain.

There were 11 different sites minnow-trapped from May to October, pole seining in July, and a permanent site (4P) established for repetitive minnow trapping. Of all fish captured, 95% were juvenile coho, with smaller numbers of Dolly Varden (15), rainbow (25), sculpin (1) and whitefish (1) present.

Barriers to Fish Movement

Table 11. Summary of culvert inspections in Reach 5.

Number	Location	Main Effect on Fisheries
GCT-2	Lower King Creek, at Portage Road.	Checkpoint for bedload material. Gradient barrier < 5m upstream of the culvert.
GCT-3	CN Rail line, southeast side of flood plain	Some potential for fish trapping during high water events.
GCT-4		Acts as a check point for nutrients and material transport during flood events re: "flood pulse" theory.
GCT-5		

The flood plain at this reach is quite wide but has become disconnected through anthropogenic activities over more than a century of settlement. This falls into two categories:

- The rail line has caused some areas on the south side of the flood plain to become isolated, and it is possible that there is fish stranding as these zones become flooded during high water, and then isolated when the water recedes.
- A similar statement could be made about old agricultural activity that has flattened out the subtle natural contours of the flood plain to permit machine cultivation. Since the farm is no longer being worked, the contours are beginning to re-form, which has resulted in some isolated fixtures, dead-end channels, potholes, etc. that are probably trapping some fish as floods recede.

Fish Habitat Notes

While much of the land has been acquired for fish and wildlife restoration purposes, there is still some agricultural use that needs to be reconciled with this objective. In particular,

livestock should be excluded from this area, as bank trampling and riparian zone destruction has negatively affected fish habitat.

This is an attractive area for rearing juvenile coho salmon. The substrate in this reach is characteristically fine material, the banks are steep and offer some cut-bank cover, the temperature is somewhat warmer than adjacent areas (to 11.5^{o}C) which would attract rearing juveniles and the main channel is generally deep. However, there is considerable variation in water temperature, which is one of the factors that prompts fish to shift and migrate. This feature of the fish habitat in Reach 3 is an example of why habitat connectivity is important.

Table 12. Temperature range between trap sites during summer and fall periods, showing comparatively larger variation in Site 4P and immediately downstream (5P).

Permanent Trapping Site	Summer Temperature Range	Fall Temperature Range
1P	14.0-15.0	12.0-13.0
2P	7.5-8.0	6.0-7.0
3P	7.0-8.0	6.5-7.0
4P	**7.5-11.5**	**6.5-10.0**
5P	**7.5-13.5**	6.5-7.5
6P	6.0-8.5	6.0-9.0
7P	7.5-8.0	7.5-9.5

