

Seasonal Abundance and Habitat Use of Fish Species
Utilizing Side Channel Habitats of the Lower Duncan
River, BC, 2004/2005

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ABSTRACT

Knowing the fish species of a regulated stream reach, their habitat relations, and the seasonality of these relations is a key step in mitigating the impacts of dam operation. Although the fish species that inhabit side channel habitats in the lower Duncan River system are known, relatively little is known about their seasonal abundance and specific habitat relations. This study was designed to address this information shortfall. We employed nighttime snorkeling surveys and single-pass electrofishing to investigate species composition and abundance in five side channels of the lower Duncan River at three times of the year: late summer (September 2005), late fall (November 2004), and late winter/early spring (April 2005). Sampling effort was stratified into five habitat type categories: riffles (RI), runs (RU), runs associated with wood debris cover (RUW), slack water (S), and slack water associated with wood (SW). Rainbow trout were the most widespread species among sampling sites, and were relatively abundant and numerically dominant in RI and RUW sites in September sampling, and in all habitat types associated with flowing water (RI, RU, RUW) during November and April. Mountain whitefish were also widespread in flowing water habitats and numerically dominant in RU sites during September, but their abundance was lower in side channel sites in November and especially April sampling. With respect to specific physical habitat variables evaluated over all sites irrespective of habitat type category, both mountain whitefish and rainbow trout abundance were positively correlated with stream flow and negatively correlated with the presence of fine substrates. Rainbow trout abundance was most strongly positively correlated with the area of woody debris cover at sampling sites, and was negatively correlated with depth. The most abundant non-sport fish species encountered were redbreast shiners and juvenile longnose suckers, which were numerically dominant in slack water habitats during November and April sampling. In contrast to the salmonid species rainbow trout and mountain whitefish, redbreast shiner and young longnose sucker abundances were positively correlated with the presence of fine substrates and negatively correlated with water velocity. Flow regulation in the lower Duncan River system has resulted in increasing deposits of fine sediments in side channel and back channel habitats, which no longer receive scouring flows. These changes have likely reduced the capacity of the lower Duncan River side channels for salmonid production.

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INTRODUCTION

Intensive flow regulation in river systems has been shown to reduce the abundance of fish in rearing habitats, alter taxonomic composition and reduce complexity of riverine fish communities, and disrupt microhabitat relations (Scheidegger and Bain 1995; Poff et al. 1997; Freeman et al. 2001; Bowen et al. 2003). The specific mechanisms by which impacts to fish communities from flow regulation occur, however, are not well understood. Unpredictable and variable flows in a regulated stream can be seen as a high frequency disturbance that affects fish differently depending on how they use stream habitat (Poff et al. 1997). Knowing the fish species of a regulated stream reach, and knowing the habitat relations of individual or groups of species and the seasonality of these relations, therefore, are key steps in attempting to mitigate the impacts of dam operation. With respect to spawning success for salmonid fishes, for example, deposited eggs can survive for weeks in dewatered gravel, but this will not be true if dewatering occurs during periods of either freezing or very warm temperatures (Hunter 1992). In another example, Harvey (1987) found that young-of-the-year cyprinids were highly vulnerable to downstream displacement by flooding, but the magnitude of effects appeared to be related to timing of flood events relative to the timing of reproduction.

With respect to juvenile salmonids, daytime concealment behaviour may exacerbate the impacts of intensive flow regulation. Juvenile salmonids commonly conceal themselves during the day at low water temperatures (< 9-10°C; e.g. Bradford and Higgins 2000 and references therein). In daytime experiments conducted at low water temperatures, Atlantic salmon juveniles in field enclosures (Harby and Halleraker 2001) and steelhead and Pacific salmon in artificial stream channels (Bradford et al. 1995) became stranded in dropping flows because they were concealed within the substrate and unwilling to leave. Stranding rates were much lower at night, when fish were above the substrate, suggesting that this is a better time of day to ramp down flows in regulated systems, especially when water temperatures are low.

Fishes that use shallow and slow water habitats are often greatly reduced in abundance in regulated streams (Poff et al. 1997). During early life history stages particularly, fish inhabiting shallow habitats may not be able to respond rapidly to flow changes because of small body size and weak swimming ability. In the lower Duncan River, where the flow is largely regulated by releases at the Duncan Dam (located 11 km upstream of Kootenay Lake), side channels represent a substantial portion of total available habitat. Compared to the mainstem, side channels in the Lower Duncan River are relatively shallow and low in velocity, and juvenile fish rearing in these habitats may be particularly vulnerable to flow changes.

Previous fish studies in the lower Duncan River (R.L.&L. 2000; Golder Associates 2003; AMEC 2003) have identified a number of species that utilize side channels and have shown that daytime concealment by juveniles can be expected at lower temperatures. However, relatively little is known about specific habitat relations of the various fish species present or seasonal variability in these relations, information that might help to plan future mitigation efforts. We examined the seasonal use of side

channel habitats in the lower Duncan River by various fish species in an effort to expand existing knowledge about fish community structure and habitat use. More specifically, the objectives of this study were to:

1. Establish index sites for fish population sampling that are representative of the diversity of habitats in lower Duncan River side channels.
2. Sample index sites for fish species composition using the most appropriate methods during three seasonal periods: late summer, late fall, and late winter/early spring.
3. Describe habitat relations, as much as possible, specific to each species/life stage category present, in order to identify potential impacts of dam operation in lower Duncan River side channels.

This report summarizes the results from sampling periods in November 2004, April 2005, and September 2005, and describes habitat relations in Duncan River side channels for the dominant fish taxa during each of these three periods.

METHODS

Study area

The lower Duncan River study area (Figure 1) has been thoroughly described in recent reports (M. Miles and Associates 2002; AMEC 2003; Golder Associates 2003). The Duncan River, which drains into the North end of Kootenay Lake, British Columbia, has a total drainage area of 4,750 km², of which 2,400 km² are located upstream of the Duncan Dam (M. Miles and Associates 2002). There are four major, unregulated tributaries to the lower Duncan River (defined here as the lowermost reach extending downstream from the dam to Kootenay Lake): the Lardeau River (1,620 km²) and Meadow, Hamill, and Cooper creeks (125, 310, and 240 km², respectively; M. Miles and Associates 2002).

Fish species presence in the Duncan River system, as indicated in reports from previous fish sampling, was summarized by AMEC (2003; Table 1). Mainstem fish habitats are also described by AMEC (2003). Because the lower Duncan River flows through a broad alluvial fan at the head of Kootenay Lake, side channels and braids occur extensively. Large accumulations of woody debris, including major log jams, are found throughout the lower Duncan River channel, and are an important component of fish habitat complexity and cover in both mainstem and side channel areas. Side channels, in general, provide low gradient habitats of shallow to moderate depths and low to moderate current velocities. Currently, fine materials are the dominant substrate type at most side channel locations. As described in the channel stability assessment of M. Miles and Associates (2002), regulation of the lower Duncan River has resulted in reductions of channel widths as back channels and side channels, which no longer receive scouring flows, become re-vegetated. Reduced post-regulation flows have been inadequate to

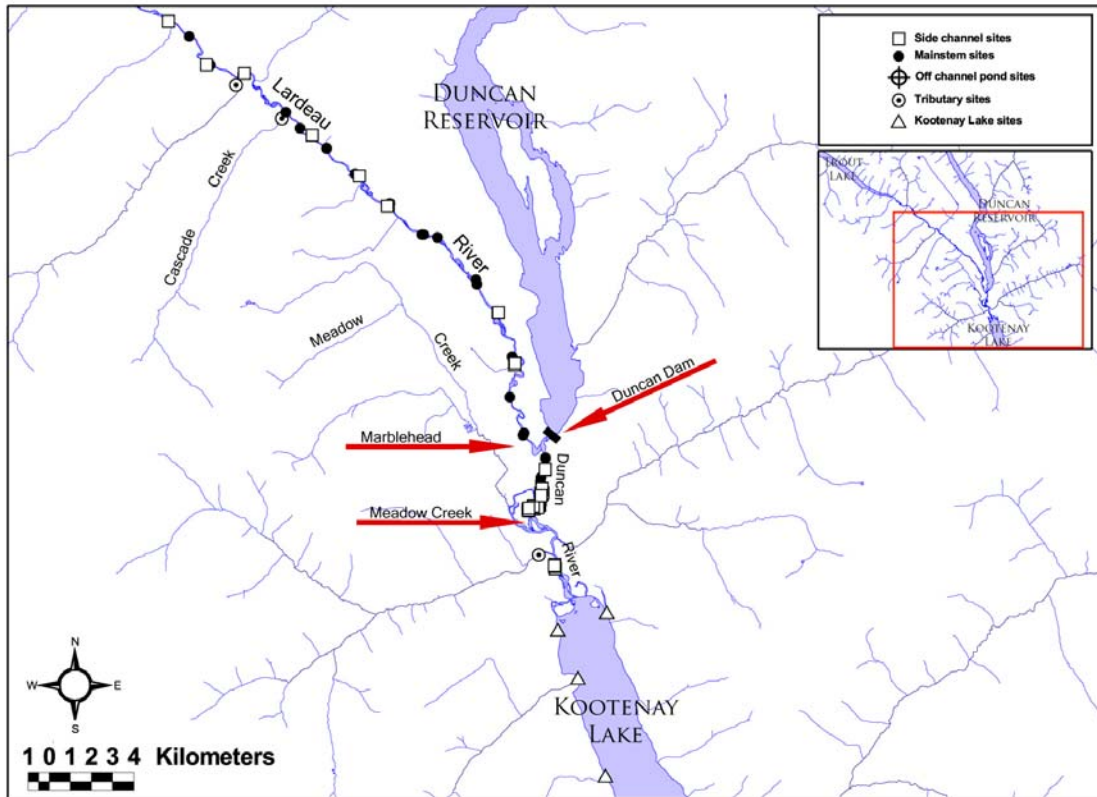


Figure 1. Location of lower Duncan River study area within the Lardeau-Duncan River system. Study sites located upstream of Marblehead in the Lardeau River, and downstream of Meadow Creek in the lower Duncan River (red arrows), were sampled as part of a separate study of juvenile rainbow trout distribution and abundance (Decker and Hagen 2006 in prep.).

remove sediment introduced into the lower Duncan by its tributaries (Lardeau R, Meadow C, Hamill C, Cooper C), which has resulted in large accumulations downstream of Duncan Dam. This process of channel narrowing, and reduction of substrate particle size, will continue in the post-regulation environment, with the effect that fish habitat complexity in the lower Duncan River and its side channels will continue to decline (M. Miles and Associates 2002).

Table 1. Fish species present in the Duncan River drainage (from AMEC 2003).

Scientific name	Common name
<i>Salvelinus fontinalis</i>	brook trout
<i>Salvelinus confluentus</i>	bull trout
<i>Lota lota</i>	burbot
<i>Oncorhynchus nerka</i>	kokanee
<i>Catostomus macrocheilus</i>	largescale sucker
<i>Catostomus catostomus</i>	longnose sucker
<i>Rhinichthys cataractae</i>	longnose dace
<i>Prosopium williamsoni</i>	mountain whitefish
<i>Ptychocheilus oregonensis</i>	northern pikeminnow
<i>Mylocheilus caurinus</i>	peamouth
<i>Prosopium coulteri</i>	pygmy whitefish
<i>Oncorhynchus mykiss</i>	rainbow trout
<i>Richardsonius balteatus</i>	redside shiner
<i>Cottus cognatus</i>	slimy sculpin
<i>Acipenser transmontanus</i>	white sturgeon

In accordance with the study terms of reference, we selected three major lower Duncan River side channels for study of fish abundance and habitat relations, and added two sites each from two additional channels (five side channels in total) as well to ensure that seasonally rare habitat types were represented. The channels were selected during reconnaissance of the lower Duncan River system on August 20 and 21, 2004, when discharge in the lower Duncan River was relatively high (75-100 m³/s; Water Survey of Canada, stn. 08NH119) and all side channels had flow through them. The side channels were systematically selected to represent a range of flows and likelihoods of dewatering, although it should be noted that this was evaluated subjectively during a period of relatively high flow.

Side channel #1 is located approximately 3.6 km downstream of the Duncan Dam on the west bank (M. Miles and Associates 2002; AMEC 2003 Appendix A, Figure 3; Golder Associates 2003, Figure 3.2). It is a large channel of approximately 900 m length separated from the main channel by a large bar at its upstream end and an extensive vegetated island along its lower end. Gravel and cobble substrates dominate the upstream end of the channel, with fines predominating in the lower 600 m.

Side channel #2 is located approximately 7 km downstream of the Duncan Dam (M. Miles and Associates 2002; AMEC 2003 Appendix A, Figure 6; Golder Associates 2003, Figure 3.4), immediately below the Argenta Bridge, on the west bank. It is a small channel that dewateres almost completely at low to moderate flows. Side channel #2 is separated from the main channel by a large gravel bar at its upstream end and a large

wooded island for the remainder of its approximately 600 m length. Substrate composition along the length of the site is best described as a mix of gravels and fines, with limited areas of cobbles.

Side channel #3 is located approximately 1.8 km downstream of the Duncan Dam on the east bank (M. Miles and Associates 2002; AMEC 2003 Appendix A, Figure 2). It is a short, approximately 100 m long channel of mainly fine substrates situated downstream of a large log jam.

Side channel #4 is located approximately 2.7 km downstream of the Duncan Dam on the east bank (M. Miles and Associates 2002; AMEC 2003 Appendix A, Figure 2). It is approximately 600 m long, and is separated from the mainstem by extensive debris accumulations. Long runs over cobble/gravel substrates, associated in many locations with wood debris accumulations, make up the upstream portion of the channel, and the downstream end is of higher gradient consisting of a sequence of short riffles over cobble/gravel.

Side channel #5 is a short channel flowing behind a bar at the downstream end of side channel #4, located approximately 3.1 km downstream of the Duncan Dam on the east bank (AMEC 2003 Appendix A, Figure 2; M. Miles and Associates 2002). Side channel #5 is a large braid of the mainstem at moderate and higher flows, and was only sampled during April.

Stratification of side channel habitats and site selection

We initially intended to conduct the late summer sampling event concurrent with the reconnaissance in late August 2004, then sequentially sample the same locations during late fall and late winter/early spring field trips. However, because of high turbidity in the lower Duncan River at that time, originating from the Lardeau River, fish surveys were not possible and only reconnaissance of side channels and site layout in one channel (side channel #1) occurred. Fall sampling was therefore postponed until the following year (September 2005). This study assumes, therefore, that patterns in habitat use and abundance are repeated from year to year. During the reconnaissance it was decided that the diversity of habitats available in side channels could best be described using simple habitat type criteria: flow characteristics and the presence or absence of large wood debris cover. Available habitat types were stratified into five of categories: riffles (sloped, broken water surface), runs (non-riffle areas of positive current velocity) with and without wood debris, and slack water with and without wood debris. Runs were habitat units with or without wood accumulations that had a positive current velocity at the thalweg (measurable with a mechanical flow meter requiring a minimum of approximately 0.02 m/s to turn the propeller on the flow meter). Slack water habitat units had no measurable current velocity at the thalweg. Riffles are infrequent in lower Duncan River side channels, but represent a potentially important habitat type, especially for young-of-the-year (YOY) rainbow trout, a species of particular interest in the Duncan River system.