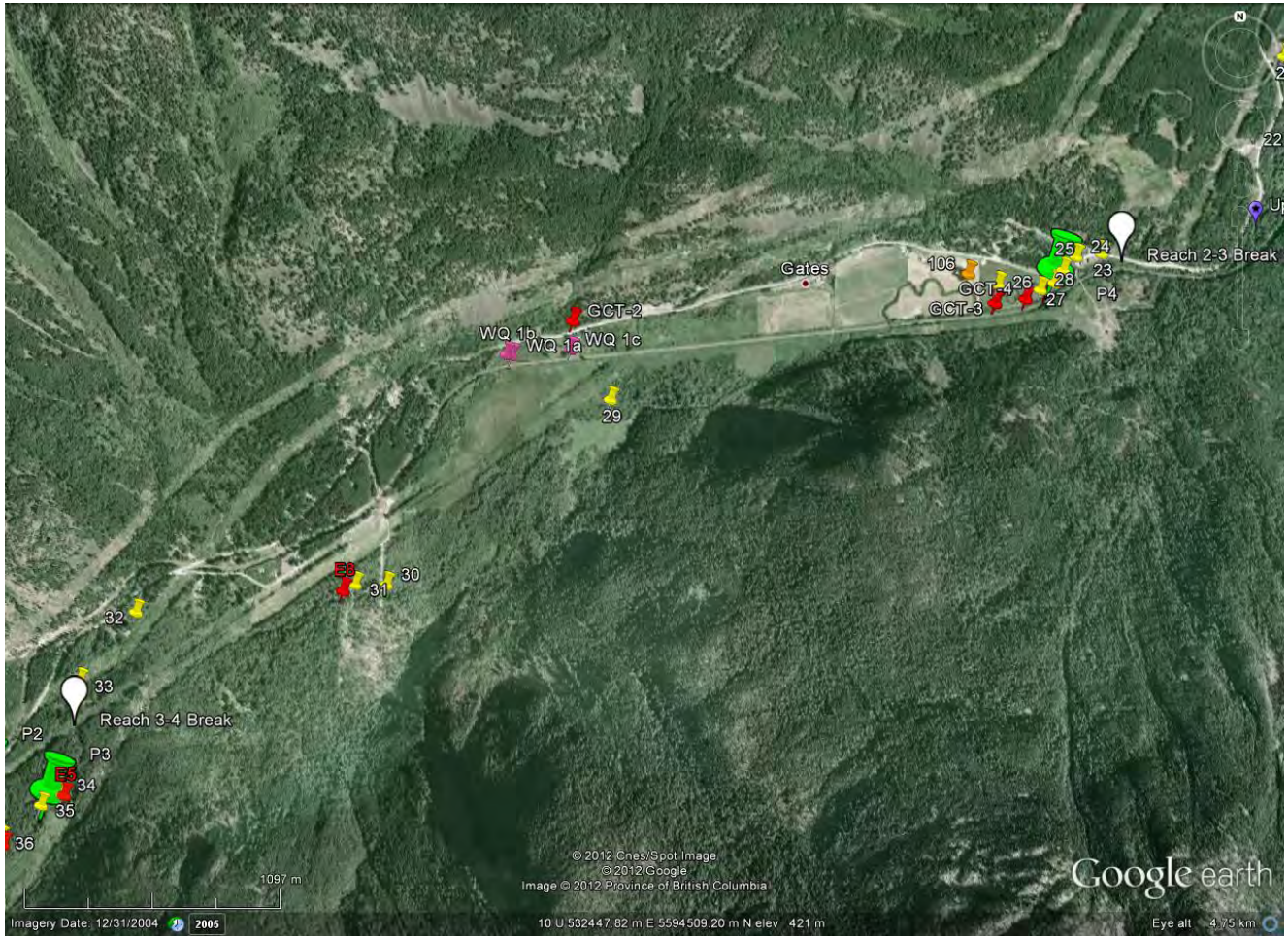


Figure 20. Gates Creek Reach 3. Map shows Gates Creek flowing northeast. Icons show culvert assessment sites (red), water quality sites (pink), electrofishing sites (red, E5, E6) minnow trap sites (yellow), permanent trap site P4 (green), downstream limit of coho spawning area #1 (purple teardrop), beach seine site (orange) and reach breaks (white teardrop).

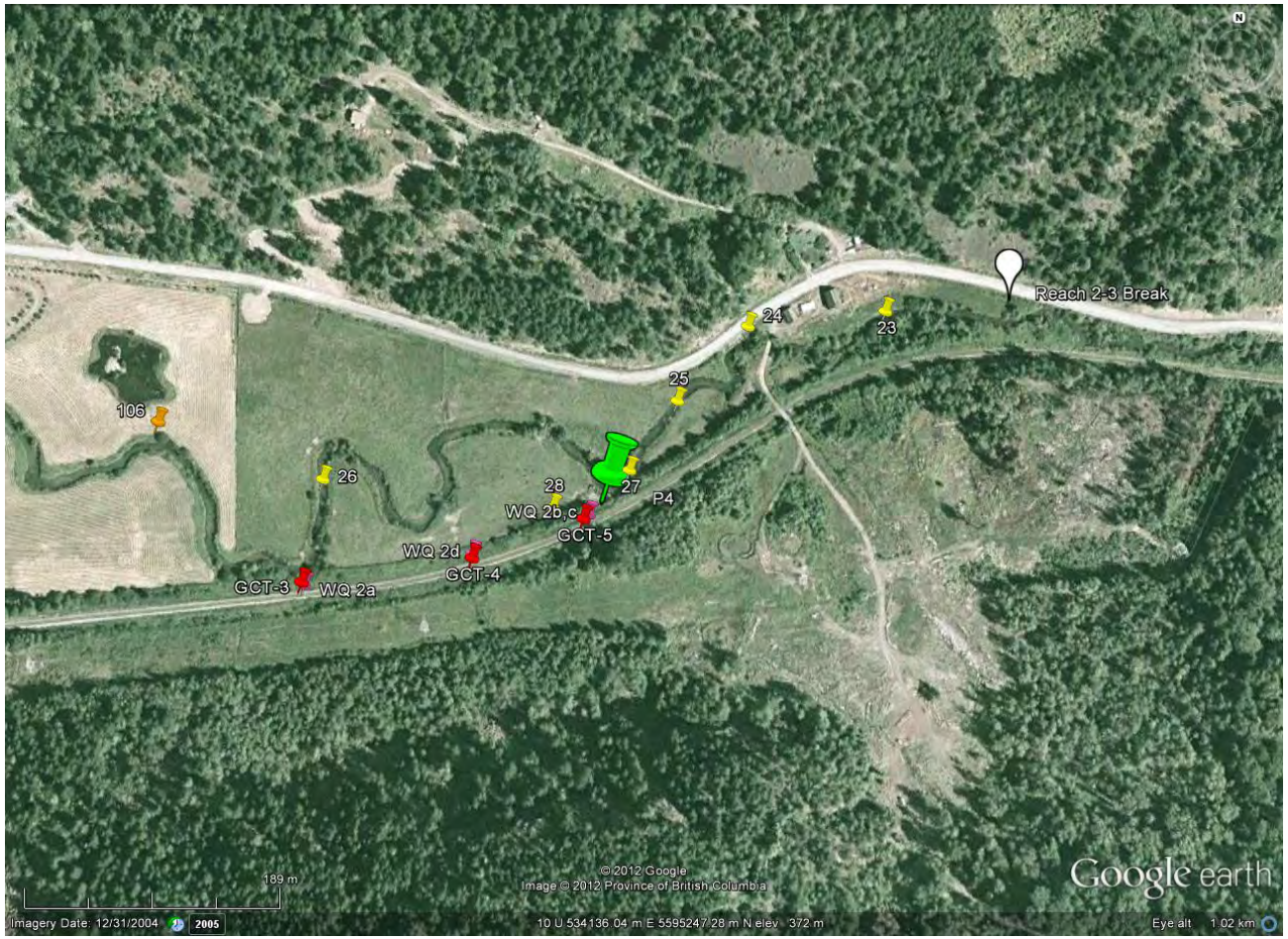


Figure 21. Detail of Gates Creek Reach 3 (east end). Map shows Gates Creek flowing northeast. Icons show culvert assessment sites (red), water quality sites (pink), minnow trap sites (yellow), seine site (orange) permanent trap site P4 (green) and reach breaks (white teardrop).

Reach 2 - Gates Creek near Devine

Coho Utilisation

Juvenile coho use the sidechannels and other off-channel habitats of this reach rather than remaining in the mainstem. While mainstem trapping sites were limited (re: high flow, lack of sheltered riparian areas), they were also unproductive for coho, and were abandoned after the May-June sampling period. Note that all the off-channel habitats in this reach, including tributary confluence areas, are surrounded by private property and were not fully accessible for sampling.

Most of Reach 2 includes a spawning area populated by a scattered population of coho salmon.

Table 13. Summary of fish captured in mainstem and sidechannel habitats in Reach 2.

Species	Mainstem Habitats (May-June sampling)	Sidechannel Habitats (May - October Sampling)
Coho	**11**	**23 (May-June only)** **826 (July - October)**
Dolly Varden	7	9
Rainbow Trout	11	7
No Fish Captured	21 sets	4 sets

Barriers to Fish Movement

The mainstem of Gates Creek, in Reach 2, has no obstructions that would impede the upstream migration of spawning salmon. However, the fact that nearly all the juveniles were located in off-channel habitats indicates that there may be a velocity effect that is displacing fish out of the thalweg. Mainstem velocities were not measured in this study.

Tributary mouths are only accessible to juvenile coho for a short distance, mostly due to gradient barriers at the edge of the narrow valley. Blackwater Creek had a number of culverts, some with old fishway structures on them; however, it was evident that no juvenile coho were present upstream of the lowest structure. Traditional knowledge should be sourced to determine whether or not this watershed was ever inhabited by anadromous fish beyond the lower 200m within the Gates Creek valley.

Table 14. Summary of culvert inspections in Blackwater Creek.

Number	Location	Main Effect on Fisheries
BW-1	30m upstream of confluence with Gates Creek	• Potential barrier to upstream-migrating adult coho salmon. • Undersized culverts are a checkpoint for bedload material and accelerate stream velocity.
BW-2	300m upstream of confluence with Gates Creek.	
BW-3	~ 1 km upstream of confluence with Gates Creek	

Fish Habitat Notes

Given their importance, tributary and off-channel habitats in Reach 2 deserve enhanced habitat protection measures, as well as some restoration. In particular:

- Blackwater Creek has had sections of significant alteration. For instance, upstream of the culverts in the lower reach, the main Blackwater Road is constructed adjacent to the stream in a narrow valley so that there are continual impacts on the aquatic habitat from road maintenance activities. The headwaters produce rainbow trout and the upper watershed is adjacent to Birkenhead Lake Provincial Park. This is a sizeable sub-basin and a special effort is warranted.
- Lower Spruce Creek offers some fish habitat at the confluence with Gates Creek, although minnow trapping and electrofishing did not recover any juvenile coho. Much of the creek passes through private property and a second site inspection is warranted.
- The most productive off-channel habitat for juvenile coho is located in drainage ditches on a farm property off the left bank of Gates Creek (permanent trapping site 5P). These areas seem to be permanently wetted, sheltered, and well connected to the mainstem. However, the property is under active agricultural management, and a partnership should be developed.

Table 15. Summary of Spruce Creek fish habitat survey.

Reach	1
Reach start	Confluence with Gates Cr
Reach End	FSR bridge
Length	~ 150 m
Channel width (m)	7.2
Wetted width (m)	6.1
Substrate	2.5% fines 2.5% gravel 25% cobble 70% boulder 0% bedrock
Habitat	60% riffle 40% pool 0% glide 0% cascade
Maximum pool depth (m)	0.69
Instream Cover (% of stream area/type)	40%/LWD, cutbanks, boulders, pools,
Overhang (% of stream area/type)	30%/bushes, alder
Canopy (% of stream area/type)	80% /cedar, maple, birch, fir, alder
Fish presence	Dolly Varden Rainbow trout Bull trout
Comments	Waste metal in stream. 5^{o}C