Initially we had hoped to sample comparable numbers of sites in each habitat type stratum during each seasonal sampling period, and also maintain the same sites for each sampling period. However, when site layout was subsequently completed in November (November 9-12, 2004) prior to the first fish survey, flows had decreased from 75-100 m³/s in late August to 21-25 m³/s, which substantially affected depth and velocity characteristics in the previously selected side channel sites. For example, some runs became slack water as flow within the side channel dropped. We realized, therefore, that some sites would be classified in different habitat type categories depending on the season and flow through the side channel, and that the number of sites representing each of the five habitat type strata would not be consistent for each sampling period. We therefore made measurements of depth and velocity at all sites during all three sampling periods, so that we could relate fish abundance to continuous habitat variables in addition to discrete habitat type categories.

Habitat measurements at sampling sites were made during the daytime prior to conducting the snorkeling surveys at night (or daytime 1-pass electrofishing in shallow sites). Physical site attributes recorded during site layout included visual estimates of cover (categories included overhead vegetation, turbulence, deep water and substrate cover as percentages of the site area; undercut bank as a percentage of the combined length of the stream banks, and total surface area (m²) of the site covered by wood debris), substrate composition (boulder, cobble, gravel, and fines as percentages of the site area), D90, D50, site length, wetted width, channel width, and average thalweg depth and velocity (average of 5 measurements distributed uniformly along the length of the site and taken at the deepest point along a cross-channel transect). D90 and D50 refer to, respectively, the estimated diameters of substrate particles for which 10% and 50% of the site area consists of larger particles.

Nighttime snorkeling surveys

The use of snorkeling surveys can increase sampling efficiency several-fold compared to conventional multi-pass electrofishing (Hankin and Reeves 1988). In our study we employed snorkeling counts to estimate fish abundance at most survey sites, the exceptions being three sites in November 2004, one site in April 2005, and four sites in September 2005 that were too shallow for divers to work effectively in. These shallow sites were sampled using single-pass electrofishing. Snorkeling counts can provide reliable estimate of fish abundance if calibrated using more accurate methods at a portion of the sampling sites (Hankin and Reeves 1988; Thurow and Schill 1996). Because we were conducting a reconnaissance-level survey of fish abundance and habitat use, we did not incorporate calibration of snorkeling counts into our study design. Methodologies for calibrating snorkeling counts, such as multiple-pass electrofishing or mark-recapture methods (Hankin and Reeves 1988; Thurow et al. in prep.; Hagen et al. 2005) are time-consuming, but can be employed in lower Duncan River side channel habitats in future if more quantitative estimates of abundance are desired.

Numerous studies have shown that daytime concealment behaviour is common for juvenile salmonids (e.g., Bradford and Higgins 2000 and references therein), and likely depends on factors such as temperature, time-of-day, season and habitat. Daytime

concealment occurs also for non-salmonid species that use lower Duncan River habitats (AMEC 2003). Variability in daytime concealment behaviour may partly explain differences in the accuracy of daytime diver counts among streams (Cunjak et al. 1988), or within streams at different times of the day (Thurow and Schill 1996) or at different temperatures (Hillman et al. 1992). Because of the high likelihood of concealment behaviour during the day, we conducted all underwater surveys at night during a four-hour period beginning 0.5 hours after dusk.

To illuminate the sampling sites at night, snorkelers used handheld dive lights. Snorkelers worked in groups of two unless the site was very narrow in which case they worked alone. Each snorkeler entered the site at its downstream end and systematically swept in an upstream direction the area between his bank and the agreed upon mid-point of the site. Great care was taken to avoid disturbing silt on the channel bottom, especially in slack water areas.

The fork lengths of all fish observed and their species identity were visually estimated and recorded in waterproof notebooks. If fish were numerous or schooled, snorkelers tallied numbers in length categories instead of recording individual lengths. To aid in the estimation of fish length, snorkelers drew ruled scales on the cover of their notebooks. At night, snorkelers were typically able to hold the notebooks within 30 cm of a fish to measure its length without disturbing it. During the course of underwater surveys in November 2004, one of the snorkelers captured individuals of each species observed by using paired, large aquarium nets that had been attached to 0.5 m long handles. After capture fish were handed to an observer on shore who confirmed the species identification, using a fish identification key if necessary. Juvenile rainbow trout and bull trout were also collected at night using the nets, to acquire scales and tissue samples for aging and genetic analyses, respectively. Genetic analysis of the population structure of lower Duncan River rainbow trout was conducted in the lab of Eric Taylor of the University of British Columbia. Scale samples were removed from a location approximately 2-4 rows above the lateral line and between the back of the dorsal fin and the origin of the anal fin, and stored between labelled glass slides. All captured fish were released back into the site after being measured, in a location where both divers could observe the released fish and compare their estimation of its length to the recorded length. In this way divers were able to evaluate their own length estimates on a nightly basis.

One-pass electrofishing

In September, all sites in side channels #1, 3, and 4 had sufficient depth for snorkeling to be feasible. The four sites sampled by single-pass electrofishing in September were in side channel #2, which had flow through it but could easily be spanned by a stop net. An electrofishing pass was initiated at the downstream site boundary, and consisted of a thorough search in an upstream direction, followed by a systematic sweep back towards the downstream net. In November, two of the three sites sampled by electrofishing were isolated pools in side channel #2, while the third site consisted of a riffle along one bank in side channel #4. At the riffle site, a fine mesh seine was used as a stop net at the bottom site boundary, and extended out from shore as

far as the current would allow and anchored. Electrofishing proceeded always from the fast water forming the offshore boundary towards the shore, to avoid chasing larger juveniles from the site. The opposite shoreline was deep enough along the shore to be surveyed by a diver. In April, the same riffle in side channel #4 was sampled by single-pass electrofishing.

All fish captured during electrofishing were anaesthetized, identified as to species, measured for fork length (nearest mm), and released back into the site following the completion of sampling. A portion of the catch was sampled for weights as well. Scales were taken from a portion of the rainbow trout catch to aid in determining length-at-age.

Kokanee redd and adult counts

We enumerated kokanee salmon spawners and redds during the late September 2005 sampling period, when spawning was actively underway, and counted kokanee redds that were both wetted and out of the water during November 2004.

Analyses

As mentioned above, sample sites were attributed to one of the five habitat types based on flow characteristics at the time of sampling. Our index of fish abundance, as opposed to a population estimate of known reliability, associated with each habitat type category was the uncalibrated mean linear density (fish/100 m) for each species or species/age category. For individual sampling periods, habitat relations for four relatively widely distributed species, the salmonid species rainbow trout and mountain whitefish and the non-sport fish species redbreast shiners and longnose suckers, were described using simple linear correlation (Zar 1996) with habitat measures among all sites, irrespective of habitat type category, treated as continuous variables.

Salmonid fish ages from scales were determined by inspecting scales mounted on glass slides using a microfiche reader/printer, with regions of closely spaced circuli on the scale denoting annuli. The best scale for each individual fish was printed for future reference and for making scale measurements. Samples of adult (Hagen et al. 2006) and juvenile (Decker and Hagen 2006 in prep.) Gerrard rainbow trout scales collected in separate studies during springtime and fall 2005, respectively, were also inspected to assist in determining age-1/age-2 length cut-offs for rainbow trout.

RESULTS AND DISCUSSION

Seasonal fish surveys

Discharge in the lower Duncan River varied substantially among the three sampling periods, meaning that hydraulic habitat characteristics (Appendix 1) at sampling sites also varied greatly. Codes and sample sizes for the five habitat type strata are shown in Table 2.

Table 2. Habitat type strata sample sizes and codes for lower Duncan sampling

Description of habitat type	Stratum code	Sampling period		
		Sep-05	Nov-04	Apr-05
riffle	RI	4	2	3
run	RU	8	2	3
run with woody debris	RUW	9	4	4
slack water	S	1	7	5
slack water with woody debris	SW	2	6	4
	Total	24	21	19

During September 24-26 sampling in 2005, discharge in the lower Duncan River varied between 227 and 231 m³/s when fish sampling occurred. We sampled a total of 445 m of side channel habitat in the lower Duncan system, distributed among 24 sites in the five habitat type categories (Table 2). All four study channels were open to the lower Duncan River at their upstream ends, meaning that thalweg velocities (Appendix 1) at the sampling sites were positive and only three sites could be classified as completely slack water (one site each of S and SW classifications in side channel #1, and one SW site in side channel #2). Water temperatures measured with handheld thermometers at the time of sampling were consistently 12°C. Six mainstem shoreline sites totalling 305 m of habitat in two categories, shallow and deep, were also sampled concurrently as part of a separate study of Gerrard rainbow trout abundance (Decker and Hagen 2006 in prep.).