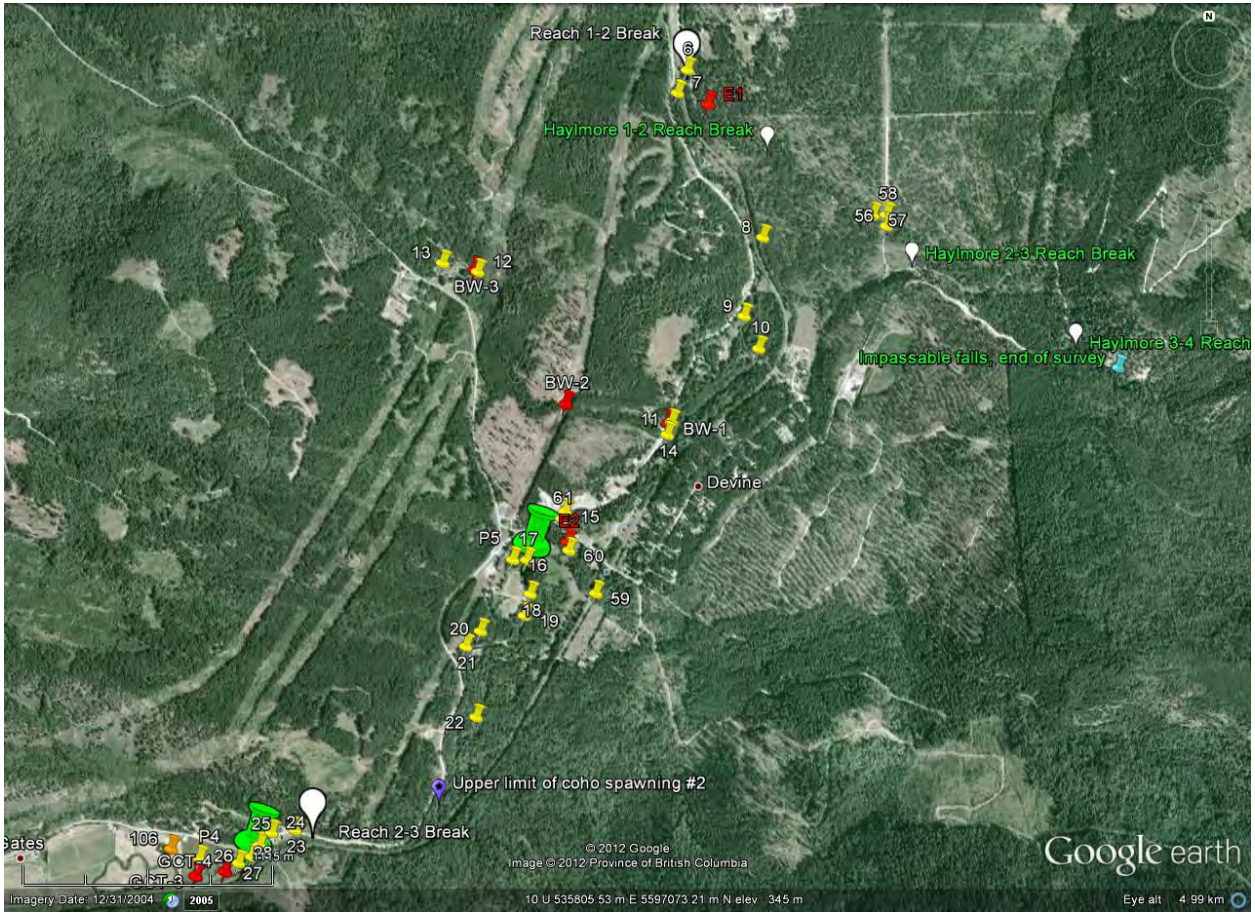


Figure 22. Gates Creek Reach 2. Map shows Gates Creek flowing north. Icons show culvert assessment sites (red), minnow trap sites (yellow), electrofishing sites (red: E1, E2), permanent trap site P5 (green), upper limit of coho spawning (purple teardrop) and reach breaks (white teardrop).

Reach 1 - Gates Creek near D'Arcy

Coho Utilisation

In years when these can be observed, this reach of Gates Creek is known to contain scattered spawning of coho salmon, as well as significant numbers of spawning sockeye. This year (2011) spawning pink salmon carcasses were also found, mostly downstream of the weir (see below).

There were very few juvenile coho captured; however there were no available minnow trap or seine sites except for one small area at the mouth. Given that there is no off-channel habitat adjacent to the mainstem it is assumed that there is little coho rearing habitat in Reach 1. Isolated trapping sites in the mainstem recovered Dolly Varden and prickly sculpin.

Small numbers of juvenile coho were found up the Haylmore Creek watershed, indicating that there were some coho spawning near the anadromous barrier 3 km upstream of the confluence.

Barriers to Fish Movement

Figure 23. Weir across Gates Creek at spawning channel intake, 1.3 km upstream of Anderson Lake.

There is a weir structure at the spawning channel intake about 1.3 km upstream from the Anderson Lake confluence. This structure is thought to impede upstream passage of migrating adult sockeye salmon; however coho salmon are less compromised as they ascend the fishway during lower flow conditions: Pink salmon carcasses were found above the weir; however, this species is not abundant in Gates Creek and their spawning distribution is unknown. Work to reduce the effect of this migration barrier is ongoing.

There is probably a habitat fragmentation effect on resident stream fish, especially Dolly Varden and rainbow trout, which would depress these populations. However, since both of these species are significant predators on salmon fry we assume that the negative effect of the weir is balanced by the positive effect of increased predation.

Note that there is no evidence of upstream movement of juvenile coho salmon. Given this behaviour pattern, and the configuration of the weir, it should be assumed that juvenile coho are making a one-way trip downstream, past the weir.

Fish Habitat Notes

Juvenile rearing habitat in the Gates Creek mainstem is almost non-existent in Reach 1. There has been some river training: a rail line, highway, power line, spawning channel, and subdivisions are all accommodated within fairly narrow valley walls. Except for the Haylmore confluence, there is no off-channel fish habitat, and almost no quiet marginal or backwater areas where juvenile salmonids might linger.

The lower channel of Haylmore Creek is unstable and does not provide good juvenile habitat. Electrofishing near the confluence was unproductive, but some juvenile coho were located in braided habitat about 1.5 km upstream. This implies that there are some coho spawning upstream of this point, and downstream emigration of the fry has settled some individuals in a sheltered sidechannel.

Figure 24. Haylmore Creek Reach 2, example of unstable channel segment.

Table 16. Summary of Haylmore Creek fish habitat survey.