We sampled a total of 410 m of side channel habitat during the November 2004 field trip, distributed among 21 sites in the five habitat type categories. During November 10-12 sampling, when discharge in the lower Duncan River varied from 108 to 118 m³/s, only side channel #4 was open to the mainstem at its upstream end. Side channel #2 had two inputs from the mainstem, located approximately 300 m from the top end of the channel, providing modest flow to the lower part of the channel. In contrast to September sampling, the majority of sites surveyed were classified as S and SW (Table 2). Only two sites were sampled for the riffle stratum (RI); riffle areas in side channels #1 and #2 could not be sampled because these habitats, located over bars at the upstream ends of the channels, were dry at the time of the survey. The run category (RU) was also represented by only two sites, and this was because flows through run sites laid out in August 2004 had dropped to negligible levels by the time of sampling in November (Appendix 1). During the November sampling period, only two wetted habitat units were available for sampling in side channel #2. These were stagnant pools in an otherwise dry channel. Temperatures at the time of sampling ranged from 3°C to 10°C, with the coldest temperatures being associated with small, isolated pools.

We sampled a total of 318 m of side channel habitat during the April 2005 field trip, distributed among 19 sites in the five habitat type categories. During April sampling, when discharge in the lower Duncan River had dropped to 81-85 m³/s during April 6-7, 2005, side channel #4 was still open to the lower Duncan River mainstem at its upstream end, but other channels largely consisted of slack water. Side channel #2 was dry, and

sites in side channel #3 were not sampled because of the abundance of slack water sites in other channels. Instead, two sites in a new side channel, side channel #5, were added to increase representation in flowing-water habitats. Temperatures at the time of sampling ranged from 4°C to 7°C, with the warmest temperatures being associated with groundwater and seepage-fed areas in side channel #1 that were not receiving inputs from the mainstem.

We identified a total of 11 fish species in lower Duncan River side channels during the study (Table 3). These same species were identified in sampling in the lower Duncan River in 2002 (Golder Associates 2003) with one exception: all but two sucker juveniles that we inspected were keyed out as longnose suckers, which were not reported by Golder Associates (2003), who identified largescale suckers were the only *Catostomus* species present. AMEC (2003) did not key out suckers to the species level, but noted a similar species assemblage with the exceptions of burbot, which they observed in mainstem habitats, and longnose dace, which they did not observe.

Table 3. Fish species detected during nighttime underwater surveys in lower Duncan River side channels 2004/2005.

Scientific name	Common name	Species code
<i>Salvelinus confluentus</i>	bull trout	bt
<i>Oncorhynchus nerka</i>	kokanee	ko
<i>Rhinichthys cataractae</i>	longnose dace	lnd
<i>Catostomus catostomus</i>	longnose sucker	lns
<i>Catostomus macrocheilus</i>	largescale sucker	lss
<i>Prosopium williamsoni</i>	mountain whitefish	mw
<i>Ptychocheilus oregonensis</i>	northern pikeminnow	npm
<i>Mylocheilus caurinus</i>	peamouth	pm
<i>Oncorhynchus mykiss</i>	rainbow trout	rb
<i>Richardsonius balteatus</i>	redside shiner	rss
<i>Cottus cognatus</i>	slimy sculpin	ss

Fish abundance

Higher flows in September 2005 were associated with a greater diversity of species and life stages in lower Duncan River side channel sites (Tables 4a-c; Appendix 2 - counts; Appendix 3 - densities). It was only during September sampling that adult life stages of mountain whitefish and longnose sucker (Tables 4a-c; species codes: mw ad, lns ad) were observed. Likewise for peamouth, largescale suckers, and subadult bull trout (Tables 4a-c). Kokanee salmon spawners (ko ad) were abundant in the lower Duncan system during September sampling, and we encountered them in all habitat types during nighttime snorkel surveys (Table 4a). However, juvenile life stages of non-sport fish species and the small species redside shiner appeared to have an expanded range and be more abundant within our sampling sites during low flows of November 2004 and April

2005 (Tables 4a-c), perhaps as a result of migration from other areas. The mainstem of the lower Duncan River would probably not have been the source - juvenile non-sport fish were not found in abundance along mainstem margins in September 2005 (Table 4a).

Rainbow trout juveniles (young-of-year and age-1+) were the most widely distributed fish species present in lower Duncan River side channels (Appendices 2, 3), and were observed in all habitat types during each sampling period (Tables 4a-c; Figures 2a-c), achieving highest densities in runs with wood cover. Rainbow trout YOY were relatively abundant and numerically dominant for all habitat categories associated with flowing water (RI, RU, RUW) during the November and April sampling periods, and also in RI and RUW habitats in September (Tables 4a-c; Figures 2a-c). Scale and length-frequency analyses indicated fork length cut-offs for the two age-classes of 90 mm in September and November, and about 110 mm in April, when young-of-year and age-1+ age categories had changed to age-1+ and age-2+, respectively (Table 4c). Uncalibrated rainbow trout juvenile densities in mainstem margin sites (Table 4a: ms shallow, ms deep) compared favourably with the best side channel habitat types in September (Table 4a: RI, RU, RUW). It should be noted, however, that we did not investigate the accuracy of snorkeler counts during this study. Because snorkeling efficiency in side channel and mainstem habitats may differ, comparisons should be considered preliminary.

Mountain whitefish juveniles were abundant in flowing water habitats during September 2005 sampling (Table 4a, Figure 2a), when they were by a substantial margin the most abundant species in runs without wood cover (RU). However, their abundance appeared to be substantially lower in lower Duncan River side channels during the November and April sampling periods (Tables 4b, 4c; Figures 2b, 2c), possibly signifying a niche shift to mainstem habitats or out of the lower Duncan River altogether. No fish species other than rainbow trout or mountain whitefish were abundant in flowing water habitats. The highest fish density observed in any habitat type during our study was that of mountain whitefish juveniles along shallow mainstem margins in September (Table 4a), consistent with the notion that mountain whitefish use of mainstem habitats in the late fall and winter was responsible for lower apparent abundance in our side channel sites.

Table 4. Mean uncalibrated fish densities for five habitat types in lower Duncan River side channels in (A) September (plus two mainstem habitat types), (B) November, and (C) April. See Table 3 for species codes.