Reach	1	2	3	4
Reach start	Confluence with Gates Cr	Cabin on river right	Where gradient changes to 7%	Confined stream channel
Reach End	Cabin on river right	Where gradient changes	Where confinement begins, ~ 50m upstream of bridge	Not surveyed, ending at falls, for descriptive purposes.
Length	650m	930m	800m	250m
Channel width (m)	13.1	11.6	15.05	
Wetted width (m)	11.3	7.9	11.75	
Substrate	5% fines 15% gravel 40% cobble 40% boulder 0% bedrock	5% fines 15% gravel 50% cobble 30% boulder 0% bedrock	5% fines 15% gravel 20% cobble 60% boulders 0% bedrock	Some bedrock
Habitat	85% riffle 15% pool 0% glide 0% cascade	50% riffle 30% pool 20% glide 0% cascade	50% riffle 50% pool 0% glide 0& cascade	
Maximum pool depth (m)	0.46	0.71	0.67	
Instream Cover (% of stream area/type)	20%/boulders, also cutbanks and logs	40%/half from boulders and half from LWD	50%/most from boulders, some from LWD	
Overhang (% of stream area/type)	80%/deciduous trees	60%/alder and cedar	80%/mixed deciduous and conifers	
Canopy (% of stream area/type)	40% /mixed forest, deciduous and conifers	60% /mixed forest, deciduous and conifers	60% /mature forest. Cedar, Cottonwood, birch, pine, small maple	
Fish presence	Fish seen, not identified			Fishing area for Dolly Varden
Comments	Some stable side channels throughout the reach.	300m upstream of cabin, LWD jam with 3 large channels; new and old channels, banks terraced.	Substrate rocks tightly wedges, noticeable abundance of invertebrates, periphyton.	

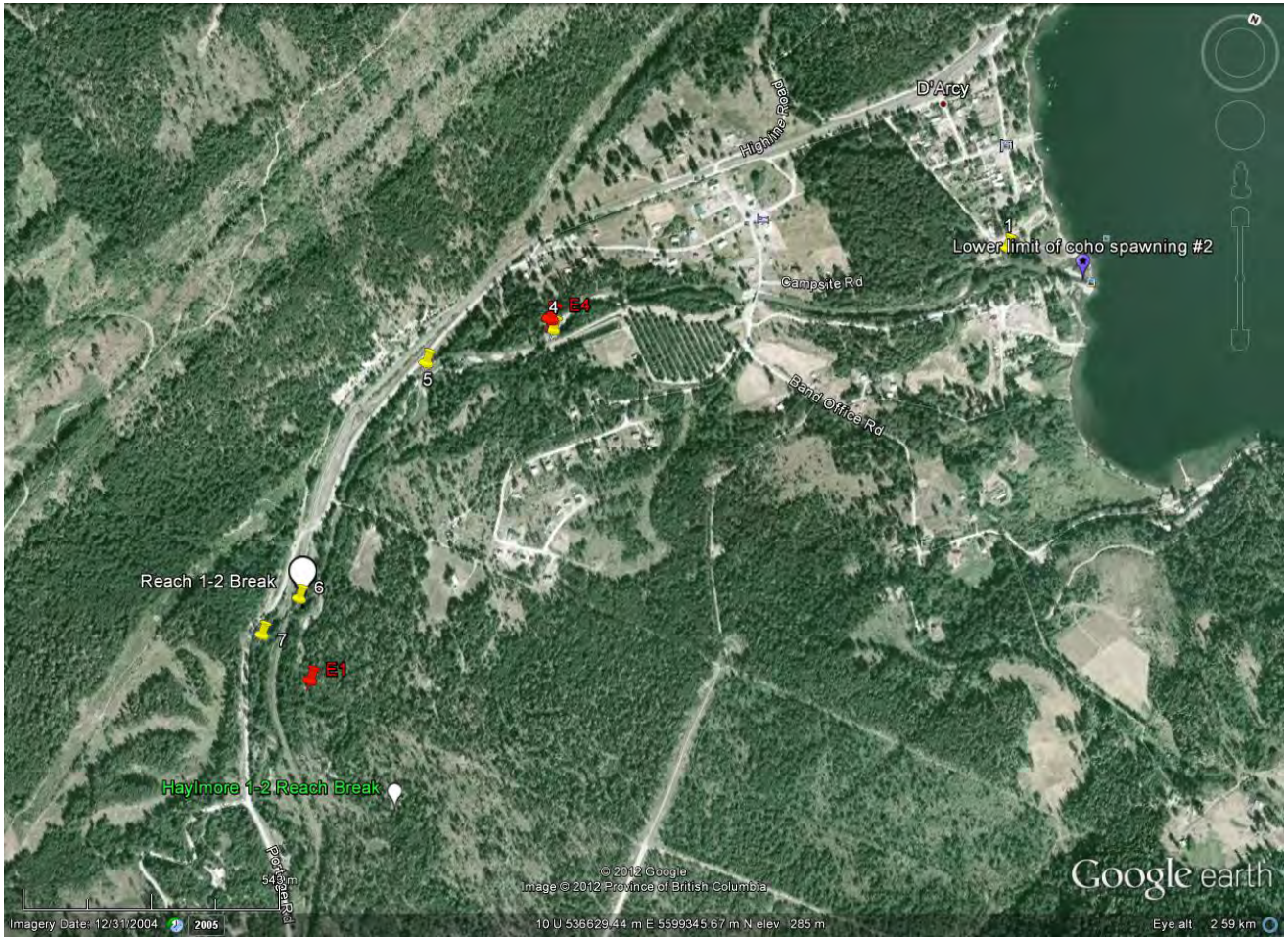


Figure 25. Reach 1 of Gates Creek, showing Anderson Lake foreshore and community of D'Arcy. Map shows Gates Creek flowing northeast. Icons show minnow trap sites (yellow), electrofishing sites (red: E1, E4), lower limit of coho spawning (purple teardrop) and reach breaks (white teardrop).