A. September

September		Uncalibrated density (fish/100 m)														
habitat type	rb	rb1	mw	mw1	adult	ko	adult	bt	subad	lnd	lnd	lnd	lnd	lnd	Total	
ri	45	0	16	2	0	3	0	0	0	0	0	0	0	0	66	
ru	56	5	103	3	2	21	0	0	0	13	3	1	2	21	2	232
ruw	56	7	50	6	9	32	2	0	0	2	2	0	0	5	1	173
s	9	0	0	0	0	18	0	0	0	0	0	0	0	9	0	36
sw	8	0	3	0	0	22	0	0	0	0	0	0	0	0	11	43
ms shallow	49	5	171	10	0	15	0	1	1	1	0	0	0	3	1	256
ms deep	54	4	29	1	10	68	1	0	0	0	1	0	0	1	1	169

B. November

November		Uncalibrated density (fish/100 m)									
habitat type	rb	rb1	mw	bt	lnd	lnd	lnd	lnd	lnd	lnd	Total
ri	77	0	18	0	3	0	0	0	0	6	104
ru	50	3	27	0	0	0	0	0	0	0	80
ruw	101	6	16	2	0	0	2	4	3	133	
s	7	0	3	1	0	8	0	13	1	33	
sw	12	0	2	0	0	23	0	42	2	82	

C. April

April		Uncalibrated density (fish/100 m)									
habitat type	rb1	rb2	mw0	mw1	ko	lnd	lnd	lnd	lnd	lnd	Total
ri	87	2	0	5	3	10	0	0	0	35	56
ru	42	0	0	1	11	0	0	2	2	1	18
ruw	108	7	0	6	1	0	14	0	0	1	30
s	9	1	1	1	30	18	26	6	46	6	136
sw	21	3	2	2	34	2	24	13	65	6	149

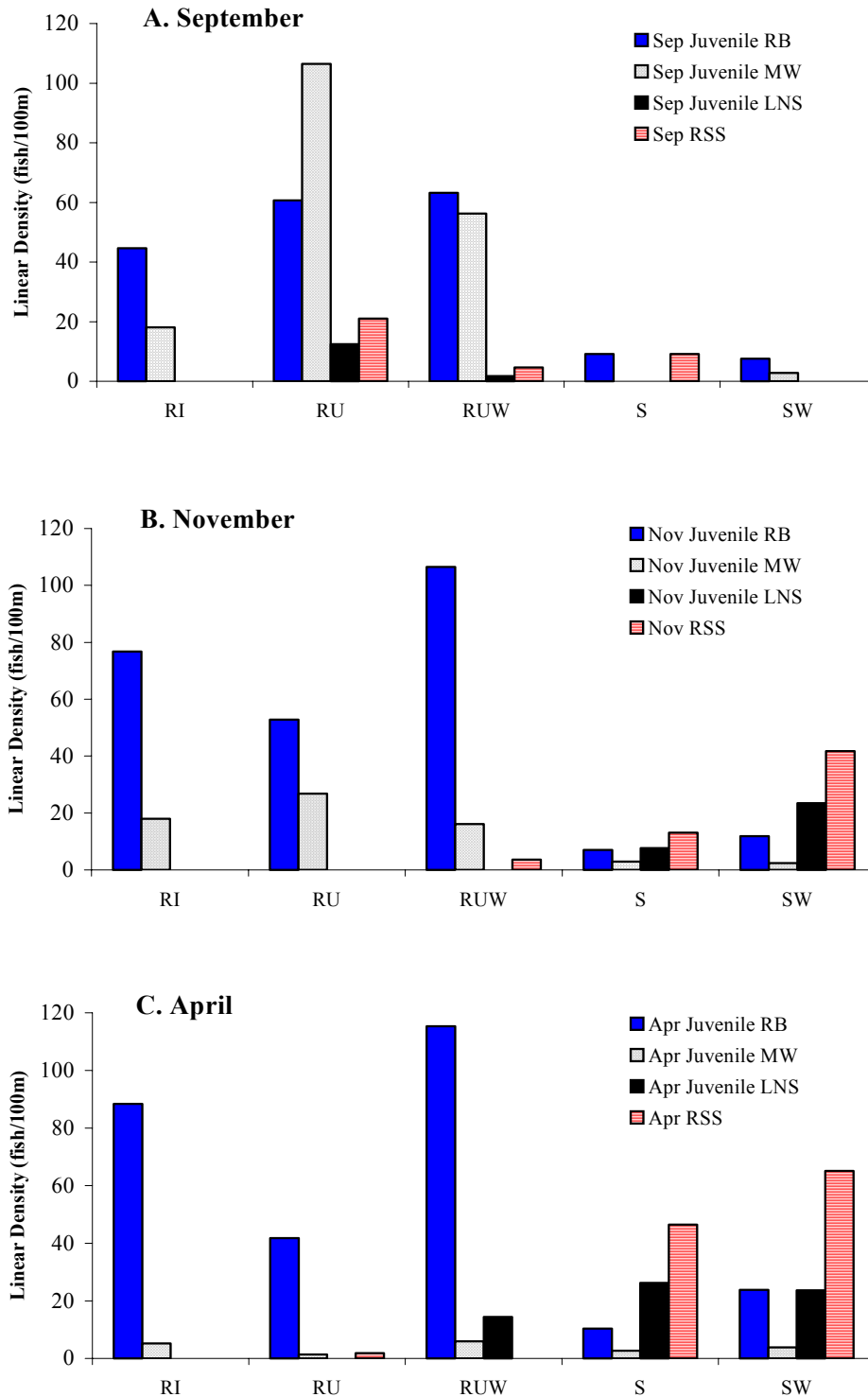


Figure 2. Uncalibrated linear density estimates (age classes pooled) for juvenile rainbow trout (blue solid bars), juvenile mountain whitefish (open dotted bars), juvenile longnose sucker (black solid bars), and reidside shiner (red striped bars) during (A) September, (B) November, and (C) April.

With respect to non-sport fish species, most had a patchy distribution within the side channels sampled, were observed at low abundances, and were primarily represented by juvenile life stages (Tables 4a-c; Appendices 2, 3). The most widespread and abundant non-sport fish species appeared to be the redbside shiner, which was found in 6, 9, and 8 sites in side channels #1 and #3 for the September, November, and April sampling periods, respectively (Appendices 2, 3). During November and April sampling, redbside shiners were relatively abundant and numerically dominant in slack water habitat with wood cover (SW), followed by longnose suckers and rainbow trout (Tables 4b, 4c; Figure 2b, 2c). Total fish abundance for these periods was lowest in slack water habitats without wood cover (S), where the same order of numerical dominance among species was observed as for the SW category. The very low sample of S and SW habitats in September (Table 2) may have influenced our finding that redbside shiners were not abundant in slack water habitats. Alternatively, our use of thalweg velocity to categorize habitats may have been misleading; slack water habitats along margin areas still existed in run habitats during September sampling. Highest abundances of redbside shiners for that sampling period were found in runs without wood cover (Table 4a; Figure 2a). Redside shiners were present along mainstem margins in September, but at very low densities (Table 4a).

Longnose sucker juveniles were also relatively widely distributed, being found in 3, 5, and 8 sites in side channels #1 and #3 for the September, November, and April sampling periods, respectively (Appendices 2, 3). They were most abundant in slack water habitats during November and April sampling, but similar to the redbside shiner their highest abundances during September sampling were within runs without wood cover (Table 4a; Figure 2a). Longnose sucker juveniles were found only at very low densities along mainstem margins in September (Table 4a).

No observations of either longnose dace or northern pikeminnow juveniles were made during September sampling, and observations were limited to single individuals at one location for these two species during November (Appendix 2: site ri-2 in the case of the longnose dace, and site ruw-2 for the northern pikeminnow). Longnose dace and northern pike minnow juveniles were both observed at four sites during April, but were only observed at even moderate abundance at one site each in side channel #1, site ru-2 where 6 longnose dace were observed, and site ruw-3 where 12 juvenile northern pike minnow were counted. Largescale suckers were rarely observed in our sampling sites, and only two juvenile individuals were identified in side channel #1 in September (Appendix 2: sites ruw-4 and s-3).

Slimy sculpins were found at up to 8 sites (April), but with the exception of site ri-2 in side channel #4, where 16 individuals were electrofished in April, no more than 4 individuals were ever observed in a site. It is likely, however, that true abundance and distribution of this species was greatly underestimated because of its cryptic colouration and extreme benthic orientation.

Physical habitat associations

The four most widely distributed species among our lower Duncan River side channel sites, juvenile life stages of the salmonid species rainbow trout and mountain whitefish, and non-sport fish species redbreasted sunfish and longnose suckers, showed consistent associations across the three study periods with habitat variables measured during the study (Appendix 1). Salmonid and non-sport fish species appeared to be segregated according to habitat characteristics, particularly during the November and April field trips when flows were lower. Longnose sucker and redbreasted sunfish abundances were consistently negatively correlated with %gravel and cobble substrates at study sites, and with the habitat variables indicating substrate size, D90 and %substrate cover (Table 5). Longnose sucker and redbreasted sunfish abundance was also consistently negatively correlated with mean velocity across the three study periods. Abundance of both species was positively correlated with %deep water cover and, to a lesser extent, mean depth during lower flows of November and April, but correlations with these habitat variables in September were weak or negative. No other habitat variables were consistently related to abundance of these non-sport fish species.

Table 5. Seasonal correlations between habitat variables and uncalibrated juvenile non-sport fish density in lower Duncan River side channel sampling sites.

Habitat variable	Pearson correlation coefficient					
	September (<i>n</i> =24)		November (<i>n</i> =21)		April (<i>n</i> =19)	
	RSS	LNS	RSS	LNS	RSS	LNS
%Cobble substrate	-0.21	-0.13	-0.25	-0.19	-0.36	-0.43
%Gravel substrate	-0.22	-0.06	-0.27	-0.23	-0.39	-0.48
%Fines	0.30	0.13	0.36	0.29	0.50	0.60
D90	-0.21	-0.16	-0.30	-0.24	-0.42	-0.50
%Substrate cover	-0.20	-0.15	-0.23	-0.18	-0.33	-0.40
m ² LWD	-0.08	-0.09	0.09	0.07	-0.05	-0.11
%Deep water cover	0.24	-0.12	0.43	0.50	0.42	0.50
%Turbulence cover	-0.17	-0.14	-0.12	-0.18	-0.26	-0.31
%Undercut bank cover	-0.01	0.57	-0.05	0.03	0.39	0.35
%Overhead cover	-0.16	-0.12	-0.18	-0.17	-0.05	0.11
Mean depth	0.02	-0.09	0.38	0.09	0.63	0.65
Mean velocity	-0.33	-0.14	-0.19	-0.15	-0.33	-0.40

Habitat variable associations for juvenile rainbow trout (Table 6) were distinct from other species. In contrast to the non-sport fish species redbreasted sunfish and longnose suckers, juvenile rainbow trout abundance was consistently negatively correlated with %fines at survey sites and to a lesser extent with depth (%deep water cover and mean depth), and positively correlated with mean velocity (Table 6). The strongest habitat association of any species utilizing lower Duncan River side channels appeared to be the strong positive correlation of rainbow trout abundance with m² large woody debris at sampling sites, which ranged from $r = 0.46$ to 0.78 among sampling periods (Table 6).

We also observed a negative correlation with %overhead vegetation cover and a positive correlation with %turbulence cover, but it should be noted that turbulence cover was relatively rare in our lower Duncan River study channels. The negative correlation with overhead cover does not imply in this case that rainbow trout avoid it. Rather, the correlation with overhead cover is strongly affected by the near total absence of fish in side channel #2, where overhead cover was most abundant (Appendix 1).

Table 6. Seasonal correlations between habitat variables and uncalibrated juvenile salmonid density in lower Duncan River side channel sampling sites.

Habitat variable	Pearson correlation coefficient					
	September (n=24)		November (n=21)		April (n=19)	
	RB	MW	RB	MW	RB	MW
%Cobble substrate	0.26	0.13	0.40	0.55	0.51	-0.06
%Gravel substrate	0.08	0.07	0.27	-0.04	0.22	0.28
%Fines	-0.22	-0.14	-0.44	-0.50	-0.46	-0.25
D90	0.09	0.06	0.53	0.61	0.49	0.10
%Substrate cover	0.21	0.13	0.36	0.40	0.56	-0.04
m ² LWD	0.46	0.15	0.78	0.33	0.50	0.19
%Deep water cover	-0.25	-0.26	-0.21	-0.21	-0.31	-0.19
%Turbulence cover	0.01	-0.20	0.37	0.21	0.63	0.14
%Undercut bank cover	0.03	-0.22	-0.18	-0.03	-0.18	0.22
%Overhead cover	-0.33	-0.26	-0.24	-0.26	-0.32	-0.19
Mean depth	-0.07	0.00	-0.08	0.12	-0.15	0.20
Mean velocity	0.23	0.07	0.47	0.26	0.35	0.38

Habitat associations for juvenile mountain whitefish appeared to be weaker and less consistent in side channel sites. As was juvenile rainbow trout abundance, whitefish abundance was negatively correlated with %fine substrates and positively correlated with mean velocity, but correlations with all other habitat variables appeared to be weak or less consistent among seasonal sampling periods (Table 6).

Intensive studies of adult rainbow trout and mountain whitefish use of the lower Duncan River have recently been initiated by BC Hydro and BC MOE. The lower Duncan River supports a major population of mountain whitefish that spawn in late fall/early winter at depth (BC Hydro unpublished data). A major discovery of recent years is that a substantial population of large, piscivorous Kootenay Lake rainbow trout spawns in the Duncan River at the tailrace of the Duncan Dam (Hagen et al. 2006). Genetic analysis of the sample of rainbow trout collected in the lower Duncan River has indicated that rainbow trout utilizing the lower Duncan River for rearing likely cannot be considered distinct from the Gerrard stock of rainbow trout that spawns in the Lardeau River. However, unlike the offspring of Gerrard spawners, young-of-year rainbow trout juveniles that emerge at the Duncan Dam tailrace are limited to the 11 km of the lower Duncan River for fluvial rearing habitat. Side channel habitats in the lower Duncan River system appear to be seasonally important for juvenile mountain whitefish, and

important year-round for juvenile rainbow trout. For rainbow trout juveniles in particular, uncalibrated September densities in the best side channel habitat types, those associated with flowing water (Table 4a: RUW, RU, RI), were equivalent to mainstem densities. The potential contribution of these side channel habitats to the overall productive capacity of the lower Duncan River for sportfish production is unknown, but given the extensive nature of side channel areas in the lower Duncan system it may be significant even if these habitat types are a relatively small proportion of the total side channel length.

As described in the channel stability assessment of M. Miles and Associates (2002), reduced flows in the post-flow regulation environment below the Duncan Dam have been inadequate to remove sediments introduced to the lower Duncan River by its tributaries. The reduction of substrate particle sizes in side channel and back channel environments, which no longer receive scouring flows, is likely to continue. The negative correlations found in this study between juvenile salmonid abundance and fine substrates, and the positive correlations of non-sport fish species abundance and fine substrates, suggest that habitat changes resulting from flow regulation have favoured non-sport fish and reduced the habitat capability of the lower Duncan system for salmonids. The implementation of annual flushing flows to scour accumulated sediments in side channels should be considered critically as potential remediation. Given the limited stream length downstream of the Duncan Dam, flowing water habitats in lower Duncan River side channels, especially when associated with coarser substrates and accumulations of wood debris, probably represent critical habitats for sport fish production in this system. These key habitats may already represent a fairly small proportion of the total side channel area in the lower Duncan system, so special efforts to preserve or expand their area may be warranted.

The above comments notwithstanding, it is important to note that caution is required in applying our observations of seasonal fish habitat use to management situations affecting lower Duncan River side channels. This study was designed as a small, exploratory survey of fish use of side channel habitats, which may contribute to the design of future studies in the lower Duncan system. Replication, with respect to both the number of side channels and the number of sites, is insufficient for rigorous statistical inference or applied management situations. Furthermore, survey methods were chosen that allowed for rapid assessments, but they have not been related to results from more accurate assessments at the same sites. The accuracy of snorkeling counts of fish can be affected significantly by the species being observed (Rodgers et al. 1992), water temperature at the time of sampling (Bradford and Higgins 2000 and references therein), the stream being sampled (Cunjak et al. 1988), physical habitat variables (Thurrow et al. 2005), and the body size of the fish being observed (Thurrow et al. 2005.). All of these factors may contribute to inaccuracy to our seasonal density estimates for different species and in different habitats.