Anderson Lake Foreshore near D'Arcy

Coho Utilisation

Juvenile coho that are not able to maintain themselves further upstream in the mainstem are subject to an uncertain fate when they reach Anderson Lake. While minnow trapping was unproductive, seine sets recovered large numbers of sculpin, coho, sockeye, redside shiner.

There are groundwater-fed ponds near the beach that provide excellent habitat for juvenile coho; however, there are no spawners in the vicinity. It is assumed that fish migrating down Gates Creek and reach Anderson Lake are somehow able to cruise along the foreshore and enter these ponds where they evidently thrive. Two of these areas were identified for permanent minnow trapping sites (6P and 7P).

Barriers to Fish Movement

TRIM map information indicates that Young John Creek flows northeast into Anderson Lake; however, there is no defined stream channel that would allow fish passage or any movement of aquatic organisms. It appears that this stream has gone subsurface for at least several hundred meters, and roads and human settlement superimposed. The groundwater ponds evident at sites 6P and 7P seem to be fed by subsurface flow.

Table 17. Summary of Young John Creek fish habitat survey.

Reach	1	2
Reach start	Anderson Lake foreshore, Lakeshore Drive by hatchery	Wort's property fence
Reach End	Wort's property fence	Where creek goes subsurface, at the end of Wort's field
Length	Not measured	Not measured
Channel width (m)	1.2	2.0
Wetted width (m)	1	2
Substrate	100% fines	100% fines
	0% gravel	0% gravel
	0% cobble	0% cobble
	0% boulder	0% boulder
	0% bedrock	0% bedrock
Habitat	0% riffle	0% riffle
	10% pool	50% pool
	0% glide	0% glide
	90% cascade	0% cascade
Maximum depth (m)	0.13	.17 (very low flow)
Instream Cover (% of stream area/type)	40%/SWD, sticks and leaves	60%/SWD, sticks and leaves
Overhang (% of stream area/type)	90%/brush, woody debris	95%/alder, maple bushes
Canopy (% of stream area/type)	80%/fir, bigleaf maple	95%/deciduous
Fish presence	No	No
Comments	No culvert at road, water goes subsurface	Drainage issues.

These ponds are more freely accessible at spring high water levels than they are in late summer and early fall when the water level drops in Anderson Lake. However, they are never completely isolated and the groundwater-fed nature of these ponds keeps them ice-free and productive. There are some minor culverts and lakeshore alterations that should be remediated

Fish Habitat Notes

This section of the Anderson Lake foreshore is clearly an important rearing area for juvenile coho salmon. It is possible it is food or cover-limited (see **Off-channel Habitat Utilisation**), and further work should be done.

Figure 26. Groundwater-fed pond adjacent to permanent sample site P6, within 50m of the Anderson Lake foreshore.