Channel dewatering

In addition to physical habitat characteristics at sites, a major factor affecting habitat suitability for fish species in lower Duncan River side channels in our study appeared to

be the frequency of channel dewatering. Side channel #2, which was selected to represent frequently dewatered habitats, was virtually devoid of fish during September sampling (Appendices 2, 3), despite favourable habitat and depth/velocity conditions at that time. In contrast, rainbow trout young-of-the-year were found in side channel #4, which appears to remain wetted throughout the year, in relatively high abundance during all sample periods (Appendix 3). Dewatering of side channel #2 had probably occurred several times in the weeks preceding our September field trip, during the course of experiments designed to evaluate the effects of rapid flow changes on fish survival (Golder 2006). Of the 6 rainbow trout, mountain whitefish, and slimy sculpin recovered from side channel #2 sampling sites in September (Appendix 2), only one rainbow trout and one slimy sculpin were captured alive. Because of the limited scope of our study, we cannot speculate on the effects of frequent dewatering on other small side channels in the lower Duncan River. However, results from side channel #2 suggest that production from certain small channels may largely be lost in a flow regulation environment where rapid flow changes were introduced for the purpose of optimizing hydroelectric power production, or under Columbia River treaty obligations. Under these conditions, mortalities of salmonid fish living in small side channels may be particularly severe during periods of low water temperature, when fish are concealed within the substrate during the day and unwilling to leave (Bradford et al. 1995; Harby and Halleraker 2001). Habitat surveys systematically conducted across a range of potential flow levels could identify which channels had the greatest risk of stranding fish, or would be lost to fish production.

During the September 2005 field trip we counted a total of 40 adult kokanee, many in the process of spawning, in side channel #1, and 144 adult kokanee in side channel #2 (Table 7). We did not observe any kokanee spawners in side channel #3, and side channel #4 was too deep and turbulent to see into, although it should be noted that snorkelers observed adult kokanee in sampling sites in both of these channels at night (Appendix 2). Spawning within the side channels was confirmed by the presence of 34 newly-constructed redds in side channel #1 and 69 redds in side channel #2 (Table 7). During the November 2004 field trip, when kokanee spawning had been completed for the year, 74 of the 216 redds observed in side channel #1 were out of the water, and virtually all of the 97 redds observed in side channel #2 were dry (Table 8). Spawning was also confirmed for side channel #4, where 6 wetted redds were observed. Kokanee young-of-the-year were observed in 8 sites in side channel #1 and 2 sites in side channel #4 during April snorkel counts (Table 4c; Appendix 2).

Salmonid eggs can survive for weeks in dewatered gravel (Hunter 1992), but this is unlikely to be true during extended exposure to freezing temperatures during winter months, as was likely be the case for dewatered kokanee redds in side channels #1 and #2. As discussed above with respect to juvenile salmonid mortalities in frequently-dewatered side channels, systematic habitat surveys of lower Duncan system side channels across the range of expected flows could aid greatly in predicting losses due to kokanee redd stranding. Egg survival experiments in dewatered redd sites may also be warranted if quantifying losses is required.

Table 7. Kokanee adult and redd counts from lower Duncan River side channels, September 2005 (distance is measured traveling upstream from mouth)

Date	Side channel	Distance u/s (m)	Redds	Ko adults	Ko carcasses
25-Sep-05	1	0-400	too deep for count		
		400-500	too deep for count		
		500-600	3	0	0
		600-700	9	2	1
		700-800	18	31	0
		800-900	4	6	0
12-Nov-04	2	0-100	0	0	3
		100-200	0	0	0
		200-300	53	111	0
		300-400	12	24	2
		400-500	0	0	0
		500-600	4	4	0
12-Nov-04	3	All	0	0	0
12-Nov-04	4	All	too deep for count		

Table 8. Kokanee redd counts from lower Duncan River side channels, November 2004

Date	Side channel	Distance u/s (m)	Dry redds	Wetted redds
12-Nov-04	1	0-400	0	0
		400-500	25	100
		500-600	10	25
		600-700	27	5
		700-800	5	10
		800-900	7	2
12-Nov-04	2	0-100	2	0
		100-200	7	0
		200-300	58	7
		300-400	7	0
		400-500	0	0
		500-600	16	0
12-Nov-04	3	All	0	0
12-Nov-04	4	All	0	6

Habitat stratification

The classification scheme for habitat types that we employed was not consistent from season to season at specific sites in the lower Duncan River. However, the classification scheme is simple and is probably well suited for future habitat surveys at given levels of discharge in the river. In this preliminary analysis, the five habitat type categories chosen appeared to discriminate between suitable habitats for early life stages of salmonids and non-sport fish, with rainbow trout and mountain whitefish juveniles dominating in flowing water habitats and redbreasted sunfish and young longnose suckers dominating in slack water habitats. Within flowing waters, rainbows preferred riffles and areas of wood cover relative to mountain whitefish. These side channel habitat strata may therefore be useful in future for more extensive habitat surveys in the lower Duncan system, should there be a need for more quantitative assessments of fish populations in lower Duncan River side channels.

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REFERENCES

- AMEC Earth & Environmental Ltd. 2003. Diel fish use of aquatic habitats in the lower Duncan River, BC. Report prepared for BC Hydro, Castlegar.
- Bowen, Z. H., K. D. Bovee, and T. J. Waddle. 2003. Effects of flow regulation on shallow-water habitat dynamics and floodplain connectivity. *Transactions of the American Fisheries Society* 132:809-823.
- Bradford, M. J. and P. S. Higgins. 2000. Habitat-, season, and size-specific variation in diel activity patterns of juvenile chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*Oncorhynchus mykiss*). *Canadian Journal of Fisheries and Aquatic Sciences* 58:1-10.
- Bradford, M. J., G. C. Taylor, J. A. Allan, and P. S. Higgins. 1995. An experimental study of the stranding of juvenile coho salmon and rainbow trout during rapid flow decreases under winter conditions. *North American Journal of Fisheries Management* 15:473-479.
- Cunjak, R. A., R. G. Randall, and M. P. Chadwick. 1988. Snorkeling versus electrofishing: a comparison of census techniques in Atlantic salmon rivers. *Canadian Naturalist* 115:89-93.
- Decker, A. S., and J. Hagen. 2006 in prep. Rapid assessment methods for estimating total juvenile Gerrard rainbow trout standing stock in the Lardeau River, British Columbia - 2005/2006 pilot study (working title). Consultant report prepared for BC Ministry of Environment, Nelson BC.
- Freeman, M. C., Z. H. Bowen, K. D. Bovee, and E. R. Irwin. 2001. Flow and habitat effects on juvenile fish abundance in natural and altered flow regimes. *Ecological Applications* 11(1):179-190.
- Golder Associates Ltd. 2003. Lower Duncan River fish and aquatic habitat study, fall 2002 data report. Consultant report prepared for BC Hydro, Castlegar.
- Hagen, J., A. S. Decker, and R. G. Bison. 2005. Calibrated rapid assessment methods for estimating total steelhead parr abundance in the Thompson River system, British Columbia - 2004 interim report. Report prepared for BC Ministry of Water, Land, and Air Protection, Kamloops.
- Hagen, J., J. Baxter, J. Burrows, and J. Bell. 2006. Rainbow trout (*Oncorhynchus mykiss*) spawner migration through the lower Duncan/Lardeau Rivers and residence time at Gerrard, BC, as estimated by radio telemetry, 2004/2005. Report prepared for BC Ministry of Water, Land, and Air Protection, Nelson, and BC Hydro, Castlegar.