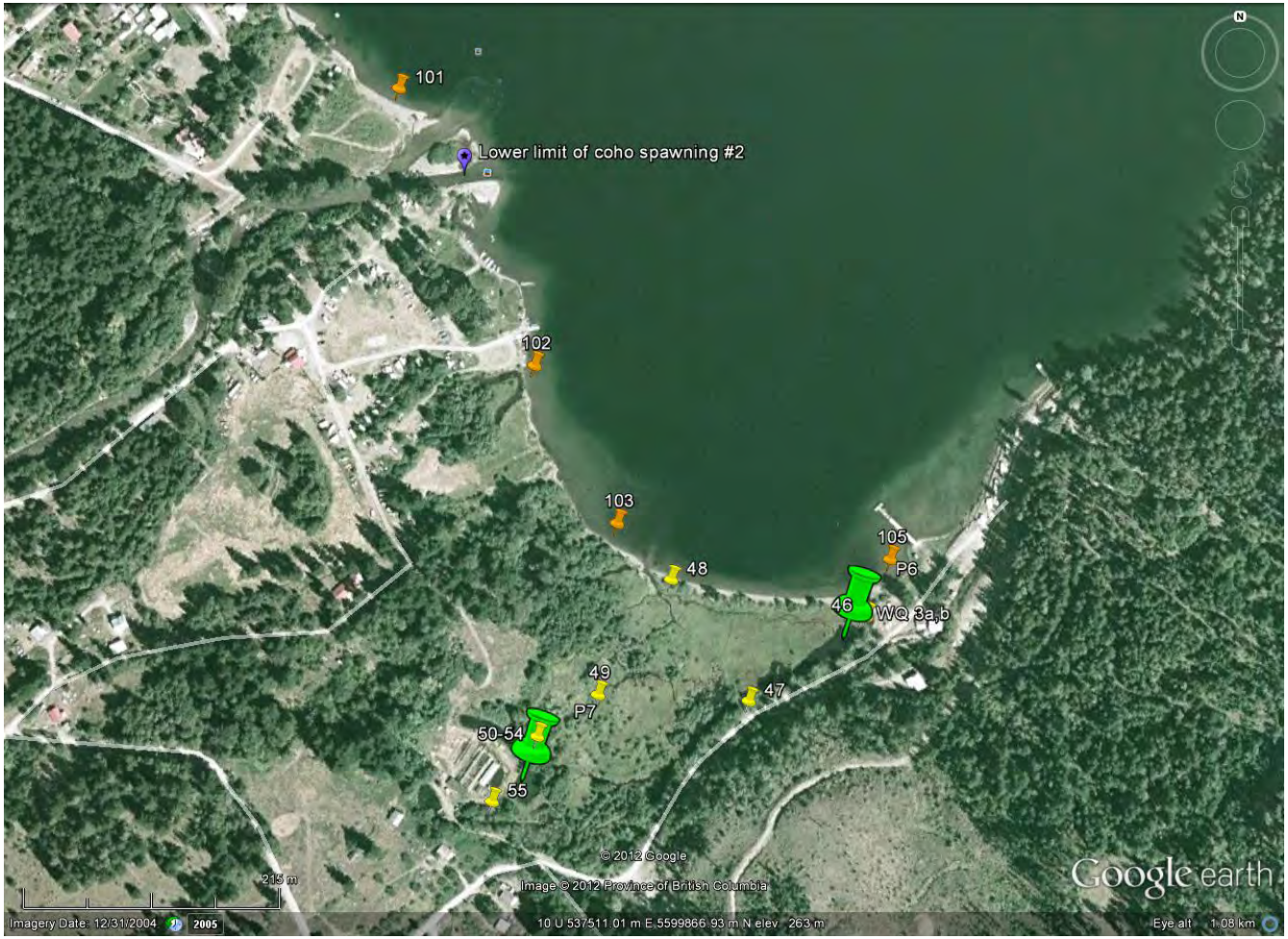


Figure 27. Anderson Lake foreshore and community of D'Arcy, showing Gates Creek flowing northeast and groundwater ponds to the south. Icons show lower limit of coho spawning (purple teardrop), minnow trap sites (yellow), beach seine sites (orange), water quality sites (pink), and permanent trap sites 6P and 7P (green).

Lower D'Arcy Creek

Coho Utilization

Pink salmon were seen spawning 100m upstream of the Anderson Lake confluence, coho salmon spawners, and coho juveniles are observed above the lower 4 culverts; however, no anadromous fish are found past this point. Resident fish, mainly rainbow trout, are found above the Portage Road crossing; however, the survey ended at the drinking water supply compound, respecting the total diversion of the creek into storage structures and extreme slope above this point.

Barriers to Fish Movement

There is potentially 1500m of stream habitat available to coho salmon before the break in the slope. However, only the lower 130m is available to them without substantial in-stream obstructions.

Table 18. Summary of culvert inspections in lower D'Arcy Creek.

Number	Location	Main Effect on Fisheries
D-1a	Downstream end of private property on Eastkan Road, concrete box culvert.	Partial barrier to spawning and rearing salmonids.
D-1	Private property, Eastkan Road.	Partial barrier to spawning and rearing salmonids.
D-2	Koocha and Eastkan Road intersection	Partial barrier to spawning and rearing salmonids.
D-3	Eastkan Road, upstream of private property	Partial barrier to spawning and rearing salmonids.
D-4	Twin culverts under Portage Road and CN Rail line.	Complete barrier to anadromous fish re: culvert lengths, water velocities.
D-5	Under Got-Bar-O Road, N'Quatqua administration.	Partial barrier, resident fish habitat.
D-7	800m up Portage Road.	Partial barrier, resident fish habitat.
D-6	Inside water supply system gates	Complete barrier, no fish.

Fish Habitat Notes

The lower 200m of this creek has been extensively modified as it flows through private properties in the community of D'Arcy; however, above that point, it is nearly pristine.

Table 19. Summary of D'Arcy Creek fish habitat survey.

Reach	1	2	3	4	5
Reach start	Anderson Lake foreshore	Rollard property	Upstream end of Richmond property	"private drive" culvert	Culvert
Reach End	Rollard property line	Upstream end of Richmond property	First culvert on FSR ("private drive")	Next culvert up	Water reservoir
Length	~ 130m	~ 350m	~ 170m	~ 200m (?)	~ 700m
Channel width (m)	4.1	3.0	4.2	2.1	2.0
Wetted width (m)	3.7	2.8	3.0	2.0	2.0
Substrate	65% fines 20% gravel 10% cobble 50% boulder 0% bedrock	70% fines 20% gravel 7.5% cobble 2.5% boulder 0% bedrock	45% fines 50% gravel 2.5% cobble 2.5% boulders 0% bedrock	45% fines 50% gravel 3% cobble 2% boulders 0% bedrock	40% fines 45% gravel 10% cobble 5% boulders 0% bedrock
Habitat	8% riffle 40% pool 52% glide 0% cascade	0% riffle 40% pool 53% glide 7% cascade	6% riffle 44% pool 28% glide 22% cascade	30% riffle 30% pool 10% glide 30% cascade	30% riffle 70% pool 0% glide 0% cascade
Maximum depth (m)	0.44	> 1.0	0.57	0.49	0.57
Instream Cover (% of stream area/type)	60%/LWD, roots, cutbanks	60%/grass, watercress, cutbanks	60%/branches, cut banks, grass	50%/grass, cutbanks LWD, pools	60%/ cutbanks, pools, LWD
Overhang (% of stream area/type)	90%/trees, some instream	10%/grass, snowberries, bridges, gazebo	75%/branches, bushes, deciduous	60%/bushes, deciduous trees, cutbanks	90%/ cedar branches, bushes, LWD
Canopy (% of stream area/type)	100%/95% deciduous, 5% conifers	35%/willow, birch, fir, cedar, alder, maple	85%/deciduous, conifers. Mature forest.	85% fir, bigleaf maple, alder, cottonwood trees.	100%/ fir, cedar, maple, cottonwood
Fish presence	Pink (spawners) Coho (spawners) Dolly Varden Rainbow trout Suckers Sockeye (spawners)	Pink (spawners) Coho (spawners) Dolly Varden Rainbow trout Suckers Sockeye (spawners)	Pink (spawners) Coho (spaawaners) Dolly Varden Rainbow trout Suckers Sockeye (spawners)	Dolly Varden Rainbow trout	None seen
Comments		6 private properties 4 culverts (see notes)	2 culverts (see notes)	Stream bed very compacted.	A few small waterfalls. Extremely brushy.

Figure 28. Lower D'Arcy Creek. Map shows Creek flowing southeast through D'Arcy subdivision into Anderson Lake foreshore. Icons show lower limit of known coho spawning (purple teardrop), minnow trap sites (yellow sites 6P and 7P (green) and reach breaks (white teardrop).

Recommendations

Further research

DNA profiling for Gates Creek coho. In watershed terms, these fish enter the Fraser River and reach Gates Creek at the end of a 600km migration. However, there is a very small connection to the coastal Birkenhead River drainage which existed at one time. Given that interior coho are recognized as having discrete population characteristics, potentially with different behaviours and habitat utilisation, some genetic profiling would be useful.

Survival and movements of juvenile coho in Anderson Lake. The presence of large numbers of sculpin at the mouth of Gates Creek is an indication that the fate of downstream-migrating juvenile coho should be addressed. Such information speaks to the question of how much investment should be made in in-stream and marginal habitat

to maintain coho within the Gates Creek mainstem, relative to preservation of lakeshore habitat near the mouth.

Stewardship

Farm partnerships: Agricultural properties in the mainstem of Gates Creek could be working with environmental stewards to improve fencing, pasture and off-channel habitat management. These improvements would be to maintain bank structure and riparian zone productivity to keep coho juveniles in mainstem habitats longer. Individual landowners should be contacted and funding mechanisms such as Environmental Farm Plans explored.

Lakeshore mapping: Given the recent development of lakeshore properties, their collective alienation of the riparian zone, and our knowledge of how valuable some of this habitat is (especially in Anderson Lake), it is appropriate to begin a shoreline mapping program to augment discussions on this important land use planning matter.

Blackwater Creek watershed: There are a combination of factors that are depressing this historically important creek, including fish passage obstructions at several culverts, siltation from road runoff, and miscellaneous agricultural impacts. Further field work is required on the specifics of habitat condition and fish habitat utilisation further upstream in the watershed, to begin establishing partnerships and specific action plans.

Habitat Management

Unstable tributaries: Haylmore and Spruce Creeks show evidence of instability in their lower reaches, and this should be addressed from a total watershed perspective. Some level of watershed assessment profiling would provide guidance to the provincial agencies on their land management decisions.

Restoration Projects

Instream structures: The objective of these structures would be to create depth in some mainstem areas (especially near the Gates Lake outlet) and to provide a hydraulic complexity for small fish to maintain themselves more easily in the mainstem.

Fishway adjustments: The distribution of coho salmon in the Gates Creek watershed is a subset of the distribution of the spawning adults, and it is essential that the fishway at the spawning channel intake (<500m from the mouth) is functioning as efficiently as possible. It is also important to ensure that smaller, stream-resident species such as rainbow trout and Dolly Varden char (presumed to be bull trout in this case) have the ability to migrate when their biology demands it. For the time being, secondary importance is being placed on sockeye, pink and Chinook salmon, as they are mostly concentrated downstream. It should be expected that fishway re-design and re-construction will be a factor for many years, and annual fish observation and passage evaluation should be ongoing.

Fish passage improvement: This should be focussed on culvert removal or remediation in D'Arcy Creek and flood plain connectivity in the vicinity of the Buffalo Farm conservation property, to ensure that upstream habitat is plentiful and suitable for stream-rearing salmonids. While there are plenty of culverts in other areas, most have hydraulic impacts rather than constricting fish distribution.

Groundwater pond improvement: In foreshore areas adjacent to Anderson Lake, groundwater ponds have proven to be important habitats for juvenile coho salmon. In this case rearing habitat could likely be improved by increasing its productivity through the installation of habitat complexing structures and re-visiting some of the man-made shoreline alterations.

Lower D'Arcy Creek reconstruction: Reach 1 of this creek has been highly altered by resident landowners and others, so that fish migration is compromised and riparian habitat is destroyed. Alienation of this reach is one of several barriers that inhibit coho salmon access to at least 2 km of productive stream. There is a technical opportunity to re-route600m of the lower creek through an adjacent wooded area to the south that would allow further access to 1.5 km upstream.

Revegetation at the Buffalo Farm conservation property: While this property has been purchased and maintained for ecological purposes, it continues to be used for livestock grazing, with negative effects. This practise should be stopped, and some remedial planting and streambank protection employed.

Flood Creek stabilization: The lower 200 m of Flood Creek has substantially destabilized, with negative impacts on the very limited off-channel habitat area that is provided by the tributary confluence. Special design assistance is required to ensure that culverts under Portage Road, and the CN Railway are optimized.

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