- Hankin, D. G. and G. H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. *Canadian Journal of Fisheries and Aquatic Sciences* 45:834-844.
- Harby, A., and J. H. Halleraker. 2001. Ecological impacts of hydro peaking in rivers. *Hydropower and Dams* 4:132-135
- Harvey, B. C. 1987. Susceptibility of young-of-the-year fishes to downstream displacement by flooding. *Transactions of the American Fisheries Society* 116:851-855.
- M. Miles and Associates, Ltd. 2002. Channel stability assessment - lower Duncan River. Consultant report prepared for BC Hydro, Castlegar.
- Poff, N. L., J. D. Allan, M. B. Bain, J. R. Karr, K. L. Prestegard, B. D. Richter, R. E. Sparks, and J. C. Stromberg. 1997. The natural flow regime. *BioScience* 47(11):769-784.
- R. L. & L. Environmental Services Ltd. 2000. Fish and aquatic resources in the lower Duncan River, 1998-1999 investigations. Consultant report prepared for BC Hydro, Castlegar.
- Rodgers, J. D., M. F. Solazzi, S. L. Johnson, and M. A. Buckman. 1992. Comparison of three techniques to estimate juvenile coho salmon populations in small streams. *North American Journal of Fisheries Management* 12:79-86.
- Scheidegger, K. J., and M. B. Bain. 1995. Larval fish distribution and microhabitat use in free-flowing and regulated rivers. *Copeia* 1995:125-135.
- Thurrow, R. F. and D. J. Schill. 1996. Comparison of day snorkeling, night snorkeling, and electrofishing to estimate bull trout abundance and size structure in a second-order Idaho stream. *North American Journal of Fisheries Management* 16:314-323.
- Thurrow, R. F., J. T. Peterson, and J. W. Guzevich. 2005. Utility and validation of day and night snorkel counts for estimating bull trout abundance in 1st to 3rd order streams. *North American Journal of Fisheries Management*.
- Zar, J. H. 1996. *Biostatistical analysis*, 3rd edition. Prentice-Hall, Englewood Cliffs, New Jersey.

Appendix 1. Physical habitat measurements in lower Duncan River side channels

Site	Side channel	Substrate				Cover						D50 (cm)	D90 (cm)
		%B	%C	%G	%F	%B	m2 LWD	%DP	%Turb	%UC	%OH		
ri-1	1	0	5	85	10	0	3.5	0	15	10	0	3	5
ru-1	1	0	5	75	20	0	0	0	15	15	0	2.5	6
ru-2	1	0	0	5	95			40				0.2	0
ru-3	1	0	0	0	100		1	15				0.2	0
ru-7	1	0	5	60	35	0	0.5	0	5	0	0	2	5
ruw-1	1	0	0	10	90		36	15	10			1	0
ruw-2	1	0	0	0	100		60	70				0.2	0
ruw-3	1	0	0	0	100		40	80				0.2	0
ruw-4	1	0	0	0	100	0	35	90	0	50	5	0.2	0
s-1	1	0	5	15	80					40		6	0
s-2	1	0	0	0	100	0	0	90	0	0	15	0.2	0
s-3	1	0	0	0	100			40				0.2	0
sw-1	1	0	5	80	15			20				5	3
sw-2	1	0	0	0	100		11	15			15	0.2	0
ri-4	2	15	55	10	20	30	0.5	0	30	0	10	8	33
ri-5	2	10	60	25	5	20	0	0	50	0	15	10	45
ruw-7	2	0	0	0	100		10				35	0.2	0
ruw-8	2	0	0	15	85		20			5	25	0.2	5
ruw-8a	2	10	40	20	30	20	5	0	5	0	15	4	25
s-4	3	5	0	10	85	0	0	0	0	0	0	0.3	0.2
sw-3	3	5	0	10	85	5	23	15			15	0.2	3
ri-2	4	0	80	20	0	30			30			11	21
ri-3	4	0	20	0	5	5	2		20			5	20
ru-4	4	0	45	45	10	20						6	23
ru-5	4	0	85	10	5	25			5			10	22
ru-6	4	0	60	30	10	20	0	0	0	0	0	8	22
ruw-5	4	0	50	40	10	10	30				5	7	9
ruw-6	4	5	20	25	50	5	200	10	10			0.2	15
ri-4a	5	0	5	60	35	0	0.5	0	5	0	0	2	5
ruw-9	5	0	25	60	15	10	50	0	5	0	0	5	8
du0-6	ms	0	5	75	20	10	35	0	10	0	0	3	6
du0-7	ms	30	0	20	50	15	50	60	10	0	10	5	90
du1-6	ms	0	30	40	30	10	20	25	15	10	20	3	20
du1-8	ms	5	15	20	50	0	60	25	10	0	5	0.2	12
du1-9	ms	0	60	20	20	25	7	0	25	0	10	12	19
du2-6	ms	0	35	35	30	15	2	0	15	0	0	5	10

Appendix 1, continued. Physical habitat measurements in lower Duncan River side channels

Site	Side ch.	Habitat type			Site length (m)			Mean wet width (m)			Mean depth (cm)			Max depth (cm)			Mean velocity (cm/s)		
		Sep	Nov	Apr	Sep	Nov	Apr	Sep	Nov	Apr	Sep	Nov	Apr	Sep	Nov	Apr	Sep	Nov	Apr
ri-1	1	ri			29			5			37			44			91		
ru-1	1	ru	s		20	20		6	5		41	15		51	21		85	0	
ru-2	1	ru	s	s	15	19	18	31	14	11	83	33	22	100	39	30	53	20	0
ru-3	1	ru	s	s	10	13	15	39	24	21	197	98	111	220	120	130	42	0	0
ru-7	1			ru			18			5			23		28				7
ruw-1	1	ruw	sw	sw	21	20	20	18	9	11	146	101	105	220	115	150	56	0	0
ruw-2	1	ruw	ruw	ruw	35	14	16	10	18	10	96	60	80	130	83	130	45	0	2
ruw-3	1	ruw	sw	sw	16	16	24	22	8	7	87	43	33	102	70	45	16		0
ruw-4	1	ruw	sw	sw	30	30	13	38	24	21	197	117	130	220	150	150	42	0	0
s-1	1	ru	s		13	13		15	8		61	22		65	25		26	0	
s-2	1	s	s	s	11	11	12	9	10	9	100	20	22	150	24	25	0	19	0
s-3	1	ru	s	s	11	13	30	22	8	7	84	42	32	91	82	48	3	0	0
sw-1	1	ruw	sw		23	23		17	9		65	47		96	83		25	0	
sw-2	1	sw	ruw	ruw	21	21	22	8	2	2	82	20	13	90	24	20	0	0	15
ri-4	2	ri			15			6			13			18			56		
ri-5	2	ri			19			8			24			31			26		
ruw-7	2	sw	sw		18	18		11	3		71	36		100	55		0	0	
ruw-8	2		sw			37			2			20		40					
ruw-8a	2	ruw			17			9			19			23			19	0	
s-4	3	ru	s		13	13		10	6		94	52		100	60		9	147	
sw-3	3	ruw	sw		22	24		6	5		80	64		107	80		21	0	
ri-2	4	ri	ri	ri	16	16	16	36	17	19	41	40	14	56	44	17	70	68	57
ri-3	4		ri	ri		20	20		15	15		44	34		50	42		0	65
ru-4	4	ru	ru	s	15	16	16	16	15	13	77	41	32	87	48	39	63	35	0
ru-5	4	ru	ru	ru	18	17	17	33	27	27	77	38	38	89	43	46	94	46	18
ru-6	4			ru			25			24			34		37				19
ruw-5	4	ruw	ruw	sw	17	17	17	15	13	11	91	45	39	98	55	55	99	0	0
ruw-6	4	ruw	ruw	ruw	20	20	20	26	18	16	80	42	31	100	51	47	80		21
ri-4a	5			ri			18			5			28		37				77
ruw-9	5			ruw			16			9			38		47				27
du0-6	ms*	shal			59			34			25			34			43		
du0-7	ms*	deep			50			81			130			170			22		
du1-6	ms*	deep			50			95			88			107			33		
du1-8	ms*	deep			50			76			61			69			32		
du1-9	ms*	shal			46			85			26			44			53		
du2-6	ms*	shal			50			82			11			15			15		

*mainstem margin habitat

